Abu al-Qassem Khalaf ibn Abbas al-Zahrawi

Abu al-Qassem Khalaf ibn Abbas al-Zahrawi, known as Albucasis, was the greatest surgeon of the Islamic period and the Middle Ages (476-1500). Although he is an ever-glittering star of the world of medicine, little information is available on his life. He was born in the 10th century A.D. in Al-Zahra, a place neighboring Cordova in southern Spain. He practiced medicine during the reign of Abd al-Rahman III, the Omavid caliph of Spain (reigned 928-961) and years after him in Cordova. He was the special physician of Mansur the Omavid Army's great commander. He lived a long life and according to Leon's African, he was killed in the Cordova war. Albucas wrote the voluminous book of Al-Tasrif leman Adjaza an al-Ta’leef (A Practical Guide for Those Who Are Unable to Use a Complete Medical Collection) in 30 volumes, which is another medical encyclopedia. The chapter on surgery in Al-Tasrif was translated into Latin in the 12th century by the Italian Gérard de Crémone. Later on, all the 30 volumes were translated and published several times under the title of "Alsahravius". The Arabic version and the Latin translation of the 30th volume, which is on surgery, were published in Oxford in 1878.

A major part of the Al-Tasrif deals with the compound drugs. The first part of the book contains theoretical discussions or the general medicine with views of the predecessors such as Rhazes. The second (the practical) part of the book discusses man's diseases from head to toe and concludes by discussions on child nutrition, the nutrition of the elderly, gout, abscesses, pains, and fevers. The 30th Volume on surgery should be considered the masterpiece of Albucasis. Albucasis mostly relies on his own experiences and findings. The real science of surgery was introduced to Europe after the translation of Al-Tasrif and saved millions of lives during centuries. The history of French literature indicates that due to revolts and conflicts in Italy in 13th century, a number of scientists from that country migrated to France and introduced Albucasis's way of surgery. Lanfranc who visited France in 1290, said: "The French surgeons are almost all fools who hardly understand their own language. All of them are deceitful laymen. In the schools of France, instructors used to put Albucasis in the same level as Hippocrates and Galen."

The world of Islam did not use the surgical knowledge of Albucasis and Rhazes. Due to side effects of the surgery, they neglected this branch of medicine. Europe, however, paid more attention to surgery and used works of Rhazes and Albucasis.

Views of the Grand Surgeons

Rhazes considered special significance to surgical operations. He wrote a book on the way of using metal instruments in surgery and orthopedics. He has explained various surgeries such as rooting out trichiasis (additional hair in the eye); laryngotomy and prevention of suffocation. He has mentioned lithotomy and calicectomy, and has suggested catheter for urodynia. Calicectomy was performed by some other surgeons in the past but Avicenna opposes the idea and instead he suggests catheter: "Some physicians cut the dorsal part or flank of the patient on the occasion of calix of kidney, which is very dangerous and a wise man never does this. In case of bladderstone cathaterization is recommended."

Some Wonders of Surgery in Iran

Iranian surgeons were called Ostad (master) in the past and sometimes they performed astonishing surgical operations. We gave a few examples before. Mahmoud Vasifi (d. 1552) the author of Badaye al-Vaqaya (Interesting Events) says Master Sheikh Hassan the surgeon, sewed the bowls of one of the commanders severely injured by a dagger by jaws of ants and cured him. This should be taken as the first
type of the absorbable surgical sutures. This book also writes about Master Zeyn al-Abedin the orthopedist that cured dislocated illium of women without touching her. The story was this that he kept a cow thirsty for three days feeding it with dried straw. Then he put the women on the cow and fastened her feet hard below the abdomen of the animal. Then he gave buckets of water to the animal. The cow's abdomen swelled as it drank water and pressed the illium of women and located it on the place.

**Applying Surgery in Iranian Veterinary Medicine**

Unlike physicians, Iranian veterinary surgeons were interested in carrying out minor and major surgeries and had no fear of the probable complications. Some of them were skilled in their job. In the following lines we will refer to some of the surgical treatments.

Treating Lameness and Hoof Tenderness: They treated lameness by massage, revulsive poultices, dry cupping, and operative surgery in some cases. They treated hoof’s lesions by rubbing out and scraping damaged zone and application of caustic materials such as lime, then applying softening ointments such as sheep fat, sugar, etc., and in some cases by cauterization.

Osteopathia: Osteoma, osteoblastoma, osteoclasis and abnormal vertebra were treated by surgical operations such as ostectomy, vertebrectomy, application of slat, haemostasis and roller bandage. Hydrarthrosis used to be treated by applying cold bathing, prescribing corrosive poultice, dry-cupping and deviation of blood flow from an area to another. They considered the incision of the lesion a dangerous practice and preferred cauterization.

Colitis: In cases of severe colic, suppositories and enemas containing onion juice, garlic or soap were employed. A piece of band was placed around the body at the neck and back, and pulled tight to evacuate intestinal gases, or a reed-pipe was placed in the rectum to allow a continuous flow of gases. When the urethra was obstructed and the bladder was full, this was massaged through the vagina or rectum until empty. Various hernia such as abdominal hernia and inguinal hernia were important in surgery. In the case of bovine abdominal hernia if the intestine was perforated the sick animal was incurable but if it was not injured, they washed the intestine and returned it to abdomen and sutured the area.
**HISTORY OF BOVINE SURGERY**

A. David Weaver

Bearsden, Glasgow G61 1AW, Scotland, UK

**Introduction**

Compared with the equine species, little has been written about bovine surgery, in terms of particular procedures and techniques. As the most important animal species producing meat, milk and hides, this appears surprising. Much has been written on infectious diseases of cattle, such as rinderpest and FMD, and more recently bovine spongiform encephalopathy.

**Ancient times**

Aristotle in the fourth century BC, among his many scientific writings, described castration in several animal species, including cattle. Yet in India, at least two millennia before his time (about 2500 BC) one of the four Books of Veda, the Ayurveda or Book of Life, had described surgery including castration of bulls. Methods included crushing the testes between two stones, or destruction of the ductus deferens with two small pieces of wood. Sometimes the penis was split in two with a sharp stone knife. Indian surgeons at this early time had developed 130 different steel instruments including forceps, scissors, needles and catheters for human and animal surgery.

**Sixteenth to Eighteenth Centuries**

Dunlop (1996), in a chapter entitled “Slow progress in animal doctoring on the farm,” refers to “The Boke of Husbandry” by John Fitzherbert (1523) who described brain surgery in cattle. This involved the removal of cerebral hydatid cysts in the “Turn” (turning sickness). A disease chart of a bull, modified from a French publication by Markham in a text “The Countrey Farme” in 1616 identifies what appear to be the dislocated hip (“the thigh out of joint”), urolithiasis (“unableness to pisle”, “the stone in the pizzle”, “the stone in the bladder”) and rectal or anal trauma (“the draughtgut hurt”). Details of the surgery are not given. Some time later, at the end of the seventeenth century, came the slow change from crude empirical treatment, including surgery, to a quest for deeper knowledge. Many scientists became involved in animal experimentation and dissection, including descriptions of the lymphatics (Aselli) anatomy and physiology of the lens (Descartes), pancreatic function (Graaf) and attempts at canine blood transfusion (Lower).

Michael Harward, a seventeenth century animal doctor with over 30 years predominantly cattle experience, condemned widespread superstitious practices and urged cattlemen in Ireland to adopt the way (“blessed by God”) of a “skilful and industrious ox leech”. Harward not only also removed hydatid cysts from the brain of cattle, as advised by Fitzherbert 150 years previously, but also performed abdominal surgery in cases of horn gore injury. If the abdominal wall was torn and bowel evagination was present, with severe damage to bowel wall, Harward could perform resection and end-to-end intestinal anastomosis, with the cow strung up by the hind legs. His continuous thread or silk suture started at the mesenteric attachment and he emphasised the vital importance of suture tension (“neither too hard nor too slack”). Clearly in many of these alarming cases the cow survived.

Crawshay (1636) in his textbook “The Countrymans Instructor” described caesarean section in cattle, (“with a vertical flank incision, removal of calf and placenta”) using silk sutures for closure of the uterine wall. In contrast his advice about veterinary medicine was crude. Yet over 100 years earlier a Swiss castrator of pigs (Jakob Nufer) had performed a successful caesarian section on his own wife, who later had experienced another pregnancy.

Well over 300 years ago Markham also recognised that “more skill was required of the surgeon than of the one who administers physic”. Very little is written about the all-important restraint, presumably by ropes held by many helpers, required to prevent movement of the patient during painful surgical interventions.
Without doubt bovine surgery caused considerable pain, but several notable investigators of veterinary medicine were concerned about suffering. Pal Adami (1739-1814) a Hungarian doctor, performed some bovine surgery and from 1775 onwards investigated every possible outbreak of cattle disease, whether epidemic or sporadic, conducting both clinical and postmortem examinations. He recorded a huge range of detailed differential diagnoses, and established that, contrary to the prevailing opinion, most of the time the cumulative toll of many sporadic diseases exceeded that of epidemics. He devised inoculation methods. He implanted threads dipped in saliva, and then air-dried, from cattle with rinderpest, demonstrating the loss of pathogenicity on desiccation (attenuation), and reported the successful protection of animals. The authorities in Graz shortly afterwards banned all further experiments proposed by Adami.

Likewise Haller (1707-1777), a Swiss doctor, did remarkable work in animal experimentation, but, troubled by the suffering caused by his vivisection techniques before the advent of animal anaesthesia, later concentrated on further botanical studies, despite some revolutionary physiological work.

**Late eighteenth century onwards**

Until the middle of the eighteenth century no formally qualified veterinary surgeons existed, and any surgery was practised by more or less experienced lay persons, called horse doctors and cow or ox leeches.

Following the establishment of the first veterinary schools in the second half of the eighteenth century (e.g. Lyon 1762, Alfort 1765, Vienna 1767, Turin 1769, Skara 1775, Hannover 1778 and London 1791) the major emphasis remained the horse, until the advent of the car a century later. Little commitment was shown by vet schools towards the needs of farm livestock though a goal was “the principles and the method to cure the diseases of livestock”.

In the early nineteenth century William Youatt (1776-1847) published a total of 75 lectures in “The Veterinarian” the first English language periodical. Many of his observations were not personal experiences but reports of eyewitnesses. In his limited bovine surgical experience he records two operations of oesophagotomy, doubtless for obstructing foreign bodies.

Aristotle had recorded the form of the ruminant stomach, but it was two millennia later that rumenotomy was first well described by Möller (1895) for dealing with masses of fermenting food containing much gas, “in cases when the trocar is no longer of value”. To prevent abdominal contamination the rumen was either sutured to the parietal peritoneum or exteriorised with an assistant holding two tapes, or alternatively the tapes were passed through both rumen and abdominal wall and so through the skin. “Should the cow be likely to become unconscious and fall down, stimulants like wine and brandy, or even 4-6 pints of wine, could be poured into the open rumen”. This text makes no mention of the removal of foreign bodies such as wire.

**Anaesthesia and bovine surgery**

Ether anaesthesia was discovered in 1846, and two years later Mayhew experimented with its effects in cattle, but results were poor due to the failure to have apparatus to volatilise sufficient ether to produce a high concentration. Chloroform was discovered at much the same time, but veterinary use remained largely confined to the horse. Coinciding with publication of Pasteur’s “germ theory” (1865), Listers work (1865) on antisepsis in the prevention of wound infection revolutionised surgery, and was rapidly adopted in cattle surgery with carbolic acid disinfection of instruments and skin surfaces. Twenty years later Bergmann and Schimmelbusch (1886) independently promoted asepsis, recommending steam sterilisation of instruments.

Chloral hydrate appeared about 1872, and was incorrectly long considered a general anaesthetic agent rather than a basal narcotic. It was widely used in horses and also in cattle for sedation and surgery. But since cattle rarely require general anaesthesia, the development in the twentieth century of regional analgesia (epidural by Benesch, 1926, cornual by Brown (1938) after seeing the American Emmerson’s technique (1933), paravertebral by Farquharson 1940, and IVRA of the distal limb by Antalovsky 1965) was the major advance that finally gave the bovine surgeon effective analgesia for most surgical procedures. The advent of xylazine in the late sixties enormously helped sedation of cattle.
Current situation

Simultaneously advances in radiography, later ultrasonography, along with improvements in instrumentation and in particular of suture materials, gave increased confidence to surgeons. While sophisticated imaging has done much to aid the diagnosis of bovine surgical conditions in clinics, the farm veterinarian still tends to rely on the thorough clinical examination, as shown so vividly in the James Herriot films, which also illustrate the communication, or lack of it, with the owner.

Today, thankfully, more attention is paid to peri-operative analgesia, but drug restrictions on food animals present many problems.

How it that left displaced abomasum (LDA) was was not reported until 1948 (Hugh Begg, Scotland)? His thorough examination sometimes involved a left flank exploratory laparotomy for a suspected “wire” foreign body, but he was occasionally confused to see a gas-filled abomasum occupying much of the left flank. Are there still occasional veterinarians today who treat their cows with a chronic ketosis for two weeks instead of again carefully auscultating the left flank for the “pings” and performing what now is relatively simple surgery? But having diagnosed LDA, we still confront the problem of the optimal surgical technique for its replacement and fixation (Weaver, StJean and Steiner 2005). In “The Herdsman’s Mate” (1673) Markham, the cattle doctor, wrote that the successful cattle surgeon had the following qualities: - “accurate and ready mind; good memory; active and nimble hand; resolution and boldness; careful and vigilant, and not rash nor hasty”. Some desirable attributes remain unchanged over 300 years later!
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DESCRIPTION AND TREATMENT OF NON-INFECTIOUS CLAW DISEASES IN CATTLE

Jos J. Vermunt
Awapuni Veterinary Services Ltd, PO Box 4000, Palmerston North 5315, New Zealand.
josv@awapunivets.co.nz

Introduction

Lameness in dairy cattle is a major source of economic loss to the farmer. Losses related to lameness include not only treatment costs, but lame cows also suffer lowered milk production, reduced fertility, and are culled at three times the rate of healthy control cows. The average cost of a case of lameness is estimated to be approximately NZ $200, with compares well with recent findings in Australia, the USA and UK.

Lameness is also a serious cause of pain and discomfort to the cow; it is arguably the most important condition affecting the welfare of cows on our modern dairy farms.

Worldwide, numerous surveys have been carried out determining the incidence rates of lameness in dairy herds. All these studies clearly show that there is a wide range between farms, districts and countries, that there is a lot of lameness about, and that the problem is getting worse.

The most common types of lameness causing lesions vary between countries. For example:

- Victoria, Australia (Jubb & Malmö, 1991) - axial wall crack (22%), septic pododermatitis (= under-run sole or sole abscess) (21%), interdigital necrobacillosis (= proper foot rot) (13%), white line disease (7%), sole ulcer (4%).
- UK (Clarkson et al, 1993) - sole ulcer (36%), white line disease (22%), digital dermatitis (8%), interdigital necrobacillosis (5%), sole ulcer (6%).
- Victoria, Australia (Malmö, 2002; unpublished data) - white line disease (34%), septic pododermatitis (29%), axial wall crack (17%), interdigital necrobacillosis (9%), sole ulcer (6%).
- New Zealand (Tranter & Morris, 1991) - bruising / excessive wear (42%), white line disease (39%), septic pododermatitis (9%).
- Wisconsin, USA (Cook, 2004) - digital dermatitis (56.8%), sole ulcer (18.4%), white line disease (10.4%), sole haemorrhage (6.4%).

During the last decade, axial wall cracks and lesions associated with laminitis (i.e. sole haemorrhages, sole ulcer, white line diseases, and poor-quality claw horn) have become more prevalent, both in Australia and New Zealand.

Thin soles due to excessive wear are one of the most prevalent lameness problems in extensive grazing systems such as in New Zealand and certain parts of Australia, and in large free-stall barn systems in North America. In the USA, much of the problem is clearly due to wet feet, sand bedding, and excessively abrasive concrete. Some may also be due to overzealous functional (= preventative or maintenance) claw trimming, which is routinely carried out once or twice each year. In year-round grazing systems (Australasia), an important factor is the distance that cows have to walk, especially in the all-important peri-partum period, when horn growth stops and wear increases. The moisture content of sole horn of thin-soled cows is higher than in cows with normal sole thickness (van Amstel et al, 2004), making the claw horn softer and, therefore, more susceptible to wear and pathological lesions. Also, more lameness occurs in seasons with high rainfall, and a high incidence of lameness usually follows periods of heavy rain.

In general, two broad categories of claw lameness in cattle are recognised: 1) those conditions affecting the claw capsule – claw horn lesions, many of which are believed to be caused by laminitis or trauma, and 2) those conditions resulting from infectious agents. This paper aims to describe the various non-infectious claw lesions and diseases, and their respective treatment.
LESIONS OF THE INTERDIGITAL SPACE

Interdigital hyperplasia (corns; interdigital fibroma / granuloma)

The terms fibroma and granuloma are misnomers; this condition is a proliferative reaction of the interdigital skin and / or subcutaneous tissues (i.e. overgrowth of normal skin in the interdigital space). The lesion presents as a hairless and firm mass – possibly partially eroded – which occupies part or all of the interdigital space. The incidence varies between herds, being highest in Holstein Friesian and Hereford cattle. However, considerable confusion exists about the possible role of inheritance.

Tension and stretching of the distal interdigital ligament is implicated in the aetiology. This results in excessive spreading of the digits, which in turn stretches the interdigital skin. Chronic irritation and inflammation – either being mechanical, chemical or bacterial (e.g. interdigital necrobacillosis) - have been advanced as other contributing factors in the aetiology, particularly in older animals.

Commonly, more than one limb is affected, and the larger lesions are usually seen in the hind limbs. The degree of lameness depends on the size and site of the lesion. Large infected masses (often as result of papillomatous digital dermatitis, and frequently bilateral) may lead to severe lameness.

In simple cases, treatment may be unnecessary, but the claws should be trimmed with special attention to the axial walls, to allow more space for the lesion. Curative (= corrective or therapeutic) trimming, i.e. modeling or dishing of the sole in the middle third to produce a concavity extending to the abaxial border, allows for improved self-cleaning.

Larger lesions, especially those associated with marked lameness require radical resection by knife surgery. The interdigital space is anaesthetised using the interdigital nerve block or intravenous regional anaesthesia (see below). The area is cleaned and the skin around the base of the lesion is incised so that the mass, together with a section of underlying fat, is removed. The toes are then wired together (i.e. a hole is drilled in the point of each toe, the wire placed through these holes and then tightened) to prevent separation of the two claws. The two digits are strapped together with an Elastoplast bandage or strong plastic tape, which should be removed after one week. The wire is left in place, usually until it wears through on its own accord. Prophylactic antibiotic treatment is indicated.

As an alternative to knife surgery, de-bulking followed by electro-cauterization or cryosurgery may be used. With all three methods there is a high rate of recurrence.

LESIONS OF THE HORN AND SENSITIVE LAMINAE

Excessive wear of claw horn

Under New Zealand and Australian conditions, where most milk production is from cattle at pasture, cows have to walk relatively long distances each day. When the claws are kept moist due to environmental conditions (rain, irrigation etc), the time spent on concrete at the time of milking, plus time spent walking along races (farm tracks or laneways), may lead to severe wear of claw horn (especially of the weight bearing surface or the sole). In some areas, this may become a major problem. In areas of high rainfall where it is difficult to properly maintain farm tracks and where relatively abrasive material is used for tracks, excess wear (with a predisposition to sole bruising and sole penetration) can lead to major lameness problems and consequently lost production. Excessive wear is also seen in situations where a new milking shed has been installed or where the yard area has been re-concreted, and where the concrete has been left too rough. This acts as sandpaper to rapidly wear down the claws. In such situations, it is possible to see over half the herd lame within a few weeks of entering the new shed.

The problem of excess wear of sole horn is also very common amongst heifers soon after they enter the milking herd. These animals often tend to be milked last and, therefore, spend longest on the concrete.

Excess claw wear is often associated with either aseptic or septic traumatic pododermatitis (see below).

Treatment is by removing affected animals from the herd, resting them in a paddock close to the
dairy shed, and milking them once a day until recovered (which can take up to a month). The time spent on concrete should be kept to an absolute minimum.

**Aseptic traumatic pododermatitis** (bruised sole)

Generalised bruising occurs when the sole is worn abnormally flat (as compared with the concave contour of the sole in a normal claw) and thin. The sole depresses easily under thumb pressure, and dark clots of blood are visible through the sole. In some cases - if the wear has made the horn extremely fragile - the sole is repeatedly traumatised, and the corium may be exposed, damaged, infected or eroded. This condition affects all claws similarly, and the animal develops a distinct sore-footed gait. The gait is abnormal, but lameness involving a specific limb may not be identified.

Treatment is as described above for excessive horn wear. If the sole is completely absent, the animal may have to be destroyed on humane grounds.

**Septic traumatic pododermatitis** (punctured and under-run sole; penetration of the sole; sole abscess)

This condition results when a foreign body (any form of sharp material, but most commonly sharp flints) penetrates the sole horn. Dirt and bacteria accompanying the penetration cause a purulent and/or necrotic infection of the underlying soft tissue (mainly corium). A similar infection may occur through very small defects (e.g. small cracks) in the white line. Animals with soft horn (due to laminitis or a wet environment) will obviously be predisposed.

Sole penetrations can occur in normal claws (e.g. as a result of a nail or other sharp object), but are most common in excessively worn claws. Poorly maintained cow tracks are a major problem in grazing herds.

The onset of lameness is usually rapid and the pain intense, because the infection is trapped between the corium and the sole horn. Animals with pus under the sole have a characteristic gait. As they walk, they do not put the affected claw straight onto the ground, but will often allow the claw to make contact with the ground first (especially on a hard surface) and then slide it along the surface before fully bearing weight.

When the claw is examined, the area immediately above the coronary band is slightly swollen, which is best observed on the axial part of the coronary band area. The site of penetration may or may not be obvious. Probably the most common site for pus to accumulate is around the toe area or half way the sole towards the axial wall. Often, a very thorough examination of the claw is necessary to detect the area of the under run sole. In more advanced cases, pus often escapes at the skin-horn junction of the bulb, where separation of the horn can be observed.

Treatment consists of draining the pus and trimming away all under-run horn (even if it is very extensive, i.e. the whole sole requires removal). To relieve the affected claw from weight bearing, a Cowslip or wooden block must be fitted to the sound claw. In most cases, the wound can be left open, and neither antibiotics nor an external dressing are required. Antibiotics may be indicated if one is unsure of the depth of the penetration.

**Sole ulcer** (ulceration of the sole)

This condition is defined as a limited reaction of the corium (typified as a red, raw, protruding mass of granulation tissue), circumscribed by under-run horn. Early cases may comprise a haemorrhagic area with or without a horn defect. Typically, one or both hind lateral claws of heavy, high-yielding dairy cattle - kept under confined conditions - are affected. In Australia, the incidence of sole ulcers has increased over the last five years or so, probably due to increasing levels of grain feeding (subclinical laminitis; see later) and the continuing trend towards “Holsteinisation” (i.e. North American Holsteins) of the national dairy herd.

The site of this lesion is specific, namely immediately distal to the axial prominence and plantar process of the distal phalanx (flexor tuberosity). The defect appears in the sole horn at the sole-bulb junction, slightly towards the axial border. Most authors agree that sole ulcer is caused by local damage, such as compression of the corium accompanied by haemorrhage. The function of the horn producing
cells in this area is impaired, and faulty horn or horn of poor quality is formed, or a complete shut-down in horn production occurs.

The exact aetiology of the injury to the corium is still disputed, and many theories have been advanced to explain the localised lesion. The theory that sole ulcers occur as a secondary lesion to laminitis (i.e. as a result of sinking of the distal phalanx) has received particular attention recently. Although laminitis is probably involved, the specific site of a sole ulcer suggests that anatomical and / or mechanical factors must also play a role in the pathogenesis.

Sole ulcers commonly occur in both lateral hind claws of the same animal, but may remain unnoticed for some time (bi-lateral hind limb lameness may be difficult to detect). Generally, the onset of lameness is sudden and often severe. On cleaning and paring the sole, a break in the horn may be apparent. In others, the sole horn may be discoloured and soft at the “specific site”. Once the corium is exposed, granulation tissue rapidly fills in the defect. In some cases, infection invades the deeper structures of the claw and may even travel up the deep flexor tendon sheath. At this stage, the bulb and coronary band are swollen and inflamed. Eventually, osteitis of the distal phalanx may develop.

Treatment of early sole ulcer (haemorrhage without pain or a break in the sole) consists of curative trimming, i.e. lowering and sloping of the sole behind the toe towards the heel in order to transfer weight from the affected claw. It is important that the weight-bearing surface at the toe is retained. If sufficient weight transfer can not be achieved without the sole becoming excessively thin, a Cowslip or block may be applied to the sound claw.

In cases of pre-ulcers, where the sole haemorrhage is associated with pain and covered with a thin horn layer, application of a block or Cowslip to the sound claw is preferred.

Advanced sole ulcers (full thickness horn defect with protruding corium) need adequate exposure of the diseased tissue, and removal of all under-run horn, debris and exuberant granulation tissue. The horn around the protruding corium should be sloped and thinned. This slope should extend across the weight-bearing surface including the abaxial wall, but not the toe. Normal protruding corium should not be cut. However, if the protruding corium appears to be granulating, it should be cut to the level of the already thinned sole. Intravenous regional anaesthesia or an interdigital nerve block is very useful in this situation, and the tourniquet used for the former technique will also control any haemorrhage. The affected claw can be raised by applying a block or Cowslip to the sound claw. This will remove weight bearing completely, allowing for more rapid healing of the lesion. In severe cases, a 3-5 day course of parenteral antibiotics may be necessary (procaine penicillin, oxytetracycline or tylosin).

Because sole ulcers often occur bilaterally, it is good practice to examine also the other foot after treating the “lame” leg.

A new curative trimming technique for sole ulcers, heel ulcers, and white line disease is the formation of a so-called “heel-less claw” (Manabe et al, 2004). This involves paring the plantar two-thirds of both the sole and wall of the affected claw (most often the lateral) as thin as possible, i.e. to the point where the sole is very soft. The toe triangle (dorsal third or apical part of the sole back to the extent of the axial white line) should be preserved at all times, since this will form the effective weight bearing surface for the affected claw. It is crucial to have a sound toe triangle, which is trimmed perfectly flat and perpendicular to the leg axis. The transition between the toe triangle and the thinned sole should be made as an abrupt step and not gradual, so no weight bearing occurs on the heel of the affected claw.

This “heel-less” technique should only be used if the sound claw (usually the medial) is high enough to provide at least a half inch greater heel height than the diseased claw, so sufficient weight transfer can be achieved (i.e. the weight is transferred adequately to the sound claw and the toe triangle of the affected claw). If this much difference can not be created, then a block or Cowslip should be used on the sound claw in the normal manner.

Since a sole ulcer involves specific damage to the corium, any new horn is slow to form, and the lesion is generally slow to heal. Many ulcers never fully resolve, and those cows continue to have a chronic low-grade lameness, needing curative claw trimming three to four times yearly for the remainder of their productive life. A large proportion, therefore, may have to be culled if treatment is not carried out
quickly and aggressively.

**Heel ulcer** (necrotic heel tract; sole fracture)

This lesion occurs in the centre of the sole at the junction between the harder sole horn and the softer heel horn, i.e. a little further caudally than the typical site of a sole ulcer. It has been suggested that the heel ulcer lesion may be caused by pinching of the corium under the caudal edge of the distal phalanx (Blowey, 1998). The abaxial border of the posterior edge of the distal phalanx is situated more caudal and occupies the central sole area, whereas the flexor tuberosity is anterior and axial to this site. This could explain the similar pathogeneses, but different sites of the heel ulcer and sole ulcer lesions.

Curative claw trimming, i.e. taking the weight off the plantar two-thirds of the sole of the affected claw and transferring weight bearing to the sound claw) is usually all that is required. If trimming can not produce sufficient weight transfer, a Cowslip or block should be applied to the sound claw.

**Toe ulcer** (white line disease at the toe; toe abscess)

In many cases, the white line in the toe region may only be stained with blood or serum. In more advanced cases, penetration of the sole may take place, with associated infection. Severe, complicated lesions may result in separation of the sole and osteitis of the tip of the distal phalanx.

Haemorrhage and / or separation of the white line in the toe region may be associated with laminitis involving rotation of the distal phalanx. The incidence is usually sporadic, but outbreaks may occur. For example, toe ulcers and vertical fissures (sand cracks) are the most common causes of lameness in bulls held at A.I. centres in New Zealand (Vermunt, 2003; unpublished data). Another explanation could be that the intense haemorrhage in the toe area of the front claws is caused by trauma when bulls are dismounting. Toe ulcers are also associated with thin soles (excessive wear), which may be caused by either over trimming of the sole or concrete walking surfaces.

Toe ulcers occur commonly in the front claws, and affected animals are often severely lame, showing a heel first foot placement. In chronic cases the toe is often overgrown and the heel is rather shallow. In these cases, a horn lesion may not be present at first examination. For this reason, it is important to remove a thin layer of sole at the toe and to cut the toe length back to 7.5 cm. This often exposes a lesion at the toe or in the white line. Using a hoof tester at the toe may indicate the presence of pain.

Treatment consists of removing the loose horn around the affected area, drainage of purulent material, and resting of the affected claw by applying a block or Cowslip to the sound claw. All under-run horn involving the sole and the walls should be removed. This may show a crater-like defect in the corium at the toe. In our experience, toe ulcers are notoriously slow to heal, and lesions, which are not infected, may benefit from protection using a thin layer of methyl-methacrylate (the same adhesive used for fixing wooden blocks or Cowslips).

**White line disease** (white line abscess)

In general, the term white line disease refers to the conditions of haemorrhage, fissure and abscess, which may occur at the site, usually the outer claw two-thirds of the way back from the toe. In this paper, emphasis will be placed on the more advanced condition of white line abscess.

The white line or white zone forms the cemented junction between the wall of the claw and the sole and, as such, is a point of weakness. One type of horn merges into another. The horn of the white line is softer than elsewhere and disintegration occurs easily. Separation (followed by impaction, penetration of the corium, and infection) and abscess of the white line are the commonly recognised clinical lesions. Once separation occurs, small fragments of dirt or even stones may be forced into the defect. The resulting infection usually tracks proximally and caudally along the direction of the dermal lamellae of the wall (septic laminitis), rather than beneath the sole, and often leads to abscess and / or sinus formation at the coronary band. Alternatively the infection may track inwards, involving the deeper tissues of the claw and resulting in deep digital sepsis (e.g. retro-bulbar abscess or septic arthritis of the distal interphalangeal joint).
White line abscesses occurring towards the toe are more likely to under-run the entire sole, rather than track proximally up the lamellae to discharge at the coronary band.

Most lesions are observed in the region of the abaxial border of the sole cranial to the bulb, followed by the toe area. In the hind limb, the abaxial border of the sole is the area of maximal impact forces during locomotion and absorbs the highest pressures during mid-stance. It is also subjected to torsion forces when the cow turns sharply.

In the front limb, the abaxial border of the sole near the toe receives the greatest concussion on impact.

Generally, the abaxial white line immediately distal to the bulb of the heel of the lateral hind claw is involved. The lameness is of variable onset and severity. Diagnosis is based on close examination, and the horn must be carefully pared back. Frequently, both hind legs are affected simultaneously, masking the lameness until complications start to develop.

Predisposing factors in the aetiology of white line lesions are excessive walking on hard surfaces, excess twisting and turning of cows whilst in the milking yard, wet and dirty underfoot conditions which softens horn, claw deformities, in particular overgrowth of the toe, and laminitis. Haemorrhages in the white zone and a decline in horn quality, as a result of laminitis, reduce the strength and integrity of the white line.

White line disease is a common cause of lameness in cattle at pasture, particularly in those that have to walk long distances.

Treatment must involve the establishment of adequate drainage. The lesion at the bearing surface is opened using hoof cutters or hoof knife in order to expose the corium beneath. All under-run horn (including that of the sole) should be removed. If infection has tracked up underneath the wall, then all loose and under-run horn of the wall should be carefully trimmed away, starting at the bearing surface, thereby exposing the infection track. Care should be taken not to traumatize the corium.

Lesions (abscess with sinus formation) erupting at the coronary band may also be traced distally. These require the removal of all or most of the abaxial wall throughout the length of the defect. A plug of necrotic tissue is often present in the tract. For stability reasons, a small and thin bridge of horn may be left across the defect, distally to the necrotic tissue. If adequate drainage is established, these lesions generally heal well, although slowly (can take 4-6 weeks). Application of a block or Cowslip for transfer of weight to the sound claw is usually beneficial, but is necessary in cases where the lesion is extensive and the corium has been exposed, and where the animal has to remain in the herd. Antibiotics are indicated in severe cases.

Lesions in the axial white line and toe region often develop a painful protrusion of granulation tissue. This is often an indication that not all of the under-run horn was removed at the first examination. Removal of this horn and resection of the granulation tissue with a sharp hoof knife, followed by claw blocking usually ensures recovery.

A different form of white line disease (which some authors refer to as an atypical toe ulcer) is sometimes seen in large dairy herds, where cows have to walk very long distances on concrete. The lesion occurs in or adjacent to the abaxial wall near the toe. It is caused by excessive wear of the horn of the sole and wall in that area.

Treatment involves the application of a block or Cowslip to the sound claw and / or resting the animal on a soft-bedded surface.

Laminitis (aseptic pododermatitis; founder)

This condition has a complex aetiology and uncertain pathogenesis. It is considered to be due to a disturbance in the micro-circulation of the corium, with ensuing degenerative and possibly inflammatory changes at the dermal-epidermal junction. Sequelae include impaired horn production with diffuse softening and discoloration, and haemorrhages in the sole and heel (subclinical laminitis); double soles, heels and walls; ulcers in the sole, heel and toe; white line lesions (haemorrhages, separation, and abscess); and, in chronic cases, deformation of the whole claw.
Acute or subacute laminitis is an aseptic inflammation of the corium, which coincides with a systemically sick animal. It has a rapid onset and evokes pain with various degrees and types of lameness, resulting in aberrations in stance and gait. Initially, there may be hyperaemia at the coronary band associated with heat and increased pulsation. The claw horn, however, shows few - if any - visible changes. Historic evidence of the insult may be observed in the claw some time after the laminitic episode has resolved. Subacute laminitis is a milder degree of acute laminitis. Both forms often progress to the chronic form.

Chronic laminitis has no systemic signs. This condition develops over a prolonged period of time; successive bouts of laminitis eventually lead to a characteristic deformation of the claw, i.e. slipper foot. The claw has an elongated and concave dorsal border, and a flattened, broadened sole. Sole ulcers and a widened white zone are also common features. Grooves and ridges are present in the claw wall, resulting in a rippled appearance; the ripples being closer at the toe and diverging towards the heel. The animal usually has difficulty in walking.

Subclinical laminitis - by definition - produces no immediate clinical signs, and abnormalities in posture or locomotion usually do not occur. It is a chronic condition recognised only retrospectively by the delayed appearance of sequelae: deteriorated horn quality (soft and rather waxy), haemorrhages in the weight-bearing surface of the claw (especially the white line, apex of the sole and axial side of the sole-bulb junction). These haemorrhages are distributed over all claws in quite a symmetrical fashion. There is also an increase in the incidence of lesions such as sole ulcer, double soles, and white line disease. This form of laminitis also gradually progresses into chronic laminitis.

The commonly accepted hypothesis is that toxic substances, such as histamine, lactic acid, serotonin and endotoxin, are formed or released in the digestive tract (mainly as a consequence of rumen acidosis), or are produced during post-partum diseases. These toxic, vaso-active components, together with a coagulopathy, severely disturb the haemodynamics in the corium, leading to tissue hypoxia and nutrient starvation, followed by ischaemic necrosis and degeneration of the horn-producing structures. An insufficient supply of sulphur-containing amino acids reaching the keratin-producing cells could lead to lower levels of di-sulphide bonding in the keratin tissue and synthesis of structurally incompetent horn or cessation of keratinisation. The di-sulphide bonding in keratin gives the claw its structural integrity.

While the aetiology and pathogenesis may not be fully understood as yet, an increased incidence of laminitis-associated lesions is commonly observed with increasing levels of concentrate feeding, particularly if no attempt is made to buffer the ration adequately in order to minimise the effect of subacute rumen acidosis (SARA). However, other nutritional factors (e.g. wetness of the diet, protein content and type, lack of physically effective fibre, and feeding of wet fermented grass silage) may also be involved.

Although the development of laminitis can be nutritionally based, there is a growing body of evidence to suggest that the associated claw horn lesions may result from other “trigger” factors. Workers in the UK have shown that there is an inevitable worsening in claw horn lesions at parturition – particularly in first-calving heifers.

Claw horn lesions result from a failure (or increased elasticity) of the suspensory apparatus, which holds the distal phalanx within the claw horn capsule – this then increases its mobility and likelihood of “sinking” within the claw. This sinking leads to compression and damage to the corium situated beneath the distal phalanx, which, in turn, affects the integrity of the sole horn produced.

The increased elasticity of the suspensory apparatus is believed to be triggered by the action of metallo-proteinases (MMPs) and other similar enzymes, which become activated at calving time – perhaps mediated hormonally. There is also some evidence that SARA may also cause MMP activation. An exotoxin released from Streptococcus bovis may activate MMPs in a dose-dependent manner. Obviously, S. bovis is an organism known to proliferate in the rumen of cattle during acidotic events, which commonly follow shifts to high grain feeding.

Alternatively, could it be that histamine – produced by conversion of the amino acid histidine by certain rumen bacteria (Allisonella histaminiformans) – is a bigger contributing factor to perturbed supply of nutrients to the horn-producing tissues than is commonly thought? Apparently, histamine absorption across the rumen wall only increases if the rumen pH is significantly decreased (<6), as is the case in SARA.
Whatever the cause of the initial insult, the disease process may be exacerbated by a compromised cow environment, in which cows spend excessive time standing, or insufficient time lying.

Thus, although the resultant claw horn lesions observed at the sole surface are similar, they may be caused by quite different initial trigger factors – namely systemic changes occurring at parturition and SARA. In addition, claw balance and excessive claw horn growth and wear may influence the severity and location of the lesions. Factors such as biotin and zinc, which influence horn quality, may also be significant in determining lesion severity.

The main treatment for acute or subacute laminitis consists of non-steroidal anti-inflammatory drugs and anti-histamines. As in the horse, the use of corticosteroids is contra-indicated.

Treatment of chronic laminitis consists of functional claw trimming, but is only indicated in mild cases. It is rarely possible to restore normal weight distribution, because horn of the entire claw has softened, causing the wall to become partially detached and collapsed.

Treatment of subclinical laminitis is difficult, because the disease is insidious and - by definition - the condition is difficult to recognise. Prevention is the main aim for this type of laminitis and an epidemiological approach involving the whole herd (which is beyond the scope of this paper) is often required.

**Heel erosion (slurry heel)**

Some authors consider heel erosion to be a sequel of interdigital dermatitis and, therefore, classify this condition under the group of infectious claw diseases. However, since it is a lesion involving horn of the claw capsule, it will be briefly discussed in this paper for completeness.

The loss of horn from the bulb surface of the claw starts at the axial side of the bulb. The erosion is irregular and often followed by overgrowth of poor quality sole horn, directly anterior to the erosion. This wedge of abnormal horn causes pressure on the corium, which becomes inflamed and painful. Sequelae to chronic extensive heel erosion include heel ulcer, sole ulcer, sole abscess, white line disease, and complete heel loss. In general, hind claws are more commonly affected than front claws.

Heel erosion is a common finding in housed dairy cows, but the exact aetiology is still much debated. Some workers from the northern hemisphere believe that heel horn erosion is typical for, but secondary to an infection with *B. nodosus* (interdigital dermatitis). The repetitive pattern of cure and re-infection, which occurs during the respective grazing and housing periods, is responsible for the typical black, V-shaped fissures of the bulb area. Others believe that heel erosion may be due to non-specific bacterial and chemical agents originating from faeces and urine. It has also been suggested that at least part of this phenomenon occurs as a sequel to laminitis. Layers of haemorrhages in the horn of the sole often terminate as grooves on the bulb (identical to that in heel erosion). These grooves may become a focus of infection, followed by disintegration of horn. Also, heel horn erosion is more likely to occur when keratinisation is abnormal, which is another sequel of laminitis.

Treatment consists of functional claw trimming followed by curative trimming, during which all under-run horn must be removed. To some degree, heel erosion may be prevented and controlled by foot bathing and providing dry underfoot conditions.

**Axial wall crack**

Axial wall cracks may occur in all claws, but are more commonly observed in the lateral hind claws. In most cases, such cracks occur adjacent (i.e. run dorsally) to the axial groove of the claw. Occasionally, these cracks involve the axial groove proper. Their exact cause is unknown, but conformation (genetic) factors must be considered. A certain percentage of axial wall cracks are seen in cattle with corkscrew claws. Whether in these cases the corkscrew conformation is the initiating cause or the resulting effect of the axial wall crack condition is open for debate. However, axial wall cracks also occur frequently in cattle that have otherwise good claw conformation. Environmental factors have also been suggested, as these cracks occur across dairy breeds at an incidence proportional to breed prevalence.

Often, axial wall cracks are present without causing obvious lameness. However, lameness frequently occurs after heavy rainfall. Under these conditions, fine mud and debris become impacted and
are forced into the cracks causing infection and/or pressure on the underlying corium. Septic tracks often discharge at the axially situated coronary band. Granulation tissue may develop in long-standing cases, often resulting in severe lameness.

In some cases, the only discernible lesion is an axial wall crack. The lesion does not extend into the corium, and there is no infectious process present. In such cases, mild thumb pressure applied to each side of the pared crack may demonstrate that these sides move relative to each other. Thus, each time the cow bears weight on the affected claw, the two edges of the crack will be pulling or pushing sensitive lamellae in directions not intended. This will be painful and eventually stimulate the formation of granulation tissue.

The most successful treatment involves removing the debris from the crack and careful paring of the horn edges adjacent to the crack, using a sharp hoof knife, curette or the Dremel Moto-flex tool with a suitable burr attached. Any under-run horn needs to be pared away. It is important to avoid exposure of, or any damage to the corium, as this is likely to lead to the formation of granulation tissue. To minimise movement of an infected and painful crack during weight bearing, the affected claw should be trimmed, in particular the axial portion of the toe should be lowered. Alternatively, a block or cowslip can be applied to the sound claw.

If granulation tissue is present, this should be removed and an astringent dressing (Lotagen gel or copper sulphate) applied and held in place for several days with an Elastoplast bandage and heavy plastic tape. Antibiotic treatment is indicated if infection of the corium or coronary band is present. In some refractory cases, particularly those where granulation tissue is exuberant, claw amputation is the only practical option to permanently solve this condition.

**Horizontal fissure** (thimble)

This condition presents as a discontinuity of the claw wall, which runs parallel to the coronary band. It occurs sporadically and is due to a total, but temporary interruption of horn production. The disorder is generally related to severe laminitis, a severe systemic illness (e.g. an acute febrile disease such as mastitis or metritis, often around calving), rumen acidosis, severe eczema, or malnutrition (starvation). As the horn grows (at approximately 5 mm per month), the defect cracks, usually when it reaches halfway down the distance from the coronary band to the toe, which is several months after the event. A significant number of such horizontal fissures are simply shed from the toe without producing lameness. In some cases, however, the lower half of the claw capsule remains attached only by the sensitive lamellae, which causes severe pain (and lameness) as the cow walks. The defect may also allow infection to penetrate below the surface of the wall.

Horizontal fissures may occur in one or more claws of the same animal. Occasional cows may have all eight claws affected, or at least have evidence of interruption in horn growth on all claws.

Treatment consists of careful trimming to remove all the loose horn, which usually leaves exposed corium at the toe. A block or Cowslip should be applied to the other claw, if sound or less affected. The aim is to relieve the pain until new horn grows down the claw wall. Animals that have all claws severely affected may need to be slaughtered or destroyed on welfare grounds.

**Vertical fissure** (sand crack)

These fissures originate as a split in the dorsal claw wall extending distally from the coronary band for a variable distance along the direction of growth. Warm, dry and windy conditions (making the horn dry and brittle), sandy soils, and trauma to the coronary band are predisposing factors. Deficiencies of the trace minerals zinc and copper have also been suggested to play a role in the aetiology of vertical fissures. The front lateral claws are most commonly affected, which indicates the influence of anatomical factors.

Superficial cracks are of no consequence. Similarly, incomplete, even large cracks of the wall are frequently not associated with lameness. However, they can become a problem, especially in beef cattle and A.I bulls when deep fissures, extending down to the underlying lamellae, lead to infection accompanied by pus formation and, because there is little room for expansion, intense lameness.
Vertical fissures are categorised as follows:

- **Type 1**: limited to the coronary band.
- **Type 2**: extending from skin-horn junction to middle of the claw wall.
- **Type 3**: extending from skin-horn junction to distal claw wall.
- **Type 4**: extending from middle of the claw wall to distal claw wall.

Most vertical fissures in cattle are benign and require no treatment. However, some Type 1 fissures may become infected and discharge at the coronary band. In these cases, a small wedge of horn should be removed from either side of the fissure to provide drainage. This triangular-shaped wound should be dressed (using an astringent dressing), and a pressure bandage applied to reduce the formation of granulation tissue. The edges of large fissures (Type 2 and 3) are best trimmed out, using a hoof knife, curette or Dremel Moto-flex drill. Any debris or foreign material should be removed from the depth of the widened fissure. Filling-in these fissures with some type of a resin (e.g. Bond-n-Flex, Equithane) is optional, but has proven to be very beneficial (in the author’s experience). In order to minimise movement of a large fissure, where the two sides of the wall may be unstable during weight bearing, the axial portion of the toe should be trimmed back or a block / Cowslip applied to the sound claw. If very extensive and unstable, the two sides of the wall may need wiring together.

In fissures where proud flesh is present, the crack is opened further and the proud flesh removed. The claw is then bandaged as described above. Antibiotics are indicated in cattle with infected fissures.

**Claw deformities**

These have been extensively described in the relevant literature. Unfortunately, few claw abnormalities have been reported with evidence of studies clearly defining the role of inheritance. In the field, we see cow families with abnormalities in horn growth and we see abnormalities in the offspring of some bulls. An acquired abnormality may result as a sequel to a primary claw lesion, or may result due to stresses imposed by the upper part of the limb.

Marked deformation of the claws occurs in the **alkali disease syndrome**, a chronic form of selenium toxicity.

A **corkscrew claw** is a claw in which the abaxial wall, usually of both lateral hind claws, grows beneath the distal phalanx and displaces the sole dorsally. Once established, this condition is irreversible. Regular functional claw trimming at intervals of 3 months can prolong the useful life of an animal. Since this condition is likely to be inherited, such an animal’s progeny should not be retained for breeding purposes.

**Overgrown claw** is an elongation of the claw with increased lengths of the walls and sole, and a greatly reduced (= more acute) angle between the dorsal wall and the bearing surface. In the advanced stage, the toe will bend upwards, so that it no longer rests on the ground. The condition often involves both digits on all four limbs, but is usually more severe in the hind limbs. The cause is simply lack of wear (e.g. as a result of being confined on soft surfaces or because of excessively hard claw horn).

Treatment consists of corrective trimming. The aim is to return the shape of the claw back to normal, and to allow the animal to acquire a normal stance again. Excess horn is first removed from the abaxial wall and toe area using double-action (multi-joint) hoof cutters. Further correction can be carried out using either hoof knives or an angle grinder. Finally, the sole is shaped to slope to the axial wall.

A **slipper foot** is associated with chronic laminitis. The claw is excessively long, has a square toe, a marked concavity of the dorsal wall, and its width is markedly increased. The claw is heavily rippled or rough, and appears dull.

Functional claw trimming is contra-indicated in all but the mildest cases. It is often impossible to restore normal weight distribution, because horn of the entire claw has softened, causing the wall to collapse. The wall frequently is detached from the sole.
COMPLICATIONS ARISING FROM CLAW HORN LISIONS

Osteitis of the distal phalanx

The most common cause is bacterial invasion through the sole or sole-wall junction. This may result from penetration by sharp objects or direct spread of infection from sole abscesses and white line disease. The distal phalanx may also be exposed when moist and soft claws are suddenly subjected to extreme wear.

Lameness is usually severe, but swelling is minimal because the problem is situated within the claw. When the sole is open, a haemorrhagic and necrotic distal phalanx may be identified following the removal of necrotic debris. The apex of the distal phalanx is most commonly affected.

In those cases in which the bone can be debrided and all necrotic tissue removed, the area should be packed with an antiseptic or antibiotic compound, and a bandage applied. The affected claw should be rested by attaching a wooden block or Cowslip to the sound claw. Systemic antibiotics are administered for 7 to 10 days. The dressing should be changed weekly until a granulation tissue layer has completely covered the previously exposed bone. The defect is eventually repaired with fibrous tissue, and the sole is completely regenerated to provide protection to the bone and to permit complete clinical resolution.

When the septic process is far advanced, amputation of the claw is the best treatment. An alternative to amputation (for very valuable animals) is to resect all or part of the diseased distal phalanx through a distal approach, pack the defect, and allow granulation tissue to fill the cavity. The claw wall is preserved with this technique.

Deep digital sepsis (septic arthritis of the distal interphalangeal joint and adnexa)

Affected animals are severely lame. Pus produced in the joint may discharge through one or more sinuses at or near the site of entry of infection. Due to increased intra-articular pressure, a distinct and painful swelling develops just above the dorsal and abaxial areas of the coronary band. Sinus formation may occur along the abaxial coronary region where the joint is quite superficial. Once the joint is infected, progressive tissue destruction occurs for a prolonged period. Even prolonged treatment with antibiotics is unlikely to be successful, and amputation or radical debridement and curetting of the infected area, with or without the application of drains, are indicated.

Infection can easily spread to the tendons and tendon sheaths of the plantar / palmar aspect of the digit. In case of necrosis of the deep flexor tendon, rupture and avulsion of the insertion of the tendon on the distal phalanx occurs. In this case, the toe will point upwards because of a relatively increased pull of the extensor tendons.

Arthrodesis and resection techniques are recommended for very valuable animals only. These refined surgical procedures are often not cost effective for standard production animals. Also, the procedures are likely to be successful in relatively early cases only, i.e. not longer than 14 days. Considerable aftercare is needed (usually weeks to months – not days!), as well as facilities to confine the animal (i.e. a box stall) for several weeks. Description of these surgical techniques is beyond the scope of this paper.

In a few selected cases, attempts to establish drainage and curette the area (so called “coring”) may lead to resolution of the septic arthritis. A large (5 cm diameter) opening is cut around the sinus in the abaxial or ventral aspect of the claw using a sharp hoof knife. As much of the necrotic tissue as possible, including the distal sesamoid (navicular bone), should be removed. A block or Cowslip is attached to the sound claw, the toes are wired together, and a five-day course of systemic antibiotics is given. For several days afterwards, the wound should be flushed out with water at each milking.

Some cases of septic arthritis may “resolve” naturally, allowing ankylosis of the joint which is accompanied by extensive swelling and deformity of the digit. While waiting for this to happen, the animal is subjected to prolonged pain, which will result in considerable loss of condition and production. To relieve the pain (and reduce the losses) to some degree, a Cowslip or wooden block should be applied to the sound claw and the toes wired together. It can be argued whether or not such a treatment should be
recommended by a veterinarian, and amputation or slaughter seems the preferred option.

The common indications for claw amputation are:

- Septic arthritis of the distal interphalangeal joint
- Osteitis of the distal phalanx / distal sesamoid
- Necrosis and septic tenosynovitis of the deep flexor tendon (at its point of insertion on the distal phalanx or adjacent to and involving the navicular bursa)
- Septic processes of the coronary band and / or supra-coronary tissues.

This technique provides a short-term, but economical solution for removing damaged or infected digital structures. A rapid reduction in pain, immediate and complete removal of infected tissues, provision of surgical drainage, and a relatively rapid return to thriftiness with improved condition and milk yield, are achieved by a simple surgical procedure. However, it leaves the animal with only one claw, and survival time in the herd should be aimed at completing the current lactation.

The main disadvantages include the potential failure if case selection is poor and infection is present dorsal to the amputation site, persisting poor gait - particularly in heavy cows and bulls due to altered stance and strain on the remaining digit, especially in difficult terrain - and the early removal from the herd (few cows with amputated claws are retained for more than 1.5 to 2 years).

Claw amputation should not be performed in herds where the cow has to walk over a slatted area to be milked. Careful consideration regarding this procedure is also required in the following situations:
- Heavy animals
- Hind claws in breeding bulls (because of problems with mounting)
- Medial claws in both hind and front limbs (often there is difficulty in adjusting the proper placement of the remaining digit).

**The technique of claw amputation**

After sedation, the lower limb - including the interdigital space - is thoroughly cleaned and surgically scrubbed. A tourniquet is applied just below the tarsus or carpus. Regional anaesthesia is achieved using either a ring block or the intravenous technique (see below under “Anaesthesia of the bovine digit”).

Ideally, the amputation should be made at the level of the lower one third of the middle phalanx, distal to the nutrient artery. If a higher amputation is required, then aim for the distal one third of the proximal phalanx. The interdigital space is incised with a scalpel blade close to the affected digit along its entire length, and about 0.5 to 1 cm dorsally, and 1 to 1.5 cm at the plantar / palmar aspect. The incision is then continued around the abaxial aspect of the digit to be amputated approximately 0.5 cm above the coronary band, and cutting right up to the bone. A section of obstetrical wire is inserted into the interdigital incision and used to finalise the amputation. The sawing should be done under an oblique (about 30 degrees) angle, directing upwards. Skin flaps (recommended by some authors) are not created, nor are sutures applied to the wound. If amputation occurs through the joint, then it is important to destroy the joint capsule and remove (curette) most of the cartilage from the surface of the bone. Otherwise, the on-going synovia production will interfere with wound healing.

Any protruding interdigital fat should be removed, and the open wound dressed with an antibiotic powder or water-based antibiotic ointment on a non-adherent dressing. A thick gauze pad or any other suitable absorbing material is used to cover the stump, and this is held in place by means of a pressure bandage, which should extend above the accessory digits (so these structures can be used to anchor the bandage). After the tourniquet is removed, some blood will seep through and / or flow from underneath the bandage, but this should not be excessive. If so, another firm bandage should be applied to control the haemorrhage.

A 3 to 5-day course of antibiotics must be given, and the dressing changed after 2 to 3 days. Now, a lighter and less tight bandage can be applied, which is left in position for 2 to 3 weeks. The stump surface may then safely be left exposed for further granulation to occur. Complete healing is usually achieved in 5 to 6 weeks. Animals should be kept in reasonably dry surroundings, either housed or outdoors on dry ground, during the 3 week recovery period.

Uncomplicated cases have a significant improvement in gait and reduction in pain within a few
hours of surgery. If relief is not obvious within the first week, careful re-evaluation is required. A patient should be using the limb normally by 3 weeks.

**Fracture of the distal phalanx**

This rare condition causes acute pain and severe lameness. Most reported cases are associated with fluorosis, osteitis, low copper levels, and heavy body type. Traumatic factors may then precipitate the fracture. In many cases, the animal is found to have a fracture of the distal phalanx without an obvious cause evident.

Fractures are usually articular and extend to the sole surface of the distal phalanx. Initially, there is minimal displacement, but distraction of fracture fragments increases with time, presumably as a result of tensile forces exerted by the deep digital flexor tendon and bone resorption at the fracture site.

One or two limbs may be affected with the medial claws of the fore limbs most commonly involved. If only one limb is affected, little or no weight is taken on the affected limb. If untreated, the stance and gait change so that the fractured distal phalanx bears as little weight as possible. Where both fore limbs suffer such a fracture more or less simultaneously, a typical cross-legged stance is acquired. In the extreme case, the animal may crawl on its knees (carpal joints).

Examination reveals no or little swelling above the coronary band (because of restriction of the claw wall), but heat may be detected in the claw. Compression of the claw with hoof testers and percussion is resented, as is flexion of the joints of the lower limb. The condition may be confused with acute laminitis, and precise diagnosis may require radiography.

The course of the disease is a prolonged natural resolution. Untreated, animals remain lame for several weeks. The recommended treatment is to raise the affected digit off the ground using a Cowslip or wooden block affixed to the sound claw. Properly treated, the animal will show an immediate improvement in gait and appetite, and milk production will also improve markedly. The slip or block should be left in place for at least 6 weeks.

A short-term and simplistic approach to treatment is to amputate the affected digit above the level of the fracture site. The animal will thus become weight bearing on the limb within a few days and sound within a few weeks, which may facilitate finishing the animal for slaughter faster than would be possible if the fracture undergoes the natural healing process.

When the rare double fracture occurs on the same limb, the distal limb should be completely enclosed in a short fibreglass cast to the level of the proximal metacarpal bone. Clinical healing usually occurs within 4-8 weeks.

**SOME PRINCIPLES OF TREATING CLAW LAMENESS**

- Good and safe facilities are required for handling and treating lame cows. Such facilities are lacking on many dairy farms!
- Adequate restraint is crucial. Many cases are better treated after sedation and, if required, suitable local anaesthesia.
- A thorough examination of the claw is often necessary to accurately diagnose the lesion.
- Suitable equipment is mandatory, i.e. sharp hoof knives and hoof cutters.
- Treatment of certain claw conditions can be quite painful and the use of local anaesthesia of the digit(s) can then be very helpful (see below).
- Any area of under-running or sole penetration must be adequately opened to provide satisfactory drainage.
- In case of claw cracks, as little underlying corium as possible should be exposed otherwise there is a marked risk of the formation of granulation tissue (proud flesh).
- If excess granulation tissue develops, it must be removed, the area treated with an astringent dressing (Lotagen gel or copper sulphate), and a pressure bandage applied. The owner may have to repeat this bandaging. Elevating the affected claw (by means of applying a block / Cowslip to the sound claw) is recommended.
- Lame cows should be kept close to the dairy shed, until the lameness has resolved. This can take a long time; for example, up to 6 weeks for severe cases of white line disease.
• With painful claw lesions, the pain can be greatly reduced by raising the affected claw off the ground, i.e. putting a block or Cowslip on the opposite claw (see below). This claw should be sound, as it has to take the full weight of that limb.

RESTRAINT AND HANDLING FACILITIES

Occupational health and safety in the work place is now a very important issue, and farms are not excluded from the need to provide a safe work environment. Claw trimming and treating lame cows are potentially dangerous exercises. Not all dairy farms have facilities in which veterinarians can work in reasonable safety. Certainly, there are many situations where the facilities provided are inadequate, and risks need to taken when working with lame cows.

When lifting a limb of a standing animal it is essential to restrict the cow’s movement in all directions, i.e. forward, backward, and sideways. Restraint in a chute / crush fulfils this requirement best. In production units with a high incidence of lameness, special facilities should be created or suitable restraining equipment purchased.

Ideally, a chute / crush should be adjustable for different sizes of cattle, should be relatively quiet in operation, and have a non-slip floor. It should be designed to avoid potential injury to both stock and people. In many countries, veterinarians and professional claw trimmers use mobile crushes or tipping tables for treating lame cows and / or routine claw trimming. A good example of a mobile, walk-in crush is manufactured in the Netherlands (Wopa crush). This model can be towed by a light car and manoeuvred into place by one person. The cow is led into the crush and restrained in a head gate. The animal has restricted movement in all directions, and the operator can work from the side. Hind limbs are lifted with a manual crank, and fore limbs are managed by using a belly strap and resting them on a specially designed support.

ANAESTHESIA OF THE BOVINE DIGIT

In cattle, most indications for this type of anaesthesia are related to painful interference of the digit(s) and to selected cases of surgery. When performing regional anaesthesia on the limbs of cattle, it is prudent to sedate the animal. However, xylazine has a relatively long milk withholding time (in New Zealand) and is, therefore, less often used nowadays. The dose rate will depend on whether the surgery is done on the animal standing or lying down. In most instances, animals can be treated in a standing position with the affected limb tied up against a rail. Very fractious animals are best cast and restrained in lateral recumbency with the affected limb uppermost.

Light sedation (using 6 to 10 mg of xylazine injected into the tail vein) makes dealing with lame cows much easier. It quietens the animal, and also diminishes defecation and urination. For painful procedures of the digit, further anaesthesia is required from the point of view of both the cow and the veterinarian.

Besides being effective, the major other requirement for anaesthesia of the digit is that the method should be quick and simple. The two techniques most commonly used are intravenous regional anaesthesia (IVRA) and the interdigital nerve block.

Intravenous regional anaesthesia

This procedure has become the preferred analgesic technique for the bovine digit, having superseded the techniques of ring block and nerve blocks. It is indicated in any painful interference distal to the hock or carpus, and is ideal for all surgical procedures of the digit.

The technique is safe, simple and effective, and involves the injection of a local anaesthetic solution into any accessible and prominent (superficial) vein situated distal to a previously applied tourniquet. The mode of action of intravenous regional anaesthesia is not completely understood, but anaesthesia is apparently produced by diffusion of the local anaesthetic solution from the venous bed. In contrast to nerve blocks, a detailed knowledge of the regional anatomy is not required.

A strong rubber tourniquet (a “bungy” or strips of narrow inner tube) is placed around the limb either above or just below the hock / carpus; several turns should be used. If the tourniquet is placed above the hock, it is necessary to wedge a roll of bandage in the depression between the gastrocnemius tendon and
the tibia, both laterally and medially.

It does not matter, which vein is chosen for the injection. However, the veins most commonly used are the medial branch of the cephalic vein on the metacarpus (front limb) and the lateral branch of the saphenous vein on the metatarsus (hind limb). The preferred place for injecting is where they run obliquely palmar / plantar to dorsal about 5 cm proximal to the fetlock joint. Inflammatory processes are likely to distort the various structures and may make these veins difficult to locate.

Following routine preparation of the area, a 20-gauge $\times$ 2.5” needle is inserted into the vein, directed either proximally or distally depending on personal preference, and 10 to 20 ml of a 2% plain lignocaine solution is injected fairly rapidly. In order to reduce pressure, allow some blood to drain from the vein prior to administering the solution. Apply firm pressure to the puncture site on removal of the needle, and massage the injection site briefly to prevent haematoma formation.

Analgesia develops in all tissues of the entire limb distal to the tourniquet after 2 to 3 min, and is complete within 10 min. It will persist for at least 60 min if the tourniquet remains in place. Although it is safe to leave a tourniquet in place for 1 hour or more, it is wise to keep this time relatively short. Few surgical procedures ever require that length of time. Sensation and motor function return in about 5 min, once the tourniquet has been released.

Alternatively, it may be easier to use the dorsal common digital vein III or to tap into any venous plexus on the dorsal or palmar / plantar site of the limb, exactly in the mid-line and 2 to 3 cm below the fetlock joint (at the level of the proximal interphalangeal joint). It should be realised that - in infected areas - there exists a real possibility of introducing and / or disseminating an infection.

Any failures are usually due to tourniquet problems, peri-vascular injection, a too small a volume of anaesthetic solution or failure to allow sufficient time for anaesthesia to develop. The interdigital region is the last area to become fully numb, and increased amounts (up to 30 ml) of anaesthetic solution may be needed to achieve adequate analgesia. If the anaesthesia block fails, the procedure may be repeated once more.

Although extremely rare, toxicity related to the entry of local anaesthetic solution into the circulation (e.g. minor convulsions and seizures, trembling and salivation) may occur, especially with early removal of the tourniquet. Therefore, it is advisable to leave the tourniquet in place for at least 15 min.

Once the technique of regional intravenous anaesthesia has been used successfully and the person being proficient at it, few veterinarians will revert to the relatively difficult and less effective techniques of local infiltration and nerve blocks.

**Interdigital nerve block**

To anaesthetize the interdigital region and axial aspects of the claws in both front and hind limbs, only two points need to be used:

1. Dorsal mid-line, 2 to 3 cm distal to the fetlock joint and 2 to 2.5 cm deep; 10 ml of a 2% plain lignocaine solution is injected whilst withdrawing the needle (20-g x 1.5”).
2. Palmar / plantar mid-line, 2 to 3 cm distal to the accessory digits and 2 to 2.5 cm deep; another 10 ml is injected.

Good anaesthesia may also be achieved by injecting 20 ml of local anaesthetic solution into site 1 only (use a 20-g x 1.5” needle, and initially insert right up to the hub).

This quick and reliable technique is indicated for the removal of interdigital hyperplasia and painful procedures of the interdigital space, including the trimming of axial wall cracks. This nerve block does not anaesthetize the abaxial aspects of the digits and, therefore, is not appropriate for claw amputation.

**CLAW BLOCKS AND COWSLIPS**

Claw blocks and Cowslips are used to elevate the diseased claw and, therefore, should be attached to the trimmed, balanced healthy claw of the lame limb. This will transfer weight from the affected claw, thereby improving both the speed of resolution of the lesions and the welfare of the cow.

The main indications for their use are:
Any painful claw condition which affects only one claw (e.g. sole/toe ulcer, fracture of the distal phalanx, toe abscess, underrun sole, and severe white line disease).

If there is a need or wish having the lame cow to remain in the milking herd.

There is a wide range of different glue-on, wooden blocks available, as well as nail-on rubber blocks (similar to shoeing a horse). In the latter, special care must be taken that the nails (not less than four pony nails, preferably five) remain well within the white line, i.e. not penetrate or touch the corium. The surface to which a rubber block is going to be applied must be flat in order for it to seat correctly. Applying these rubber blocks requires considerable skill and practice, and it is safer to use wooden blocks, which are glued on to the weight-bearing surface of the claw. Their main disadvantage is the cost.

Other disadvantages are:

1. The application is time consuming (10 to 15 min per block).
2. A small percentage (about 5%) comes off too early, i.e. within a week.
3. Because of uneven wear, it may be necessary to remove the block prematurely.
4. They can be rather difficult to remove. The usual technique is to use an angle grinder or a set of multi-joint hoof cutters to expose the claw-block junction, and then use a large screwdriver to lever the block off.
5. The adhesive is potentially hazardous (irritant to the skin - contact dermatitis); the solvent component (methyl-methacrylate) is volatile and aromatic. Therefore, gloves must be worn when mixing and applying the adhesive.

**Method of applying the block**

The sound claw must be trimmed to a normal shape first, then thoroughly cleaned and dried. The sole should be prepared by creating a flat surface, free of loose or flaked horn. Do not remove any more horn then necessary, and it is very important not to expose the underlying corium. The sole should be rasped to roughen the surface or the sole and the distal 2 cm of the abaxial and axial wall may be lightly grooved using the sharp hook of a hoof knife. The objective is to increase the surface area for contact with the adhesive.

The next step is to de-grease the horn of the claw. This can be done with methylated spirit, acetone or petrol (not the two-stroke type because of its oil content!). The glue components are then mixed in a plastic cup (not poly-styrene!). The powder is added to the liquid, and mixed to a butter-like consistency using a wooden spatula. Some of the glue mix is then spread on to the prepared sole of the claw and the remainder on the surface of the block, which is to be attached to the claw. The block is then pressed firmly against the sole area, and the glue that squeezes out is moulded over the wall and sides of the block. Make sure that the block does not slip down towards the toe before the glue hardens and sets. Final moulding is made easier by putting a little water on the surface to reduce its stickiness. The block should not project beyond the toe, because this may cause its premature loss. The time taken for the glue to dry depends on the ambient temperature and in particular the temperature of the methyl-methacrylate liquid. The glue is usually quite hard within 4 to 5 min, but - as a safeguard - the cow's leg should remain tied up for a few more minutes. A hair dryer will speed up the drying process, but the glue tends to become brittle if it sets too quickly.

After the limb is carefully lowered to the ground, the cow should be left to stand in the crush or bail for another few minutes. The cow should then be turned out to a dry area (the suction effect of deep mud may remove the block before the glue has fully cured), or returned with the herd. If the toe levers up as the cow walks away – the block is located too far forward. In this case, a new, better positioned block should be applied.

Blocks should be removed after 4-6 weeks if they did not fall or wear off before that time.

In many situations, Cowslips and other generic products (e.g. Demotec Easy Bloc) have now taken over from the traditional wooden blocks. These strong PVC shoes come in different sizes (standard and extra), and are designed to fit over the sound claw. The large contact area of the adhesive between the Cowslip and the horn considerably reduces the chance of failure to adhere. The moulded upper of the Cowslip transfers weight bearing to the claw wall, which is a natural weight-bearing structure. It is
important that the moulded upper of the slip fits neatly against the dorsal wall of the claw. For this to happen, the toe of the claw may need to be trimmed back.

The claw is prepared in a similar way to that described for the wooden blocks. The glue components are mixed within the Cowslip itself. The liquid component should be put in first, followed by the powder. In the winter (lower ambient temperatures), it is safe to add all of the powder, but in the summer, start with half the amount of powder and add as required. The Cowslip is then fitted on to the sound claw, ensuring that it is pushed towards the heel as far as possible. Any excess glue, which exudes from the proximal part of the slip, should be transferred to the heel. Special care should be taken to make sure that the medial rear corner of the fitted cowslip does not impact against the affected claw. When this happens, the corner should be removed by cutting it off with hoof clippers after the glue has set.

Cowslips are quicker and easier to apply than the wooden blocks, but they have a slight disadvantage in that they do not raise the claw to be rested as high off the ground. Another disadvantage is that the Cowslip elongates the sole, thereby disturbing the balance of the claw. Therefore, Cowslips should not stay on any longer than 6 weeks, because they tend to wear unevenly. This may lead to excessive strain on the affected limb as well as causing the animal to adopt an abnormal gait. Generally, the duration of adhesion to the claw allows sufficient time for most lesions to heal. It is quite common for Cowslips to be still in situ 30 days after application.

Cowslips are best removed using a hammer and chisel, or by clipping along the abaxial wall with hoof cutters.

Products such as Bovi-Bond, Demotec Easy Bond and Demotec Futurapad are based on the traditional wooden block and Technovit glue. These latest blocks on the market have certain advantages, i.e. they are easier and quicker to apply and, because they do not stay on so long, tend to disturb the balance of claw less. They also raise the affected claw significantly higher than Cowslips do. Therefore, they are very suitable if the claw needs to be raised for only a week or so. The Demotec Futurapad blocks are easy and very quick to put on, and in the author’s experience often stay on for a few weeks or more.

THE USE OF POWER TOOLS

Many veterinarians prefer sharp hoof knives and multi-joint hoof cutters as their primary tools for examining and trimming claws. However, in situations where claws get very dry and hard, the use of power tools may be considered.

A motorized disk cutter (angle grinder) fitted with a fairly course disk can be used to quickly clean the weight-bearing surface of the claw. This allows small holes or penetrations to be readily visualised. The surrounding area of any penetration can be made very thin using the grinder. Usually, a delineated area of pus is clearly visible underneath the thin layer of horn. A scalpel blade is used to remove the horn from the affected area.

Similarly, and angle grinder can be used for thinning horn overlying sole ulcers and areas of white line disease where the lesion has lead to separation of the wall. Again, a scalpel blade is used for the final trimming and to remove the horn from just below the coronary band.

An angle grinder can also be used for removing excess horn (e.g. the routine trimming of A.I. bulls), but should be used with caution to avoid over-heating the horn and underlying corium. Sanding disks are generally not recommended because they may generate considerable heat. However, a recent experimental study indicated that the issue of thermogenesis (due to mechanical claw trimming using grinding disks) is negligible if correct functional claw trimming is carried out, i.e. leaving a minimum sole thickness at the toe of 5 mm (Kofler et al, 2004). Specialised disks, which cut very quickly but do not create any significant heat, are now available (e.g. the Roto-clip 6 carbide flat disk, which fits on a 4.5” grinder).

Important points to remember are:

- An angle grinder can remove horn very quickly; therefore, proceed carefully.
- Grinders are potentially dangerous tools for both animal and operator, and animals need to be sedated and well restrained.
• Always use a circuit breaker to avoid electric shock or electrocution.
• Always wear safety glasses or goggles.

A Dremel Moto-Flex Tool can be used for trimming vertical fissures and axial claw cracks. This small, high-speed power drill was originally designed as a hobby tool, and comes with a flexible drive shaft. A variety of accessories, including grinding stones, burrs, drill bits and cutting wheels can be attached to the unit. The drill operates at a speed of up to 25,000 revs/min and, when using a suitable burr, can very quickly and easily trim out cracks in the claw wall. The instrument can also be used for other claw-related tasks, such as cutting and shaping methyl-methacrylate.

**BANDAGES**

Opinions on the need to apply a dressing to exposed corium are divided. An increasing number of veterinarians (including the author) now consider that new horn forms more rapidly in the absence of a bandage. There is a danger that a dressing will physically cause the exposed corium to remain weight bearing and impede drainage. In a trial to evaluate bandaging in various claw lesions, cows with non-bandaged claws were significantly less lame. Elevating the affected claw promotes healing and is recommended for serious cases.

The use of bandages should be restricted to post-surgical applications, and even then applied for as short a period of time as possible. Bandages have potential disadvantages:

• They are bulky, and if applied over a sole lesion, undesirable pressure may inhibit healing.
• They absorb moisture, which may carry infection to the lesion.

Bandaging between the claws is contra-indicated in the management of interdigital lesions, because this practice separates the claws and tends to open the lesion. Wiring the toes together or strapping the claws together using an Elastoplast bandage or strong tape aids healing of interdigital wounds.
References


MANAGEMENT OF CLAW DISORDERS BY APPLICATION OF FUNCTIONAL AND CORRECTIVE CLAW TRIMMING PROCEDURES

J.K. Shearer, DVM, MS.
Professor and Dairy Extension Veterinarian, College of Veterinary Medicine, University of Florida
Gainesville, Florida 32610-0136, JKS@ifas.ufl.edu

Introduction
Lameness is one of the most important health problems on today’s dairy farms and certainly one of the more difficult to manage. Involvement by veterinarians varies from specific diagnosis and treatment of individual lameness conditions to consultation with the dairy owner and management team on procedures for treatment, control and prevention. There are several obstacles to timely examination and treatment of lameness by veterinarians, as well as herd owners or their employees. In many situations, farms lack appropriate restraint facilities for examining lame cows. Foot care under these circumstances becomes an arduous, if not dangerous task. It is often complicated still further by the condition of one’s hoof care equipment. A sharp knife and a good set of nippers are essential in foot care. Beyond these one must understand the pathogenesis of lameness and the most appropriate trimming and treatment techniques to provide relief.

In large herds where restraint systems are often more readily available, direct involvement by veterinarians may be limited by the sheer number of lame cows encountered on a daily basis. As a consequence, throughout North America (in fact, much of the world) foot care and claw trimming is performed by either commercial trimmers or farm employees. Methods and technical expertise amongst trimmers varies significantly. This occurs in part because there are very few formal training programs for persons interested in foot care, and in most cases, no apprenticeship is required for a person to become established in the foot care business. As a result, the quality of foot care available to dairy farms in some areas is inconsistent and on occasion contributes to a greater amount of lameness.

The following is a brief review of some of the more common conditions including options for their treatment through application of appropriate claw trimming procedures.

Laminitis (Clinical and Subclinical) and its Relationship to Claw Disease

The Classical Description. The pathogenesis of laminitis is believed to be associated with a disturbance in the micro-circulation of blood in the corium which leads to breakdown of the dermal-epidermal junction between the claw wall, and the bone with in the claw, otherwise known as the third phalanx (P3). Rumen acidosis is considered to be a major predisposing cause of laminitis and presumably mediates its destructive effects through various vasoactive substances that are released into the blood stream in coincidence with development of rumen acidosis. These vasoactive substances initiate a cascade of events in the vasculature of the corium including increased blood flow, thrombosis, ischemia, hypoxia, and arterio-venous shunting. The end result is edema, hemorrhage, and necrosis of corium tissues.

The vascular disturbances associated with laminitis affect corium tissues at the cellular level. This is considered to be particularly important, since horn is formed by specialized epidermal cells known as keratinocytes that are dependent upon a good blood supply from the corium. These cells receive nutrients from the corium by diffusion across the basement membrane (a membrane that separates the corium from the epithelium). Keratinization is the process by which keratinocytes produce keratin proteins that provide structural support to the cell and thus impart rigidity and strength to claw horn. As keratinocytes move toward the skin (or in the case of the claw horn capsule) surface they gradually reach a point at which they no longer receive
sufficient nutrients by diffusion from the corium. This leads to cell death and cornification, the process whereby cells become hardened and cornified as horn.

The quality of claw horn is dependent upon keratinization which gives the horn cell structural rigidity and strength. In conditions resulting in vascular compromise such as laminitis, the keratinocyte normal development is disrupted a consequence of being deprived of nutrients. The end result is the production of poorly keratinized, or in other words weak or inferior quality horn. Thus, the term “claw horn disruption” has been proposed as possibly a more appropriate term for laminitis, and particularly subclinical laminitis.

By virtue of its anatomical location between the claw horn capsule and P3 the corium is particularly vulnerable to inflammatory insult. Any increase in size of the corium as a result of inflammation will increase pressure, pain, and tissue damage. Bound on one side by the wall of the claw and the other by P3, inflammation of corium tissues often leads to swelling at the coronary band.

Destruction of the dermal-epidermal junction has particular consequences in cattle as it permits weakening of the suspensory apparatus within the claw. As the suspensory apparatus weakens P3 begins to "sink" or "rotate" within the claw. The result is compression of the corium and supporting tissues that lie between P3 and the sole. This sets the stage for development of sole ulcers. In some cases this "P3 sinking phenomenon" involves severe rotation of the toe portion of P3 downward toward the sole. If compression of the corium by the toe is severe enough a toe ulcer may develop. If, on the other hand, sinking of the P3 is such that the rear portion sinks furthest, compression and thus sole ulcer development will most likely develop in the area of the heel-sole junction (known by some as the "typical site" or the site most commonly associated with the development of sole ulcers). Sole ulcers are very common claw lesions in dairy cattle and constitute one of the most costly of lameness conditions. As a consequence, they justify further discussion.

**Toe, Sole and Heel Ulcers**

Ulcers are common causes of lameness in modern dairy operations. They are defined primarily by the location in which they occur. Toe ulcers occur in the toe, sole ulcers in the typical site which is immediately beneath the flexor tuberosity of P3, and heel ulcers in the heel area just caudal to the heel-sole junction. An ulcer can be described simply as a circumscribed loss of horn which exposes the corium. Since ulcers form on the weight bearing surface they tend to be one of the most debilitating of lameness conditions affecting dairy cattle. Early ulcers are often uncovered in the process of hoof trimming, particularly when paring away sole horn in the interdigital area over the site where sole ulcers typically occur (also referred to by E. Toussaint Raven as the "typical site"). They are usually noticeable as an area of hemorrhage which when trimmed away may expose the underlying inflamed corium tissues. More mature or long-standing ulcers may be covered initially by rough, irregular horn tissue that when trimmed away exposes granulation tissue which bleeds freely if damaged. Granulation tissue is evidence of chronic inflammation and generally indicates that significant damage to the corium has occurred.

As indicated, laminitis is thought to be a major predisposing cause of ulcers. The combination of excessive claw horn formation, displacement of P3, and the accelerated growth of claw horn on the anterior or dorsal and abaxial walls predispose the lateral claw to excessive loading, wear, and weight-bearing at the "typical site". The additional strain and pressure applied to the heel/sole region (or toe in the case of toe ulcers) exacerbates dysfunction of the underlying corium and leads to development of the lesion either in the heel or typical site. Treatment requires removal of the necrotic (dead or decaying) horn tissue followed by elevation of the affected claw with a foot block attached to the healthy claw. It is important that one avoid damage to the corium when removing loose and decaying horn tissue. Serious damage to the corium results in prolonged discomfort delayed healing and may increase potential for reoccurrence of the lesion. All healthy horn tissue should be left in place (See Steps 5 & 6 under Claw Trimming and Foot Care).
White Line Disease

Areas of hemorrhage are often most noticeable and severe in the white line region of the sole. This corresponds to the primary weight-bearing region of the claw. Because it is an active area of horn formation it is also highly vascular, and a frequent site for hemorrhage during bouts of laminitis. These areas of hemorrhage are generally not visible during the acute stage of laminitis, but instead, gradually rise to the weight bearing surface as the sole grows outward over a period of 6-8 weeks. At this point they become visible and useful as indicators of previous disease of the corium (subclinical laminitis). It isn’t necessary to trim away these areas of hemorrhage as they will disappear naturally with continued growth and wear of the sole.

The lesion of greater significance is that associated with laminar necrosis and white line separation that leads to the formation of subsolar abscesses (otherwise known as white line disease). White line lesions are an important consequence of laminitis for a couple of reasons: 1) laminitis and its sequelae lead to weakening or elongation of the dermal-epidermal segment and distorted claw growth that often results in widening of the white line, and 2) horn of the white line formed by the diseased corium is softer (horn is less well keratinized), and thus more subject to wear, and penetration by foreign material from the environment. As a consequence, whenever the incidence of white line disease is high, it’s important to establish the possible contribution of laminitis to the problem.

White line separation/disease resulting in abscess formation is treated by paring away all loose and damaged horn adjacent to the lesion (See Steps 5 & 6 under Claw Trimming and Foot Care). This usually requires removal of the wall adjacent to the separation until all loose horn is removed. When paring away necrotic horn with white line lesions, it is best to slope the horn to the outside. In other words, avoid digging holes in the sole when trimming away white line lesions. Sloping of the horn away from the lesion prevents contamination and packing of environmental debris into the diseased site and thereby prevents reoccurrence. A foot block should be applied to the unaffected claw to reduce weight-bearing and ease discomfort in cases where the white line separation has led to abscess formation. As with treatment of sole ulcers, there is no need to bandage the lesion unless it is required to control bleeding. The same is true for antibiotic therapy unless the infection extends to deeper tissues of the foot as evidenced by swelling and severe lameness.

Claw Trimming: 2 Approaches

In the preface of Toussaint Raven’s book “Cattle Footcare and Claw Trimming”, he gives a very important warning that "If there is no lameness problem, trimming can produce it". Although claw trimming has an important role in the management of lameness conditions, experience has shown that on occasion claw trimming can be a cause for lameness. The most common error is over-trimming. It is important to remember that one of the primary purposes of the claw capsule is to protect the corium. When excess claw horn has been removed and the sole is no longer able to properly support the cow’s body weight, the underlying corium becomes subject to damage from bruising. Furthermore, in herds where abrasive flooring surfaces encourage rapid wear, cows may develop thin soles from excessive wearing away of solar horn. Thin soles in dairy cattle represent one of the most difficult foot problems to manage. Consequently, over-trimming should be carefully avoided. The functional and corrective trimming method described by Raven provides important guidelines for the maintenance of proper toe length and sole thickness. Regardless of how one chooses to trim claws these guidelines are useful to prevent trimming-related lameness.

The Traditional Approach to Claw Trimming. Claw trimming techniques applied to cattle are based largely on procedures used by farriers and others trimming the hooves of horses whereby weight is transferred primarily to the hoof wall. The technique consists of shortening the axial wall and sloping or “cupping out” the sole in order to place the majority of weight on the abaxial wall. This can be problematic in that underdevelopment of the axial wall is a primary reason for instability of the medial claw of the rear foot. Therefore, removal of the axial wall in both claws only exacerbates instability in the foot.
Transfer of weight-bearing to the abaxial walls naturally increases shearing forces on the walls. This is believed to increase the risk of white line separation and white line disease. Sloping of the soles is also believed to encourage development of sole ulcers by shifting weight-bearing within the claw onto the “typical place” for sole ulcers. When the soles are sloped axially the claws are encouraged to splay apart with each step the cow takes. This causes stretching and irritation of the interdigital skin and is believed to contribute to interdigital fibromas in cattle.

In most traditional trimming systems, there is no attempt to balance weight-bearing within or between the claws. Studies on the pathogenesis of sole ulcers and white line disease clearly show that claw horn overgrowth leads to disproportionate weight-bearing and eventually claw disease. The reestablishment of appropriate weight-bearing within and between claws is therefore an important objective in claw trimming and represents a major difference between the traditional trimming techniques and functional claw trimming as described by Toussaint Raven.

Finally, many who apply traditional trimming procedures complete their job by grinding or chipping away abaxial wall horn near the weight-bearing surface. Cosmetically, its appearance may be more appealing, but in terms of function the claw and its weight-bearing surface are made weaker and presumably more vulnerable to disease. Removing the abaxial wall not only reduces surface area for weight-bearing, but also eliminates the hardest part of the weight-bearing surface. It requires the cow to bear weight on the white line, sole and heel only.

**Functional and Corrective Claw Trimming.** Functional claw trimming is the method described by Toussaint Raven. Readers are advised to consult this book for a more in-depth review of this topic. The following describes the basic objectives and trimming procedure.

The objectives of preventative (claw) trimming are:

1. Correction of the relative overgrowth that leads to overburdening of the claw (overgrowth is most significant for the outside claw of rear feet and the inside claw of front feet).
2. Restoration of the appropriate weight-bearing surface within each claw.
3. Correction of claw lesions at an early stage.

The following 6-Step work plan for trimming feet is recommended:

**Step 1.** Judge the length of the claws. Since the inner hind claw represents the more normal claw, this claw is used as a model for the more abnormal outer claw. The front wall of the medial (inner) claw should be 3 inches long (as measured from a point approximately half way down the periople where the hard horn starts to the tip of the toe). This length of 3 inches (7.5 cm) is taken as the correct front wall length for the average Holstein-Friesian cow. Thickness of the sole should be a minimum of a 1/4 inch (5-7 mm). **Important - when paring the sole trimmers should carefully monitor the white line and cease trimming of the sole when the white line begins to reconnect at the toe.** Spare as much heel on the medial claw as possible so that weight may be transferred to this claw in the event of a lesion occurring in the outer claw.

Next, reduce the toe of the inner claw to the required length. The bearing surface (sole and wall but not the heel) is “stabilized” on the inner hind claw. In other words, the bearing surface of the toe and wall is pared flat so that it will be at right angles to the long axis of the shin (cannon) bone in the standing position. This will ensure that the cow has a flat and stable weight-bearing surface.

A proper front wall length (at least 3 inches or 7.5 cm) will ensure adequate sole thickness particularly at the toe where sole thickness of at least a 1/4 of inch (5-7 mm) is required. **Important - when paring the sole trimmers should carefully monitor the white line and cease trimming of the sole when the white line begins to reconnect at the toe.** Spare as much heel on the medial claw as possible so that weight may be transferred to this claw in the event of a lesion occurring in the outer claw.

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**Step 2.** Using the medial claw just trimmed as a guide, trim the toe of the outer claw (rear foot) to the same length. Next, pare the weight-bearing surface (of the sole) of the outside claw to the same level as that of the
medial claw. The outer claw is trimmed to the same level as the inner claw both at the toe and at the heel. Leaving a damaged outer claw higher than the inner claw will probably lead to lameness. It is for this reason that the inner claw heel is preserved. When complete, the weight-bearing surfaces should be flat at the toe.

**Step 3.** Shape and slope the sole so that the innermost back portion of the sole slopes toward the center of the claws. Care should be taken to avoid paring away important weight-bearing surface at the toe. Excessive cupping or sloping of the sole should be avoided because it reduces the weight-bearing surface area to the outside walls. Proper sloping of the sole in this region is designed to reduce pressure in the sole-ulcer site area and open the interdigital space between the claws. Overgrowth of the sole which occludes the interdigital space causes dirt and manure to become entrapped between the claws. This increases the likelihood of interdigital disease.

**Step 4.** Balance the heels. Weight-bearing surfaces should be flat at the toes, along the walls, and across the heels. This assures an appropriate distribution of weight within and between the claws and completes the trimming process in feet where further corrective trimming procedures are unnecessary.

Steps 5 and 6 are characterized as “therapeutic and curative trimming procedures”. They are applied as needed.

**Step 5.** Pare the damaged claw lower toward the heel to increase weight-bearing on the healthy claw. In most cases the damaged claw will be the outside claw of rear and the medial claw of front feet. Specific indications for this trimming procedure would include conditions in which overgrowth has led to overloading (i.e. hemorrhage at the sole ulcer site) or excessive weight-bearing on the claw. Lowering the damaged claw reduces weight-bearing and thereby permits recovery and eventual return to normal function and health. In some cases it is necessary to apply a foot block to the healthy claw in order to reduce weight-bearing in the damaged claw.

**Step 6.** In the presence of hoof horn lesions, further corrective trimming is necessary. Remove all loose horn irrespective of how extensive it is (sole separation) and pare away hard ridges (heel horn erosion). Only healthy hoof horn should be left in place.

Once again avoid digging holes in the sole. Always slope horn away from lesion. For example, trim the area around sole ulcers and slope axially. Remove the lateral wall when correctly trimming white line lesions and slope to the outside. Avoid damage to the corium (i.e. stop when trimming leads to bleeding of the corium).

Part of fixing a foot is trimming it. In other words, unless the defect that created the problem is corrected the benefits from curative procedures are short-lived. The step-wise procedure as outlined above, forces one to observe and trim the healthy as well as the lame foot in a lame cow. Quite often, similar problems can be found in the other foot. Cows that do not respond or get worse within a couple of days should be re-examined.

**Foot Blocks for Relief of Weight-Bearing in Diseased Claws**

The application of corrective trimming procedures as described in Step 5 will often provide a sufficient difference in height between the two claws to relieve weight-bearing and promote recovery of claw lesions. However, when pain is severe or one is unable to create sufficient difference in height between the two claws, additional elevation of the diseased claw can be achieved by means of a block attached to the sound claw. Proper application of foot blocks requires attention to the following:

1. Start by properly trimming the claws according to the step-wise procedure outlined above. Before attaching a block to the healthy claw, the claw must be pared flat and in the proper plane. This will provide a bearing surface that is at right angles to the long axis of the cannon bone.
2. Prepare the claw with a rasp or grinder so that the adhesive will properly adhere to the wall and sole of the claw being fitted for the block.
3. Mix the adhesive to the proper consistency and apply to the block and claw as needed.
4. Apply the block and position it so that it lies flat on the sole and provides proper support of the heel. This is one of the most common mistakes made in applying blocks. The back portion of the claw block should be placed even with the back of the heel to provide adequate heel support.
5. Be sure that adhesive is cleared away from the area between the block and the heel. Heel horn is very soft and can easily be damaged by the hard and sometimes very sharp edges of fully cured adhesive material.

6. Remove blocks after a period of 4-6 weeks and reapply if necessary. Blocks that cause discomfort prior to then should be removed sooner.

7. After removing a block, always re-trim the foot and adjust weight-bearing as needed.

Application of Bandages or Wraps to Lesions of the Claw Capsule

Correction of horn lesions often results in small or moderate exposure of the corium. In general, minor lesions or injuries to the corium are best left untreated and without a bandage. More severe lesions in which there may be large areas of the corium exposed may benefit from topical treatment with an emollient or other mild medication under a bandage with the proviso that it be removed within 3-5 days. The direct application of caustic treatment materials on open lesions with exposed corium should be avoided. If it is the practice of the dairy to allow bandages to fall off on their own it is the opinion of this author that they are better left without a bandage from the start. The environment of most cows is such that bandages become very contaminated within a couple of days. It is doubtful that they offer significant therapeutic benefit beyond this point. Indeed, results from a Cornell study comparing cows with claw lesions with a wrap verses no wrap indicate no advantage to the application of bandage.

On the other hand, a bandage is advised for hemostasis in cases where there is severe hemorrhage of the corium or other tissues. Bandages are also advised for postoperative care of surgical cases such as claw amputation. As suggested above, these should be changed every 2 days depending upon the degree of environmental contamination. Every attempt possible should be made to house animals having had such procedures in a clean dry environment.
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TOTAL INTRAVENOUS ANAESTHESIS (TIVA) IN HORSES

PM Taylor

European Veterinary Specialist in Anaesthesia, Taylor Monroe, Ely, Cambridgeshire, UK.

More than ten years ago, Elsevier published a monograph in anaesthesia entitled Total Intravenous Anaesthesia (Kay 1991). This contained papers from a number of eminent anaesthetists, each advocating the use of total intravenous anaesthesia (TIVA). At that time TIVA was by no means as commonplace in medical anaesthesia as it is today; in some respects, the situation is now at a stage in veterinary anaesthesia, particularly for horses, as it then was for human anaesthesia. TIVA is now very widely used in human anaesthesia and is also quite commonplace in small animal anaesthesia. Over 10 years ago Pascoe (1992) outlined the case for using IV agents for maintenance of anaesthesia in small animals. Propofol was the agent of choice due to its rapid metabolism and suitability for continuous infusion. Etomidate was also recommended, particularly for patients with cardiovascular instability. It is common practice today to use TIVA for a number of specific procedures in small animals, such as craniotomy and MRI as well as for routine surgery. In horses, however, we have not yet reached this stage; it is rare for major surgery in an operating theatre to be carried out under TIVA in this species. In contrast, volatile anaesthesia is the norm.

Why should there be interest in developing TIVA techniques for use in horses? The advantages of TIVA, in contrast with volatile agent anaesthesia are:

1. IV anaesthetic agents act at receptors and allow the ultimate “balanced anaesthesia”: a number of agents, each with a specific action, may be titrated together to provide the desired components of balanced anaesthesia. Volatile anaesthetics tend to produce a global effect on all body systems.
2. IV agents are generally less cardiodepressant than volatile agents.
3. Several IV agents used in TIVA are potent analgesics. They thus contribute to pre-emptive analgesia as well as reducing reflex responses to noxious stimulation during surgery. Most volatile agents are not analgesics in their own right and only produce analgesia during anaesthesia, without affecting subcortical nociception, by virtue of causing unconsciousness. An unconscious patient cannot feel pain.
4. Lack of specific organ toxicity as now recognised, albeit uncommonly, with most volatile agents.
5. Recovery from most IV agents is more rapid and complete than after most volatile agents.
6. IV agents do not cause atmospheric pollution.
7. IV anaesthesia requires less complex delivery equipment now that technical advances in IV delivery and pharmacokinetics have made administration as easy as inhalation anaesthesia.

The final adjudicator of the best anaesthetic method for any specific purpose should be outcome. There are relatively few evidence-based reports of outcome after veterinary anaesthesia and choice of anaesthetic protocol is usually down to personal preference, familiarity, perceived theoretical advantages and cost. Fortunately for horses, there are some important equine data. Johnston et al (2002) reported a large multicentre investigation into outcome after general anaesthesia in horses: the Confidential Enquiry into Peri anaesthetic Equine Fatalities (CEPEF). Data from this study were collected from approximately 40,000 horses, and confirm that equine anaesthetic related mortality is higher than in other domestic species and man. Almost 1 in 100 healthy horses die during or within seven days of general anaesthesia. If high risk cases, such as horses undergoing surgery for colic, are included, the mortality rate is nearly 2%. In the majority of the 40,000 equine cases reported in CEPEF, anaesthesia was maintained with a volatile anaesthetic. However, data were also collected from over 2000 TIVA cases, which showed that this method carried a reduced risk of death compared with volatile agent maintenance. This poses two questions:
Why should intravenous anaesthesia be safer?

Can we exploit intravenous anaesthesia in horses to make clinical anaesthesia safer?

The CEPEF data indicate that equine perianesthetic mortality is often associated with cardiovascular failure. The three major causes of death in CEPEF were cardiac arrest (36%)

Fractures (22%) and myopathy (8%). Cardiac arrest is undoubtedly related to cardiac function! It is also now widely believed that post operative myopathy results from inadequate muscle perfusion during anaesthesia caused by anaesthetic-induced cardiac depression and hypotension (Grandy et al. 1987; Lindsay et al. 1989). Fracture of a long bone in recovery may occur in association with myopathy. Hence some 66% of the deaths recorded in CEPEF probably had cardiovascular failure as a component. It is notable that there were no deaths from cardiovascular failure during or after TIVA.

Many investigations have demonstrated the severe cardiovascular depression caused by the volatile agents, in particular halothane (Steffey & Howland, 1978). It is thus likely that the cardiodepressant effects of volatile agent anaesthesia, particularly halothane, contribute to the high anaesthetic mortality in horses.

Investigations into the endocrine and metabolic effects of anaesthesia, the so-called “stress response”, have also shown that volatile agent anaesthesia causes a substantial stress response, even in the absence of any other noxious insults such as surgery (Taylor 1989b). In contrast, intravenous anaesthesia with a number of different agents did not induce a stress response (Taylor 1990, Taylor et al 1995, Bettschart-Wolfensberger et al. 1996).

The stress response is induced by a noxious stimulus, such as trauma, or activity requiring major energy expenditure, such as extreme exercise. Under natural conditions, such as escaping from predators, the stress response is life saving. In response to anaesthesia it is at least inappropriate and may be harmful. The contribution of the stress response itself to equine anaesthetic morbidity or mortality is unknown. However, it surely acts as a sign that a noxious insult has been applied, hence an anaesthetic protocol that itself causes a stress response can be regarded as noxious.

TIVA is widely used for very short periods of anaesthesia in horses, so called “field anaesthesia”. There are also a number of reports describing the use of this type of anaesthetic maintenance for major surgery. A combination of an alpha-2 agent, ketamine and guaiphenesin (“triple drip”) is probably the most widely used (Greene et al. 1986; Taylor et al. 1992; Young et al. 1993; Taylor et al. 1998). However, all these agents are cumulative. A combination of climaizolam and ketamine is used for procedures up to 1-2 hours but also uses cumulative agents (Bettschart-Wolfensberger et al 1996).

Propofol is an ideal agent in many respects, as it is rapidly metabolised. It has not been widely used in horses due to its cost and the volume of drug required. Recovery quality after propofol anaesthesia appears to be consistently good, particularly in comparison with volatile agents (Taylor 1989a, Matthews et al 1999, Steffey et al 2004a). Since limb fractures occurring in recovery are a major cause of anaesthetic mortality, this feature of propofol suggests that it is an anaesthetic drug of considerable potential in horses. Propofol’s main disadvantage is respiratory depression (Taylor, 1989a; Mama et al. 1995; Mama et al. 1996; Nolan & Chambers, 1989, Taylor et al 2001). Use of combinations of propofol with another agent, such as ketamine, medetomidine or ketamine, to reduce the amount of propofol required have also been used successfully (Flaherty et al. 1997; Baker et al. 1999, Matthews et al 1999, Bettschart-Wolfensberger et al 2001a,b). All these intravenous methods result in good cardiovascular function and do not themselves induce a stress response (Taylor et al. 1998, Taylor, 1989a; Bettschart-Wolfensberger et al. 1996). Recently, Boscan et al (2004) have reported preliminary studies with a novel 5% microemulsion formulation of propofol in horses. These early studies suggest considerable potential for a commercially viable propofol formulation for horses. Anaesthetic quality, cardiopulmonary effects and the high recovery quality were similar to the standard emulsion formulation of propofol. Further investigation is in progress.
Alphaxolone (Saffan) is an injectable steroid anaesthetic, which has been used for many years in cats. Althesin was its commercial name for use in man. However, it is virtually insoluble in water and was solubilized, in combination with a second steroid anaesthetic alphadolone, in cremophor-EL, an oily castor bean derivative. Although alphaxolone the anaesthetic is as safe as any anaesthetic can be, the anaphyllactoid reactions to the cremophor led to its withdrawal from the human market. Recently, an aqueous formulation in cyclodextrin has been developed by Jurox, an Australian company. This has now been widely used in dogs and cats and shows promise in horses. It is still some way from full equine clinical trials, but alphaxolone’s limited cardiovascular and respiratory depressant properties make it attractive for use in the horse, now that a better means of solubilization has been developed.

In man and small animals high doses of short acting opiates such as the fentanyl group are often infused in combination with intravenous anaesthetics to enhance the analgesic component of “balanced” anaesthesia. Neuromuscular blocking agents may also be used. These methods have rarely been employed in equine surgery, largely because opioids cause excitement in this species. Although the excitement is not cortical in origin (Johnson & Taylor, 1997) and is probably dopamine mediated, attempts to block the excitement with dopamine antagonists have been unsuccessful (Pascoe & Taylor, 2003). However, the combination of low dose volatile agent, opioid and muscle relaxant has yet to be fully investigated for its potential in clinical equine anaesthesia. Mircica et al (2003) advocate the use of morphine premedication and supplementation of volatile agent anaesthesia. Steffey et al (2003) concluded that morphine was not suitable for routine use in horses anaesthetized with isoflurane as MAC was not consistently reduced. However, MAC studies of opioid effects in horses using movement as a response may not reflect the clinical situation where other sedatives may affect the sub cortical dopaminergic pathways. In addition, Mircica et al (2003) recommend doses of 100-170 µg/kg whereas the “low” dose used by Steffey et al (2003) was 250 µg/kg. Clearly the case for opioid use in horses cannot be dismissed and is worthy of further investigation.

Maintenance of anaesthesia with TIVA should undoubtedly be considered as a viable alternative to volatile agents for many reasons, not least, in horses, because TIVA may be safer. Randomised, controlled prospective clinical studies in horses and small animals are needed to make a proper comparison of the safety of TIVA and inhalation anaesthesia.
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APPLICATION OF TRANSCUTANEOUS ELECTRICAL NEURAL STIMULATION (TENS) TO INDUCE ANALGESIA AND ANAESTHESIA IN ANIMALS

Davood Sharifi,* (M.V.Sc & Ph.D), Abbas Vosoogh, (M.D) Maryam Godarzi, (B.M.T) and Fereshteh Motamedi (Ph.D)

*: Associate Professor, Department of Clinical Sciences, Surgery and Radiology Section, Faculty of Veterinary Medicine, University of Tehran, Tehran, Iran. sharifid@yahoo.com

"The application of electro medical currents is not a new concept. Ancients recognized the therapeutic value of naturally occurring electrical phenomena long before William Gilbert defined electricity in 1600.

"… One hundred years ago, electrical devices were in widespread use to manage pang and 'cure' everything from cancer to impotency. Because of the unrefined early electrical technologies …. This form of therapy fell in to disrepute by the medical profession in the early part of the 20th century.

It is interesting that by the end of the 1700's a British surgeon, Charles Kite, had invented and was using an electrical cardiac defibrillator creating storm of protest from the Christian community saying that this was reviving the dead and therefore the work of the devil.

Bringing the otherwise dead back to life with a defibrillator in no longer the work of Satan, but now electrical defibrillators are back again of good, 20th century scientific medicine.

The development of electrostatic generators in the eighteenth century increased the use of medical electricity, although its popularity declined in the nineteenth and early twentieth century due to variable clinical results and the development of alternative treatments (Stillings, 1975). Interest in the use of electricity to relieve pain was reawakened in 1965 by Melzack and Wall (1965) who provided a physiology rationale for electroanalgesic effects. They proposed that transmission of noxious information could be inhibited by activity in large diameter peripheral afferents or by activity in pain-inhibitory pathways descending from the brain. Wall and sweet (1967) used high-frequency percutaneous electrical stimulation to activate large diameter peripheral afferents artificially and found that this relieved chronic pain in patients. Pain relief was also demonstrated when electrical currents were used to stimulate the periaqueductal grey (PAG) region of the midbrain (Reynolds, 1969), which is part of the descending pain-inhibitory pathway. Shealy, Mortimer and Reswick (1967) found that electrical stimulation of the dorsal columns, which form the central transmission pathway of large diameter peripheral afferents, also produced pain relief column stimulation implants until it was realized that it could be used as a successful modality on its own (Long, 1973, 1974).

In the late 1960s the Dallas Morning News carried small filler about a portable electrical device that was being used to relax the engineers who drove the bullet train in Japan. It said that they would drive the train from Tokyo to Kyoto, and then lie in a darkened room on a cot for a few minutes with this device connected to their head via electrodes. It was said to relax them prior to their return trip north.

It was research new products,

Its output was limited to 1.5 mill amperes (mA), and there were four electrodes, two to be placed over the eyelids and two to be placed at the base of the head in back. The device was about the size of a businessman’s brief case, though much heavier due to its internal rechargeable batteries.

One of the engineers, Ray Gilmer, left the parent organization with this new idea and began NeuroSystems.

Later he added to his armamentarium transcutaneous electrical nerve stimulation (TENS) devices, electromyogram (EMG) biofeedback devices, and a device that did both CES and EMG biofeedback. He
was making nationwide sales efforts by the early 1970s. Consequently, beginning in the early 1970s. Sleep studies become increasingly rare apart from some that did achieve notable improvement of sleep when the subjects went to sleep at some later discovered that CES reduced stress states, which included anxiety and depression and anxiety, such as that found in persons withdrawing form addictive substances, along with cognitive deficits that presumably sprang from the depression and anxiety states.

The Neurotone 101 was called before the U.S. Food and Drug Administration’s (FDA) Neurology Panel in 1978 after new laws required the assessment of the safety and effectiveness of devices then on the market. They suggested to Gilmer that the name “electrosleep”might be a misnomer. Gilmer suggested that they call it “cranial electrotherapy”. The FDA wasn’t willing to commit to the “therapy” part, and they settled on “cranial electrotherapy stimulation”. “The FDA decided that any small electric current that went to be across the head, from any medical device used in the U.S.A., was to be called cranial electrotherapy stimulation. Thus even TENS units, when they placed electrodes so that current flowed across the head, would now be CES devices.

Transcutaneous electrical nerve stimulation (TENS) is a simple non-invasive analgesic technique that is used extensively in health-care settings by physiotherapists, nurses and midwives (Johnson, 1997, Pope, Mockett and Wright, 1995; Reeve, Menon and Corabian, 1996’ Robertson, and Spurritt, 1998). It can be administered in the clinic by health – care professionals or at home by patients who have purchased a TENS device directly from manufactures. TENS is mainly used for the symptomatic management of acute and non-malignant chronic pain (Box 17.1 Walsh, 1997; Woolf and Thompson, 1994) However; TENS is also used in palliative care to manage pain caused by metastatic bone disease and neoplasm (Thompson and Filshie, 1993). It is also claimed that TENS has anti emetic and tissue-healing effects although it is used less often for these actions (Box 17.1 Walsh, 1997).in Veterinary profession it was first accepted as immobilization device.

Electroimmobilisation involve passing a pulsed, low voltage electrical current through the body of an animal. Usually electrodes are applied to two parts of the animal’s body and a pulsed low voltage electric current is delivered along its spine, however, there are variations to the technique. The electrical current induces contraction of the muscles supplied by the nerves of that segment of the spine, preventing voluntary movement of the animal. Movement is regained as soon as the current is switched off.

Electroimmobilisation devices are used to immobilize animals in order to perform animal husbandry procedures where there are perceived risks to handler safety or animal safety with other forms of restraint, or for handler convenience

Electroimmobilisers can potentially be used on a range of species, including non-domestic animals. Domestic species for which electrommobilisers have been promoted for use include:
• Bovines –( cattle, buffalo and bison), Deer, Camelids
• Sheep, Goat, Birds (emus and ostriches)
Electrommobilisers can be used to carry out routine husbandry practices such an:
• Dehorning, Castration, Branding, Tattooing, Ear Marking
• Hoof trimming and Hoof examinations
• Pregnancy and blood testing, Calving assistant

In this regard, the review of literature indicated that since the end of the last century many investigations with electroanesthesia have been performed in animals and man. The interest in this method of anesthesia has emerged because anesthesia is achieved immediately after the onset of the current and the recovery is very rapid after cutting off of the current. Recently a battery operated apparatus became available (Feenix stockstill) for application of electroanesthesia and electroimmobilisation under field conditions, and an experiment was conducted with 10 calves, 10 sheep, and 9 pigs, which were equipped with EEG and ECG electrodes. To check the analgesic and other practical effects of the apparatus. The duration of current administration was 20 minutes. Three animals of each species were used as control animals (Lambooy,E; 1985).
From the analysis undertaken, it appears that animal suffer some pain or distress from electroimmobilisation. Some form of restriction on the use of electromobilisers may be appropriate. A total prohibition on the use of electroimmobilisation devices could be difficult to justify, given the potential animal welfare benefits of the devices and the pain or distress of alternative methods of restraint.

Given the potential for mis-use of electroimmobilisation devices, and that it appears some pain or distress is caused by electroimmobilisation, any person using an electroimmobiliser could be required to meet certain standards. Such persons could be veterinarians or other persons who are trained and approved to use electroimmobilisation devices. Consideration will need to be given to who trains and approves the users.

Most research has involved sheep, cattle and deer, and does not cover the scope of animals on which electroimmobilisation could be used. Consideration needs to be given to the potential differences in responses between species and whether the findings from the research can be applied to other spices.

Other factors that require further deliberation are the procedures that may be permitted to be carried out whilst an animal is electroimmobilisation and the method of application or use of the electroimmobilisation device.

This technique is a simple, cheap and effective preparation for surgery, especially if combined with tranquiliser if needed. It may be considered the only method of surgical analgesia which might be available in wartime, national disasters and other emergency situations, especially for abdominal surgery, in allergic or high-risk patients (circulation, heart, lung, kidney or liver disease). Results were compared with control patients operated under drug anaesthesia alone. They confirmed that the amounts of narcotic and barbiturate drugs needed to maintain adequate anaesthesia were reduced, the electroanaesthesia having less deviation from the baseline in heart rate, BP, EEG and body heat loss than the drugs being used during surgery. Recovery of consciousness in the EA-group was associated with more alpha – and less beta – activity in the EEG and with less time – space disorientation on waking up than in the drug used group. The electronanesthesia was associated with minimal depression of vital functions and maintained good adaptive reactions.

The results are very good and post-operative recovery is faster and less troublesome than after surgery under conventional anesthesia.

a. Per-operative benefits: EA can be used in high-risk patients, who might not tolerate general of local anaesthesia. These cases include shock (post trauma, haemorrhage), severe debilitation (after chronic disease, malnutrition or cruelty), toxæmia (renal, hepatic, pulmonary or cardiac cases, toxic pyrometer etc); obstetric surgery (Caesarean section etc). It can also be used on very young and very old animals, and in operations lasting up to 10 hours. The effect of EA on the autonomic nervous system prevents shock during the operation so that deaths during or immediately after operation under EA are extremely rare. Operative hemorrhage is also decreased.

b. Post-operative benefits: Because consciousness and reflexes (other than pain response) are retained under EA, the animal can walk unaided to the recovery area immediately after surgery. There is no risk of self-injury due to ataxia, struggling or falling, as may occur under general anesthesia or spinal block.

Many authors, operating on animals as well as human patients, report far fewer post-operative complications after EA (less ileus, less urine retention, faster return to normal appetite, less nausea etc.) Defecation and urination occur very quickly after EA and the animal will eat drink immediately after operation (if it is hungry or thirsty). It is common practice to offer cattle some hay or concentrates during operations and many dogs will placidly accept bits of meat during major surgery.

After EA, surgical incisions heal much faster, with less edema, less wound infection and less wound breakdown.

So this technique is a non-invasive electronic device system which replaces local chemical based anesthesia now in use. The electronic system is easy to use, reduces chemical usage and their side effects while assuring similar results as conventional anesthesia. Conventional systems are based on the use of
conventional chemicals. These lead to unwanted side effects, at best, which can last for days, and, at worst allergic reactions that can cause irreparable damage and even be life threatening. One looks forward to having an operation, but now, the experience can be painless and safer. As far as pain relief is concern, the mechanism of the analgesia produced by TENS is explained by the gate control theory proposed by Malzack and Wall in 1965. The gate usually is closed, inhibiting constant nociceptive transmission via c fibers from the periphery to the T cell. When painful peripheral stimulation dose occur, the information carried by C fibers reaches the T cell and opens the gate, allowing pain transmission centrally to the thalamus and cortex, where it is interpreted as pain. The gate control theory postulated a mechanism by which the gate is closed again, preventing further central transmission of the nociceptive information to the cortex. The proposed mechanism for closing the gate is inhibition of the C-fiber nociception by impulses in activated myelinated fibers.

By contacting experiment on 15 adult male rabbits and recording all the essentials and vital parameters. I do believe that research on this system will eventually let us learn to control pain, healing and doing major surgery with the least site-effects. Definitely in the near future it is more than likely that these theoretical system will be further developed to such extent as there will be no doubts about its humanness and the potentials for abuse.
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**NAVICULAR DISEASE SYNDROME IN THE HORSE: MEDICAL IMAGING AND TREATMENT.**

Em. Prof. Dr. F. Verschooten, dipECVDI

Former chairman of the department of Medical Imaging of Domestic Animals, Faculty of Veterinary Medicine, Ghent University, Salisburylaan 133, 9820 Merelbeke, Belgium

**Introduction**

James Turner, an English veterinarian, first reported on ND in 1816. He made several papers thereafter and fit them together into a book in 1832: "A treatise on the foot of the horse and a new system of shoeing by one-sided-nailing and on the nature, origin and symptoms of the navicular joint lameness with preventive and curative treatment". Most of his clinical observations are still valuable today!

Navicular disease (ND) is a well-recognized and frequently encountered problem in the front feet of warm blood horses. ND is rarely encountered in the hind feet.

Navicular disease (ND) is characterized by degeneration of the fibrocartilage of the navicular bone and of the deep flexor tendon at the contact area and by structural changes of the navicular bone. Different factors may be responsible for its development: genetic factors in the first place, degenerative events, internal trauma and management.

The aetiology is related to a bursitis or to an eccentric atrophy of all compact layers of the navicular bone. Thrombosis of the distal navicular nutrient arteries and ischemic necrosis was thought to be the main pathological change in the development of navicular disease. Arterial hyperaemia and venous congestion were found in navicular disease and linked with the pathogenesis of arthrosis.

**Radiography**

The use of radiography for the diagnosis of navicular disease (ND) was first reported by Oxspring in 1934.

Radiographic examination includes three views: two dorsopalmar views (the foot on a wooden block angulated 55° and 65° to the horizontal) and one lateromedial (LM) view. For the LM views, the central ray is directed carefully through the horizontal axis of the navicular bone. A grid with ratio 5:1 and 32 lines per cm is used in all views. The palmaroproximal-palmarodistal oblique (PaPr-PaDiO) view reveals useful or important supplementary information in only 10% of the cases. It is not indispensable to achieve the final diagnosis of ND.

Radiologists may have different opinions about radiographic signs related to navicular disease syndrome (ND), but major and undisputed signs of navicular disease are: a large central osteoporotic area in the navicular bone or in the flexor cortex; extensive, irregular new bone formation along the proximal border resulting in total enlargement of the navicular bone; sclerosis of the spongiosa (visible mainly on the LM views) or other modifications of the trabecular structure of the navicular bones, bone fragments at the distal border of the NB (see later) and finally an indistinct demarcation between the subchondral bone and spongiosa; other radiographic signs sometimes related to ND are: a thickened or thinner flexor cortex, localised new bone formations at the proximal or distal border or at the extremities of the navicular bone and ossification in or close to the deep flexor tendon. The importance of synovial fossae or canales sesamoidales in larger or smaller numbers is often debated, but in most cases synovial fossae should be considered as normal anatomical variations. They may deteriorate into larger cysts and then be an expression of increased intra-articular pressure. A sharply delineated central depression at the sagittal ridge of the navicular bone, often visible on the LM view, and a small, triangular or half-moon shaped radiotranslucency in the sagittal ridge of the flexor cortex sometimes seen on the PaPr-PaDiO
Minor radiographic findings can be a matter of debate. If no radiographic signs of ND are present – and all other causes of lameness of the foot can be excluded – horses are classified as clinical ND (CND). CND is a classification diagnosis defined as a lameness originating in the foot with clinical signs comparable to the ND-syndrome (distal digital palmar analgesia is positive, but no radiographic signs of ND present; no other clinical findings than lameness).

Ultrasonography

Additional information is obtained with ultrasonography. Feet should be carefully prepared. Changes in the deep flexor tendon, the lig. sesamoideum impar and osteochondral fragments at the distal border of the NB may be observed. The images are not comparable with the details of radiography, but they give supplementary information.

Computerized tomography

CT is unquestionably a nice imaging modality for the navicular bone, but it is not indispensable. Some horses with CND have been examined with CT, but none turned out to be ND positive.

Scintigraphic and MRI examination

These examination techniques will not be covered in the lecture.

Treatment

It should be stated first of all that ND is incurable. Because vascular changes might be involved, various vasoactive drugs are applied (see later on). The intrabursal injection of corticosteroids or the intra-articular injection of corticosteroids in the distal interphalangeal (D.I.P.) joint is described. The injection is not a cure for navicular disease, but may render a horse quickly serviceably sound for quite a long period. In the meantime it is a diagnostic test to localize pain in foot lameness.

Surgical techniques will not be described.

Intra-articular application of corticosteroid:

A 24G x 1” needle is introduced into the distal interphalangeal joint in the midline just above the coronary border, and 40 mg methylprednisolone acetate or 40 mg triamcinolone are injected into the D.I.P. joint.

Intrabursal application of corticosteroids:

An 88 mm x 1.2 mm spinal needle is introduced medially from the lateral cartilage, parallel to the median plane and obliquely in the direction of the navicular bone. The position of the navicular bone is easily determined from outside. It lies in the middle of and underneath the coronet border. Each intrabursal corticoid injection was checked by instant and reversed fluoroscopy. The fluoroscopic screen is located at the medial side of the foot as if a LM radiograph is taken. The light emitting part is directed towards the veterinarian and held some 20 cm medially from the foot. The light is dimmed but adaptation of the eyes to darkness is not necessary because the image is sufficiently bright. The diaphragm is closed to the outline of the navicular area. The position of the needle is checked when inserted and it should be in contact with the navicular bone. Aseptic technique is rigorous. Exposure factors are in the radiographic range: kV 86, mA 350 but exposure time is 0.5 second, sufficiently long to visualize the contrast medium within the bursa. Radiation measured at a distance of 1m from the foot and 45° to the central beam during one exposure is 58 mS/h. As one or two exposures per injection are required, radiation load is maximally 0.016 mS per horse treated.

The horses are stable rested for about three days and thereafter allowed to resume full activity without any
restriction, irrespective of the duration of the lameness.

An effect of the intra-articular or intrabursal corticosteroid injection is considered positive if the owners could work with the horse in the same way as they could when the horse was not lame. If owners report that lameness is only less than before, the result is categorised as negative.

Intra-articular and intrabursal corticosteroid injections have very different effects in CND horses, and these effects can be summarised as follows:
- no effect (less than 2 months) is observed in 66% of the horses treated intra-articularly, versus 40% in the intrabursal group;
- an effect of 2 months and more is observed in only 34% of the horses in the intra-articular group, versus 60% positive results in the intrabursal group.

When intrabursal injection is immediately effective, pain is apparently localised in the structures lining the bursa. When intra-articular application of corticosteroids in the D.I.P. joint is effective, it is logical to assume that the pain is localised in the joint and, specifically, in the palmar aspect of the D.I.P. joint (the small joint between the navicular bone and the 3rd phalanx). This is a hypothesis, however, because analgesia of the caudal compartment of the distal interphalangeal joint alone is not possible. Nevertheless, this hypothesis may be correct, because general DJD of the distal interphalangeal joint is not a very common problem.

Per oral medical treatment

Warfarin, isoxsuprine, metrenperone, orgotein, and propentophylline are some of the products mentioned as treatment for ND. Medical therapy of navicular disease is by per oral administration for about 3 months of 0.9 mg to 1.2 mg of isoxsuprine (Duphar) per kg body weight or by metrenperone, an experimental vasoactive substance from Janssen Pharmaceutics at a dose rate of 0.1 mg per kg b.i.d.

Metrenperone treatment result in a long-term (± 27 months) functional restoration in 21.6% of the horses. With isoxsuprine long-term (± 25 months) functional restoration is observed in 27.7%. Long-term results of both products are comparable, isoxsuprine being slightly better, but both products are not very effective. In both groups none of the horses are working on top level.

The possible effect of the products during treatment may be explained on the basis of beneficial and transient circulatory effects either in the bone or the deep flexor tendon or in both at the same time. But it is hard to explain a possible beneficial long-term-effect even if effectiveness would be higher than presently found. If horses seem to be "cured" after one or more years one may doubt whether they had ND.

Corrective shoeing

The heels are increased in height and usually a bar is constructed underneath the frog to prevent direct pressure to the navicular area. The frog should not be in contact with the bar.

Corrective shoeing has a positive effect, but this is not statistically proven in our experience.

Conclusion

In horses with CND and with mild or even severe radiographic changes of ND intrabursal injection may be effective for some time.

The horses are able to work immediately, and even laymen can easily assess the effect of treatment because the difference before and after treatment is indisputable. No medical treatment other than intra-articular or intrabursal corticosteroids injection can change a lame (C)ND-horse into a sound one so quickly.

But, whatever treatment is applied, most horses will finally be lame again. If lameness does not reappear after treatment, the horse never had ND! All horses with undisputable radiographic signs of ND become lame again.
To our knowledge it is unknown how many horses with CND will finally develop radiographic signs of ND.

**Table 1: Radiographic changes associated with navicular disease (ND) syndrome**

**Dorsopalmar view**

**Important signs:**
- localised central osteoporotic area or osteoporotic areas or any other area of the distal or proximal border, usually indistinctly delineated and, if sharply delineated, usually indicating a standstill in the evolution of the disease.
- generalised osteosclerosis (rarely observed: see LM).
- extensive new bone formation changing the shape of the navicular bone resulting in an enlarged silhouette.
- several large osteoporotic areas or cysts (5 mm and more) in the distal 3rd of the navicular bone; if well demarcated, their growth is probably arrested. These cysts may be an expression of increased intra-articular pressure or proliferation of synovial tissue.
- bone chips at the distal border, possibly bilateral, especially important when more than 7mm x 3mm in size and when surrounded by demineralisation in the navicular bone (see INTERMEZZO).
- severe synovialphysis at the lateral or the medial side of the NB.
- severe new bone formation in the middle or along the proximal border of the NB, without affecting the general shape of the NB.

**Irrelevant signs of ND:**
- one to several canales sesamoidales (= synovial fossae) at the distal border of the navicular bone ending in cysts (5 mm and <); the number, length, and location of synovial fossae are unimportant.
- asymmetrical bilateral navicular bones without any other sign.

**Lateromedial or mediolateral view**

**Important radiographic signs:**
- osteosclerosis of the medullar cavity.
- localised translucent area in the subchondral bone plate and/or in spongiosa, hazily delineated.
- enlarged silhouette of the navicular bone in either proximodistal or dorsopalmar direction.
- calcifications in the soft tissues close to the navicular bone in or around the deep flexor tendon.
- irregular new bone formation at the margo liber.
- extension of the margo ligamenti.
- indistinct outline of the area between the distal border of the NB and the caudal intra-articular border of PHIII, with or without bone fragments.
- osteoporosis of the subchondral bone plate (normal thickness or thinner than normal).
- disappearance of the sharp demarcation between the subchondral bone plate and spongiosa.

**Irrelevant signs of ND:**
- thinning of the subchondral bone plate, but normal radio-opacity often as a result of inactivity associated or not with lameness.
- well-defined exotosis at the proximal border.
- well-defined small spur at the proximal border of the facies articularis of the navicular bone opposite the 2nd phalanx.

Although the synovial fossae may be large or deeply extending into the navicular bone on DP views, they never show up on LM radiographs of excellent technical quality.
- central depression in the ridge of the navicular bone (synovial fossa) sharply delineated.

INTERMEZZO
OSTEOCHONDRAL FRAGMENTS AT THE DISTAL BORDER OF THE NAVICULAR BONE: RADIOGRAPHICAL AND CLINICAL SIGNIFICANCE.
Osteochondral fragments at the distal border of the navicular bone (OFNB) are sometimes considered as avulsion fractures, sometimes as isolated bone fragments in the ligamentum sesamoideum impar as a result of damage to the ligament, sometimes as separate centres of ossification or as a result of synovial hyperplasia (synovial osteoma). In horses with clinical and or clinical and radiographic signs of ND 45,45 % of the navicular bones had OFBN. Fragments occur more often on the unilaterally affected limb compared to the sound contralateral limb. An OFNB alone is not a sign of ND, but it is considered to be part of the ND syndrome. An OFNB is probably not painful in itself but might be associated with other pathological conditions like damage to the fibro cartilage of the navicular bone. Very small fragments may be without clinical significance, but larger fragments with reaction in the navicular bone are associated with the ND syndrome and lameness.
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NEW APPROACHES TO TENDON HEALING

Farshid Sarrafzadeh - Rezaei, DVM, DVSc.

Department of Clinical Sciences, College of Veterinary Medicine, Urmia University, Urmia- Iran

Introduction

Tendons are soft connective tissues consisting of parallel collagen fibers embedded within an extracellular matrix. This organized structure allows tendons to withstand and transmit large forces between muscle and bone. However, as tendons are subjected to repeated motion and degeneration over time, they are prone to both acute and chronic injuries. Injuries to tendons are among the most common injuries to the body.(4, 14) After injury, the healing process in tendons results in the formation of a fibrotic scar. The structural, organizational, and mechanical properties of this healed tissue are inferior to normal tendon. Although these properties improve over time, they do not return to normal levels, even after long periods. In an attempt to better understand tendon healing mechanisms and to improve these inferior properties, researchers have investigated a broad range of factors believed to affect tendon injury and repair, such as activity level, motion after injury, various injury modalities, and different injury locations. In addition, many researchers have applied tissue engineering concepts to address this problem, from creating scaffolds and constructs out of relevant biomaterials and cells to applying cytokines exogenously to injured tissue, or using gene and cell therapy. This paper provides an overview of these studies, which demonstrate that the functional outcome of injured tendons is dependent upon many factors.(1, 3, 14)

Normal tendon

Tendons connect muscle to bone and form a musculotendinous unit whose primary function is to transmit tensile loads generated by muscles to move and stabilize joints. Under normal loads, it has been shown that tendons maintain smooth physiological mechanics throughout range of motion. While subjected to higher loads, tendons prevent joint displacement beyond anatomical barriers, thus preventing injury and maintaining normal function. The composition of tendon contains relatively few cells with the predominant cell type being the rod or spindle-shaped fibroblasts. Tendons contain 86% collagen, 1-5% proteoglycan, and 2% elastin as measured by dry weights, and water is responsible for 60-80% of the total wet weight of the tendon.(4,14) Type I collagen is the major component of the matrix in the flexor tendon, making up more than 90% of the collagen in human tendons.(18) The linear organization of collagen fibers in tendons results in optimal stiffness and strength at low strains under tensile load. However, this organization makes repairing ruptured or lacerated tendons extremely difficult.(12) Tendons glide over bone and often move through canals and sheaths that help direct their path and limit the amount of friction they must overcome. Tendon sheaths consist of two layers, in between which contains synovial fluid that improves lubrication. Tendons that lack this two layer sheath are surrounded by a loose areolar connective tissue called paratenon, which acts to provide a division from and permit free motion of the tendon in relation to the surrounding tissue.(14)

Tendon healing

The commonest form of tendon healing is by scarring, which affects function and is accompanied by an increased risk of further damage. In general, the tendon heals at a relatively slow rate compared with other connective tissues; a reason for its limited healing capability could be its poor vascularization.(1)

When tendons are injured, the body initiates a process of healing and scar formation that can be divided into phases, which are briefly described below, are distinguishable by specific peaks in a cascade of cellular and biochemical events.(14) Flexor tendon healing can be divided into an inflammatory phase, a proliferative or reparative phase, and a remodeling phase. Within these overlapping phases tendon healing progresses from neutrophil and macrophage chemotaxis and angiogenesis to cell proliferation and collagen deposition. Finally, collagen is reorganized and the scar matures. Although the tensile strength of the healing tendon improves over time, it does not reach the levels of uninjured, normal tissue.(11, 14)
Inflammation

This phase of tendon healing occurs almost immediately after tendon injury. First, the injury to the surrounding vascular vessels causes the formation of a hematoma. Next, the resultant clot and hemostasis activates a cascade of vasodilators and platelets, as well as the release of pro-inflammatory chemicals from mast cells. Inflammatory cells are attracted to the injury site and aggressively engage in the phagocytosis of necrotic tissue and debris and break down the blood clot. Macrophages aid in the recruitment of new fibroblasts and release of angiogenesis promoting factors to initiate growth of capillary networks within the wound. During this phase, there is an increase in DNA, fibronectin, glycosaminoglycan, water, and collagen type III content, which collectively stabilizes the newly formed extracellular matrix. Inflammation in tendons subsides in the first few days after injury and fibroplasia and fibrillogenesis begin.

Proliferation/ reparative

During this phase, a disorganized matrix of granulation tissue is present at the injury site. Histologically, the predominant cell types are fibroblasts along with a smaller number of macrophages and mast cells. Electron microscopy studies have shown an increase in the endoplasmic reticulum of fibroblasts, which is indicative of active matrix synthesis and type III collagen and DNA concentrations reach their peak amounts during the entire reparative process. These changes are believed to help with the optimization of collagen synthesis and the gradual conversion of type III to type I collagen.

Remodeling/maturation

Histologically, fibroblasts have decreased in size and slowed their matrix synthesis, and collagen fibers have begun to orient themselves longitudinally along the long axis of the tendon. As the scar enters maturation there is a notable return of type III to type I collagen ratio, collagen crosslinks, and glycosaminoglycan, water, and DNA concentrations. The physical properties of collagen are very dependent on cross-links within and between the collagen molecules. During maturation, the number and quality of the cross-links increase, which increases the tensile strength and reduces collagen solubility. However, healed tendon has been shown in many studies to take upwards to a year to more closely approach the functional strength of uninjured tissue.

Intrinsic vs. extrinsic healing

Evidence exists that tendon repair can occur either intrinsically via the resident tenocytes or via extrinsic mechanisms, whereby cells from the surrounding sheath or synovium invade the tissue. It seems likely that both mechanisms occur, although the involvement of external cells depends on the site of injury and vascular perfusion. Two mechanisms of repair-intrinsic and extrinsic- both seem to contribute to the wound healing process. The intrinsic mechanism involves the tenocyte population from within the tendon and epitenon, and the extrinsic mechanism involves inflammatory cells and fibroblasts from the overlying sheath and periphery. The 2 models of healing also have been shown to exhibit distinct responses to injury. Studies suggest that extrinsic healing promotes adhesion formation between the tendon and its sheath. It is plausible that tendon healing most likely occurs as a combination of both processes and is dependent on tendon location, the magnitude of tendon trauma, availability of synovial fluid and a blood supply, and degree of tendon mobilization.

Tendon injury and repair

Tendon injuries are not only responsible for large health care costs, but they also result in lost work time and individual morbidity. Although, there are medical treatments for most of these conditions, continuing efforts need to be made to improve the effectiveness of the treatments and expedite recovery. In the past, most of these efforts have been directed at improving surgical, pharmacological and rehabilitative techniques. Despite many improvements in these techniques, there remain significant limitations in our management of these conditions.

Tendons suffer various degrees of injury, ranging from relatively mild inflammation to full thickness...
transection. Tendinitis is loosely defined as inflammation of a tendon due to overuse, repetitive motion, inadequate training, or injury. It is accompanied by pain, swelling and stiffness, especially during movements which stress the tendon.(12) Tendon injury can be classified by types of injury and are generally considered to be acute or chronic and either direct or indirect. Direct acute tendon injuries occur due to either contusion, non-penetrating blunt injury from accidents and sports injuries, or laceration by a sharp object. Indirect, tendon injuries are often the result of, acute tensile overload and repetitive microtrauma as seen in overuse injuries. Timing of the repair can be categorized as primary, delayed primary, secondary and late secondary. A primary repair is done within 12 h of injury, while delayed primary is within 14 days. Secondary is classified as between 2 and 4 weeks with late secondary after that period. Whenever feasible, tendon repair should be done as early as possible.(14)

**Materials for tendon repair**

A variety of biological and non-biological materials have been considered for augmenting tendon repair. Tissue grafts, synthetic fibers, biological fibers, and tissue engineered biomaterials are among those examined. Some of these, e.g. various synthetic fibers, are clearly not of use, while others remain potentially useful.(12) Tendon grafts continue to be considered a viable option for tendon repair. Experimental studies have concentrated on tendon allografts and xenografts. As might be expected, antigenicity of grafted tendons is problematic. Although some of these materials appear promising, e.g. grafts from intrasynovial tendons and carbodiimide cross-linked xenografts, none have yet achieved acceptable performance. Recent advances in this area include: 1) successful application of a plant derived crosslinking agent, genipin, for reducing antigenicity and biodegradability, this for pericardia rather than tendon, however; 2) use of non-tendon tissues like intestinal submucosa as scaffolds for musculoskeletal repair, mostly directed toward ligament repair; 3) chemical treatments to reduce antigenicity of tendon grafts.(12)

Research on artificial materials examined the potentials of synthetics like Dacron, nylon, carbon fibers, Teflon and silicone. None of these have found their way into general use, primarily because of one or more complications, including inflammatory responses, antigenic reactions, failure at the fixation sites, and deficiencies in long term biocompatibility.(12)

**Factors affecting tendon healing**

**Suture**

There are a variety of different suture techniques used clinically, each with their preferred suture material that can be employed at the discretion of the surgeon.(14) Current suturing techniques to join split ends of tendons, while providing sufficient mechanical strength to prevent gapping, are inadequate to carry normal loads.(12) The initial strength of tendon repair is roughly proportional to the number of suture strands that cross the repair site. The most commonly used techniques have involved a 2-strand repair. Increasingly 4-, 6-, and even 8-strand repairs are now used, with the aim of allowing a more aggressive early rehabilitation without a greater rupture rate. There is, however, limited information in the literature about the effect of increasing strand numbers on the healing or adhesion response in a repair. Generally, the more suture strands that cross the repair site, the more difficult the technique, the greater the amount of surgical handling of the tendon, and the greater the amount of suture material on the outside of the tendon. Increased tendon damage and increased external foreign body may increase adhesion formation. Multiple strands may compromise intrinsic healing through ischemia, resulting in adhesion formation. The production of visible adhesions results in impairment of motion and therefore function.(17)

The maximum strength of a sutured tendon in the early stage after repair may be maintained by improvements in the suture technique, and the insertion of the extensor retinaculum slip as a “core” may also increase in this maximum strength in the later stages. Inserting the biological core may also protect the sutured tendon from re-rupture just at the time when the dorsal protective splint is removed after flexor tendon surgery.(5)
Sheath barrier

Some researchers have focused on creating a barrier between the healing tendon and its sheath to reduce the effects of extrinsic healing. Various materials have been tried including alumina sheaths, silicone, and polyethylene membranes among many others. None are in routine use clinically. Other researchers have focused on reducing the inflammatory response that has been shown to induce adhesion formation. Oral and local medications, 5-fluorouracil, hyaluronic acid, β-aminoproprionitrile, and other agents have been tried with varying degrees of success. Many issues such as expense, potential side effects, and bioavailability at the site of injury thus have prevented widespread use of these agents clinically.(11)

Motion

The effects of activity levels on tendons have been studied extensively in animal models. These activity levels range from overuse, such as exercising, to disuse, such as immobilization and stress shielding. As a result of increased or decreased loads, tendon remodeling leads to structural, biochemical, and mechanical changes. Investigators have used animal models to simulate these activity levels in a controlled manner in order to study how the tendon responds and characterize its resulting properties.(14)

Postoperatively, the surgeon faces the problem of when to introduce active vs. passive motion and remobilization/immobilization. The dilemma becomes restoring normal strength and range of motion while minimizing adhesions and protecting the healing tendon from rupture and gapping at the tendon repair site.(14) Since the late 1960s, primary tendon repair, followed by various regimes of early mobilization, has become the most common method of managing flexor tendon injuries, based upon the good results reported by Kleinert et al. (1967).(5) Exercise has been reported to augment the strength and ultrastructural morphology of healing tendons. NG, G. Y. F. et al (2004) reported that weight-bearing exercise for rats commencing 5 days after tendon injuries could lead to higher breaking strength than in the nonexercise group or in those with exercise started on postinjury day 2. The same author also reported that functional loading commencing 5 days after tenotomy would result in a twofold increase in tensile strength and energy absorption capacity in the rabbit tendon. However, Murrell et al. (1998) reported that 15 min of daily swimming exercise had no effect on the repairing tendon strength in rats, as compared with the nonexercise group. Because their injury model was a complete tendon sectioning and the exercise started immediately after injury when inflammation was still intense, it is not known whether the exercise per se is ineffective to improve tendon strength or their injury model and timing of exercise did not facilitate healing. Exercise training is integral components for rehabilitation of tendon injury.(15)

However, re-rupture of the repaired tendon still occurs in about 5 to 10% of cases after early mobilization therapy, sometimes even at the later stages of tendon healing.(5)

Immobilization or constrained passive motion following suture repair is required to allow matrix synthesis and neotendon assembly to bridge the gap. Immobilization protocols necessary to restore tendon congruity result in scar formation at the repair site, rather than a linear fibrous array, and peripheral adhesions that limit tendon.(12)

One of the problems of flexor tendon surgery is adhesion of the repaired tendon to the surrounding tissue. To prevent this, early mobilization has been used postoperatively. Postoperative exercises increase the load at the suture site, and forces beyond the strength of the repair induce gap formation or re-rupture. To overcome this stronger suturing techniques have been developed to increase mechanical strength.(5) The postrepair management was immobilization in an attempt to remove all variables other than suture technique.(17)

Tissue engineering

A new approach recently advocated is tissue engineering of tendon. As the name implies, tissue engineering is the laboratory based design and development of living tissues and organs to replace or support the function of defective or injured body parts. Molecules, macromolecular assemblies and scaffolds are combined with progenitor cells and induced to differentiate into the desired tissue. For
tendon repair, two reports using this approach have appeared in the primary literature. Both used mesenchymal stem cells in gapped-tendon animal models. Unfortunately, only minimal improvements in the repair process and ultimate outcome were reported. This is not to say that a stem cell populated biomaterial would not enhance repair, only that, as with cartilage and ligament repair, stem cell technology has not as yet attained acceptable performance. One aspect that was clearly lacking in both of these studies was an appropriate scaffold on which to seed and expand the mesenchymal cells. Young et al. (1998) used a collagen gel contracted onto a pre-tensioned suture. The suture itself was the principal cause of improved biomechanical repair. Awad et al. (1999) also used a collagen gel, but the gel itself was too weak to carry load, thus it acted primarily as a cell carrier. The use of stem cells would likely be much improved if the transplanted, cell-seeded scaffold had tendon-like properties. Stem cells offer an intriguing and potentially viable approach for future studies, but differentiated tendon fibroblasts should also be considered as they may produce more immediate and superior tissue engineered tendon constructs. (12)

In addition to being used to study tendon healing mechanisms, animal models have been important in developing and testing tissue engineering methods to improve the tendon healing process. Many of the studies have focused on creating and using composites made from various biomaterials and cells to facilitate healing or to serve as potential replacement tissue. More recently, the development of these repairs and replacements have adhered to the approach of functional tissue engineering, which proposes to measure in vivo forces in uninjured tissue and to use this information as a guideline in designing appropriate constructs that can withstand in vivo loads. In addition, much research has been done on the exogenous application of cytokines to injured tendons to promote healing. The main factors to consider when creating a robust and functional tissue engineered tendon construct include a scaffold, cells, cytokines, and mechanical stress. (14)

Advances in the field of tissue engineering now allows for new approaches to treat tendon injuries. Promising technologies to accelerate tissue healing or to create new tissue constructs will likely play a major role in our future therapies. These include the use of new materials, bioactive molecules, gene transfer, as well as incorporation of viable cells in engineered materials. However, in order to develop optimal properties and combinations for these new materials there must be methods to rigorously test proposed components. In vitro mechanical testing and cell culture assays can provide key information to help focus efforts. However, experimental testing in an appropriate animal model remains an essential step in the development of these new techniques. (4)

**Functional tissue engineering (FTE)**

FTE is a new approach that places an emphasis on the importance of mechanical stress in determining the success of a construct. Because one of the main goals of FTE is to establish design parameters and safety factors for tissue engineered implants, more studies that take into account the in vivo function of the replaced tissues must be done. For example, the determination of in vivo patellar forces in rabbits during inactivity or hopping on an inclined treadmill showed that peak forces and stress during vigorous activity never exceeded 10% of their ultimate values. Peak tendon forces and the rates of rise and fall in these forces were shown to be positively correlated with activity level. By taking different design criteria into consideration, more functional and effective composites can be designed with a greater likelihood for success in vivo. (14)

**Cytokines**

A large number of studies have looked at the effects of cytokines on uninjured and injured tendons both in vitro and in vivo. Although it is relatively easy to experimentally add cytokines, there are many factors to consider, some of which include how much to add (dosage), when to add (timing), and which ones to add (combination), and how to add it (delivery). It has been shown that in a healing environment, there are changes in the expression of both cytokines and their receptors simultaneously, indicating a complex interaction of influences leading to a healed structure. The aforementioned factors and the complex interaction between cells, ECM proteins, and cytokines often lead to the reporting of conflicting
results between different studies. Finally, because healing occurs in a progressive, multifunctional way, optimal healing may require the sequential application of several cytokines in various combinations.(14)

**Growth Factor Stimulation**

The effects of growth factors on the promotion of in vitro growth of tenocytes have been documented.(18) Growth factors are proteins that have the ability to stimulate cell proliferation, cell migration, cell differentiation and the production of extracellular matrix molecules.(20) These growth factors are involved in cell differentiation and growth, including the normal processes of development and tissue repair. Several growth factors recently have been identified as playing roles in tendon healing including vascular endothelial growth factor (VEGF), insulin-like growth factor (IGF), platelet-derived growth factor (PDGF), basic fibroblast growth factor (bFGF), and transforming growth factor β (TGF-β). In addition, the transcription factor NF-κB has been implicated in the signaling pathways of these growth factors. Previous studies have shown several growth factors to be able to up-regulate collagen production in flexor tendon cells but the mechanisms of these effects were unknown. Each growth factor, with its own abbreviation, seems to have multiple forms, multiple receptors, and multiple functions. Current knowledge of the biology of tendon healing has yet to lead to clinically successful strategies to reduce scarring.(11) Furthermore achilles tendon healing can be accelerated by a single injection of a growth factor from the cartilage derived morphogenetic protein (CDMP) family.(2) All three CDMPs stimulated tendon repair to about the same extent.(8)

The efficacy of growth factor stimulation has been studied in various musculoskeletal tissues, such as muscle, cartilage, meniscus, ligament, tendon, and bone. The use of most growth factors, however, is limited by their short biological half lives. Therefore, gene transfer techniques frequently are used to test the efficacy of growth factor stimulation. Gene therapy is based on the modification of cellular genetic information.(20)

The genes encoding for growth factors are transferred into the local cells using viral or nonviral vectors. Thus, the genetic information of the local cells is modified so that growth factors are continuously released, resulting in a continuous stimulation of the tissue. Various studies have demonstrated the efficacy of growth factor stimulation for tendon tissue.(20) Growth factors and hormones may also be key in controlling the differentiation process and the production of new tissue.(3)

**Growth Factor Technology**

Transcription factors such as NF-κB are intracellular substances (usually proteins) that initiate or terminate the process of transcription, or gene expression. As these transcription factors bind to DNA in the nucleus, messenger RNA (mRNA) is copied from the DNA and eventually the coded proteins are made and cellular activity progresses. In contrast, growth factors are cell-secreted proteins that regulate cellular functions in the same cell (autocrine fashion) or in other cells (paracrine fashion), or in both. These growth factors usually are involved in cell differentiation and growth, including the normal processes of development and tissue repair and the pathologic process of cancer. Therefore growth factors usually work extracellularly via signal-transducing receptors whereas transcription factors function within the cell nucleus.(11)

**Scaffolds**

To meet the challenge of tissue engineering, various bioresorbable scaffold materials have been investigated for ligament and tendon healing, either to augment ligaments and tendons or as ligament/tendon prostheses. Kato described a carbodiimide and a glutaraldehyde cross-linked collagen fiber prosthesis to bridge gaps in the Achilles tendon of rabbits. They identified different resorption properties for the carbodiimide and the glutaraldehyde cross-linked scaffolds and observed that the scaffold material gets repopulated with cells and transforms into a fibrous scar with similar, but not identical ligament and tendon characteristics.(20)

The long-term follow up revealed that the scaffolds were replaced by a fibrous scar that did not regenerate either a neotendon or ligament. Badyla and coworkers used a clinically approved tissue scaffold derived from the small intestine submucosa (SIS) of pigs. They applied SIS to a dog model for
Achilles tendon repair and the overall strength of the construct was higher at 12 weeks than the suture-repaired control.(20)

**Autologous platelets**

Blood platelets release a cocktail of growth factors when activated, some of which are thought to initiate and stimulate repair.(2)

Furthermore platelets are known to actively participate in healing processes by delivering active molecules to the injured site by exocytosis following adhesion or their stimulation by thrombin or other strong stimuli. Growth factors secreted by platelets include platelet-derived growth factor (PDGF), endothelial growth factor (EGF), insulin-like growth factor (IGF-1) and transforming growth factor-b-1 (TGF-b-1), vascular endothelial growth factor (VEGF), hepatocyte growth factor (HGF) and basic fibroblast growth factor (bFGF).(1) Genetic modification of the tenocytes with PDGF gene therapy increases the ability of tenocytes to synthesize collagen and that the PDGF gene can be an important target of genetic modifications or molecular regulation in the tenocytes. Maximizing the production of collagen and proliferation of tenocytes is the ultimate goal of gene therapy, which most likely would involve the transfer of the most effective growth factor gene or a combination of genes critical to the healing process of digital flexor tendons.(18)

Other released substances such as VEGF, HGF and bFGF are chemotactic and mitogenic for endothelial cells promoting angiogenesis and vascularisation, a key step in healing.(1) Results of Aspenberg P. and Virchenko O. (2004) work, show that a single injection of platelet concentrate can improve tendon repair in rats. This effect is probably due to the growth factors that are released from the platelets during activation.(2)

**Thrombin**

Thrombin, a multifunctional serine protease, formed from plasma prothrombin upon calcium addition, is a key enzyme in blood coagulation. Apart from converting fibrinogen into fibrin, thrombin can directly stimulate cells inducing, for example, mitogenesis and causing them elaborate growth factors and cytokines.(1)

Platelet preparations provide an autologous natural combination of rapidly secreted growth factors; consequently their clinical use to improve the healing capacity of tendons merits investigation.(1)

**Mesenchymal stem cells**

Mesenchymal stem cells (MSCs) are pluripotent cells that are being investigated extensively in a wide variety of settings, including enhancement of tissue healing and tissue bioengineering.(13) As previously mentioned tissue engineers add cells to various delivery vehicles and introduce mechanical and chemical stimuli in culture to try and create safe and functional repair tissues. Delivery of high concentrations of undifferentiated mesenchymal stem cells (MSCs) to connective tissue defects has shown particular promise in animal studies for bone, cartilage, and tendon repair.(10)

Harris M.T. et al (2004) define MSCs as the adherent population of cells resulting from culture of a bone-marrow aspirate on a tissue culture plate.(10)

**Cell-collagen composite**

Bone marrow contains numerous cell populations including adult mesenchymal stem cells (MSCs) that can differentiate along multiple lineages to form bone, cartilage, ligament, tendon, muscle, fat, and stroma. Recently, investigators have implanted MSC-seeded constructs into surgical defects to repair articular cartilage, tendon, bone, and muscle. Although numerous factors (e.g. tissue model, wound type, in vivo loading on the repair site, presence of a suture, blood supply, and cellular infiltration) could have contributed to the differences in the extent of repair, one factor of interest was the difference in the seeding density of MSCs in the collagen gel scaffold.(3)

It has been demonstrated that implanting tissue engineered composites made from MSCs, collagen gels, and suture scaffolds into surgically created patellar tendon defects improved the repair biomechanics compared to natural repair at both 12 and 26 weeks after surgery.(3)
NSAIDs

Non-steroidal anti-inflammatory drugs (NSAIDs) are often used to manage pain after tendon and ligament injury or surgery.(16) Nonsteroidal anti-inflammatory drugs (NSAIDs) inhibit the formation of bone. However, they have been shown to increase tensile strength in healing tendons.(9) These drugs act by inhibiting cyclooxygenase (prostaglandin synthase) to block the formation of prostaglandins, which are important mediators of the inflammatory process.(16)

Due to fewer side-effects, the recently introduced selective cyclooxygenase-2 (Cox-2) inhibitors will probably promote more widespread use of this kind of drug. The effect of NSAIDs (Cox-inhibitors) on bone and connective tissue healing remains unclear. The recently introduced selective Cox-2 inhibitors should contribute to even more general use of these drugs because of fewer side-effects. Comparative data about their effects on bone formation and connective tissue (tendon) healing have not been available. Many studies have reported that they inhibit orthopic and heterotopic bone formation. On the other hand, an increase in tensile strength after treatment with indomethacin (non-selective Cox-inhibitors) has been shown in the healing rat-tail tendon.(9)

Forslund C. et al (2003) showed that Cox-inhibitors have a beneficial effect on tendon healing. The material properties of the tendon callus were improved. They have been speculated that one mechanism for the effect of Cox-inhibitors on connective tissue regeneration could be acceleration of collagen maturation. The effect of NSAID may be due to interference with collagen metabolism and crosslinking in the process of healing. Another mechanism, based on changes in collagen maturation, would be through interference with lysol-oxidase synthesis or activity.(9)

In contrast to Forslund C. et al (2003) results, RILEY G. P. et al (2001) showed that some NSAIDs have potentially deleterious (inhibitory) effects on human tendon cell proliferation and matrix glycosaminoglycan synthesis in vitro. They results are consistent with in vivo studies which have shown that ibuprofen and naproxen significantly reduce the repair strength of flexor tendons. The inhibitory effect of NSAIDs such as indomethacin and naproxen has been attributed to toxic effects. Alternatively it has been suggested that some NSAIDs may possess inhibitory activity against glycosyl transferases, enzymes that are involved in the synthesis of glycosaminoglycans.(16)

Thus it appears that some NSAIDs can affect both the synthesis and degradation of matrix, and that differences between these studies and our own data can be attributed to a number of factors such as the drug dose, species differences and the use of different NSAIDs.(16)

Ultrasound

Although the concept of using ultrasound in the healing of tendon injuries was first proposed over 75 years ago and has general clinical acceptance, its specific physiological mechanisms and therapeutic effects have been a source of conflict among researchers. Some earlier studies had concluded no beneficial effect of ultrasound treatment to tendon and ligament healing. However, more recent investigations have demonstrated that therapeutic ultrasound may facilitate fibroblast proliferation and protein synthesis, with a significant increase in tensile strength, rate of collagen synthesis, and energy absorption capacity of the tendons.(14)

NG, G. Y. F. et al (2004) have reported that therapeutic ultrasound could facilitate tissue recovery and ultrasound with dosages between 0.125 W/cm2 and 3 W/cm2 have been used in the treatment of tendon ruptures. They also reported an improvement in both strength and energy absorption capacity of repairing rabbit tendons after nine treatment sessions with 1-MHz continuous ultrasound. (15)

However, there are conflicting results on the efficacy of therapeutic ultrasound in managing tendon injuries. NG, G. Y. F. et al (2004) reported no improvement in the strength of repairing rabbit tendons with 6 weeks of pulsed ultrasound treatment at a dosage of 2 W/cm2. Similar findings of no improvement in tendon strength and inflammation with ultrasound treatment in cockerel and rat have also been reported.

These inconsistent results may suggest that animals respond differently to therapeutic ultrasound and that the effect is sensitive to the treatment parameters. Timing and mode of treatment are important factors affecting the outcome. Most studies with positive results have used continuous ultrasound at 1
MHz, but the effect of dosage has not been well-documented. Hitherto, there is not a general consensus on the choice of parameters for ultrasound treatment and the evidence for efficacy of therapeutic ultrasound on tendon ruptures remains inconclusive.(15)

The reported mechanism of the therapeutic ultrasound is that it stimulates cell division, fibroblast production and collagen synthesis during the active repair stage. The acoustic streaming effect of ultrasound could change the diffusion rate and membrane permeability of the fibroblasts, resulting in an accelerated Ca2+ uptake by the cells and faster rate of collagen synthesis. Furthermore, both thermal and nonthermal effects of therapeutic ultrasound could improve tendon extensibility, mast cell degranulation, growth factor production and fibroblast mobility.(15)The widespread use of this modality by medical and surgical practitioners suggest efficacy but a clearer understanding of the precise effects of ultrasound on tendon healing is needed.(14)

Shock wave treatment

The complex healing and remodeling processes of a tendon graft depend upon a variety of factors including the application of mechanical forces to the grafts. Recently, shock wave treatment has been shown to be effective in the treatment of certain musculoskeletal disorders including chronic non-union of long bone fracture, and tendinopathies of the shoulder, elbow and heel. In animal studies, shock wave treatment was shown to increase cortical bone formation in acute fracture and induce neoangiogenesis and improvement of blood supply at the bone–tendon junction. The exact mechanism of shock waves remains unclear. The results of previous studies in animal experiments showed that shock waves promote bone formation and healing of segmental femur defect associated with bone morphogenetic protein (BMP) expression in callus in rats, enhance bone mass and bone strength after fracture in rabbits and induce neoangiogenesis and improve blood supply at the tendon–bone junction.

The effect of shock waves on tendon–bone interface appeared to be time-dependent.(19)

Summary

The clinical treatment of tendon injuries has improved in no small part due to therapies and rehabilitation protocols developed from both clinical and experimental research. Suture repair of parted tendons has improved significantly over the past two decades. However, sutured tendons are not able to withstand the loads necessary to affect a proper repair response. It seems unlikely that sutures alone, no matter what the technique, will ever facilitate full recovery to normal function, given that post-surgical active mobilization appears necessary to stimulate proper neotendon formation and integration across the joined ends. Moreover, sutures are clearly unable to promote full recovery of gapped tendons resulting from reconstructive surgery. Thus, novel strategies are essential to improve prognosis following surgical repair of ruptured, lacerated or transected tendons. Innovative strategies could derive from one or a combination of developments resulting from diverse musculoskeletal research. From a cell biological standpoint, it is imperative to understand the phenotypic responses to injury of both endogenous tendon fibroblasts and exogenous cells that are involved in all phases of tendon healing.

Manipulating the activity of one or another cell type could vastly improve the natural repair mechanism. Closely associated with cellular activity are cytokines and growth factors. How these factors influence each cell type must first be understood, but, once attained, that knowledge could lead to therapeutic uses to regulate phenotypic expression of the involved cells. Gene therapy is another burgeoning field that could potentially drive proper assembly of the repair mechanism if engineered cells could be effectively delivered to the repair site. Tissue engineering of tendons has vast potential for creating artificial living tendon from mesenchymal stem cells or host fibroblasts. What is lacking in engineered tendons developed to date is a mechanically appropriate scaffold in which to seed the cells. However, it may be possible under managed conditions in vitro, e.g. by mechanical loading of the cell seeded tendon constructs together with cytokine stimulation, to produce a living artificial tendon with appropriate properties.

Use of synthetic materials in tendon repair remains a viable option. While most synthetics have failed in application, a woven polyester mesh appears promising for repair of Achilles tendon ruptures. The development and testing of this material underscores the need for continued research on existing synthetic fibers. Moreover, advancing industrial technologies designing new polymeric materials may result in novel fibers that could potentially be used directly or modified for use as tendon substitutes. Restoration
of normal function could in principle be achieved if the repaired tendon is mobilized and loaded immediately after surgery. This can only be accomplished if the parted ends are bridged with a biocompatible material that is mechanically comparable to tendon fibers. Effective methods for integrating the artificial tendon must be designed and implemented before these materials can be clinically tested. The long-term fate of the bridging material is another issue that could potentially affect the success of the repair. Does the material need to be resorbed at a rate that is equivalent to the production of neo-tendon, or can it remain in place for longer duration and not compromise the functional properties of the structure? Is fatigue quality an issue if the material remains in the repaired tendon? Will cells attach to these materials in a way that facilitates strain induced signals for proper cellular response? The optimal biomaterial that will provide full recovery to normal function has yet to be developed.

Although our cumulative knowledge base is vast, it is still incomplete and more research needs to be done in tendon injury and repair before we can achieve the ultimate goal of directing the healing process of an injured tendon to form tissue that is structurally and functionally comparable to that of a normal tendon.

References:


A horse that always moves about on soft earth is not in need of hoof protection, and on favorable going it has no problem in reaching its expected level of performance as racehorse/jumper/hunter or carriage horse. However since ancient time, man has learned that unfavorable going and inadequate care cause abnormal wear of unprotected hoof horn and consequently, result in lameness, rendering the horse useless. The oldest protective devices (3000 years ago) consisted of natural materials and fastened under the hoof like a shoe or sandal. The literatures from 5th century give us details of an iron horse shoe nailed on the hoof.

In order to gain an insight into proper care and effective protection for hoof which alters neither its shape nor its characteristics, it is necessary to obtain knowledge concerning the structure and function of this complex terminal part of the horse’s toe. We have to view the hoof and differentiate between the coronary groove, the coronet, the hoof wall, the hoof sole, the frog and the heel. The hoof wall is further divided into the toe, quarters and heels.

A normal front hoof is characterized by a ratio in length between toe and heel of 3:1 and a hoof angle (between toe and ground) of 46-50°. A normal rear hoof is narrower, higher and steeper than a front hoof. The ratio in length between toe and heel is 2:1 and the hoof angle is 50-55°.

Trimming should be done every 4-6 weeks on horses that are used barefoot. Shoes should be reset every 4-6 weeks on horses that are shod. Shoeing is done of 2 to 4 week intervals on race horses. The object of proper trimming is to make the shape of the foot, the angle of the foot axis and the foot level as nearly normal as possible. The foot should be trimmed so that pastern and hoof axis forms an unbroken line. The horse should be observed at rest and in motion to better determine the angles of the feet best suited to that particular horse.

Following observation, the foot should be cleaned of all debris by a hoof pick. Rear portions of the sole and frog should be cut away with a hoof knife. The wall should be trimmed with hoof nippers begin at the heel and trim to the opposite heel or trim from the heel toward the toe. A better technique is to start trimming at the toe first, lower it to the appropriate level, and then proceed back to the quarters and heels. To trim the toe properly, it should be lowered just to the point that the white line appears moist and rubbery and slightly protrudes beyond the drier adjacent area. The wall usually should be trimmed approximately to the level of the frog, but never past the sole.

After the foot is properly trimmed and leveled, the desired shoe of the correct size should be selected. The shoe definitely should be fitted to the foot rather than the foot fitted to the shoe. The shoe should be accurately centered on the foot. Shoes may be applied hot or cold, but the hot method is preferred because more accurate shaping can be done with a hot shoe. Once the shoe is fitted to the foot, the nails are driven in. The nail holes should be over the wall, starting at the outer aspect of the white line. The shoeing hammer is used to tap the shoe into position after driving the first nail. If the heel nails are driven first the toe nails should be the next and if the toe nails are driven first, the heel nails should be next, and the remaining nails should follow. The path of a horse shoe nail entering the horn structure of the wall should be parallel with the horn fibers so that nail does not cut or sever these fibers. Under ordinary circumstances, three nails on either side is enough, but most machine-made shoes have four nail holes per side. There are developments in horse shoe technique and how to protect hoof without nails. There are a whole range of adhesive and buckle-on hoof shoes. No-nail adhesive hoof shoes are made to fit all sizes of hoof and have been tried and tested in all kinds of equestrian sport. No nail hoof shoe, no nail easy shoe, cuff for iron shoes, clog buckle-on hoof shoe are the ranges of no nail hoof shoe
products. There are other groups of plastic hoof shoes which are available in sizes 00, 01, 03 for front and hind, 04 front and hind and 05 which can either be used for front or hind.

Disorders of sole, frog and white line such as bruises and abscesses are causes of lameness in horses. Canker (chronic hypertrophic pododermatitis) is usually associated with poor hygiene. Treatment for these conditions requires fitting some form of protection normally detachable in addition to the usual horseshoe. Bruises differ from abscesses in that bruises are aseptic. They are diagnosed by studying the patients history, probing the foot, and judicious use of hoof knife. Abscesses affect the dermis of the hoof and if untreated, break out at specific places in relation to affected dermis (corium). An effective protection can be achieved by applying a rigid plate, which must be detachable to permit the administration of medical treatment at regular intervals. In the case of canker, which calls for frequent treatment, after radical surgical removal of the diseased tissue the use of such a detachable plate is almost always necessary.

Laminitis (Inflammation of the sensitive laminae connecting the distal phalanx to the hoof wall) is a medical emergency and its treatment aims at preventing founder. The treatment consists of relieving the weight bearing function of the dorsal hoof wall which sustains PIII through the affected laminae. One easy and quick way of doing this is by applying a foot cast with extra support below the palmar structures, raising the heels and therefore releasing the pull of the DDFT can be useful in the acute phase. Once there is downward displacement of PIII relative to hoof capsule rotation (founder), therapeutic shoeing should have the following purposes:

a) Protect and re-establish sole depth that is about 17-20 mm of sole below the tip of PIII.
b) Unload the wall by transferring weight bearing to the palmar sole-bars and frog.
c) Promote normal hoof capsule.
d) Decompression of coronary band.
e) Reduce pain.
f) Prevent abscesses.

The Catelijns-Resello Technique of shoeing reduces all (a-f) parameters.

Trimming and shoeing in sagital plane (toe to heel) is considered for low and under run heels. In these cases, the position of the hoof axis is incorrect and too flat. It is also called insufficient hoof wall in the area of the heels or more hoof wall in the toe. The solutions for this condition include:

a) Correct shoeing period. Horses with flat hoofs should be shod more frequently.
b) Correctly fitting (comfortable), wide and long shoe branches. The branches of the shoes should be correctly fitting.
c) Rasping of a concave digital wall to ensure that it is parallel to the third phalanx.
d) Using egg bar shoe or heart bar shoe.

Lesions to the inferior check ligament benefit from a shoe with good palmar support and easy break over as is with DDFT injuries. DDFT contractures which lead to flexure deformity of distal interphalangeal joint can benefit from dorsal extensions to initially raise the heels with screwed on and easily adjustable wedge. Injuries to SDFT should certainly not be treated by raising the heels and could even benefit from a shoe with wide web at the toe and narrow heels during recovery. Traumatic injury with total or partial severance of one or more elements of the suspensory apparatus can be treated with a fetlock brace which needs an additional palmar/ plantar extension, if the DDFT is one of the affected structures. Digital extensor tendon lesions and rupture can benefit from dorsal extension during rehabilitation. Severe angular limb deformities can benefit from a combination of orthopedic shoeing and surgery.

The full rolling motion shoes diminish the articular constraints in all directions by shortening the movement arm from the DIPJ center to the lower outer rim of the shoe where lateral-medial break over takes place. The use of these shoes has given excellent results both in clinical trials and in the horses diagnosed as suffering from (articular) navicular disease, DJD of the DIPJ or palmar hoof pain.

Studies showed that the impact force a shod hoof receives on hard ground is 10-33 times that of
an unshod hoof. The vibrations set up in the hoof by vibration of the metal shoe are approximately 800 Hz, compared to “only” 150 Hz with a rubber shoe. However, shock absorption and pumping action can also be insufficient in an unshod horse, when the shape of the hoof is deformed (improperly trimmed) and/ or the hoof is too dry, and thus no longer elastic.

So from various sources throughout history it has been known that:

1. Shoeing causes the foot to become contracted (Clark)
2. Shoeing causes a deviance of the normal laminae structure (zierold)
3. The impact forces with each shod step are much greater, and the vibration of the shoe is damaging (Bein)
4. Circulation is decreased through shoeing (Pollitt)
5. The side walls, at the widest part of the hoof, have to be able to move outward (Smedegard)

Horse owners must be very careful not to over trim their horses, and should try to seek professional guidance whenever possible. Knowledge and education are absolutely crucial, both for owners as well as hoof care specialists and practitioners everywhere. Hands-on training is necessary in order to even begin to apply the guidelines accurately to your own horse, which must be trimmed in his own individual way. It must be understood that there can be no absolute values or measurements when dealing with an individual living organism, for which a multitude of factors and conditions exist at any given time, all of which are in a constant state of change as all living things are.

In this lecture hopefully, hoof trimming for different hoof conditions, shoeing normal hoof, shoeing problem hoof, different horse shoes particularly new generations of horse shoes will be introduced and discussed.
CURRENT CONCEPTS OF LARGE ANIMAL CASTING

J. Ferguson

Director, Large Animal Surgical Clinic, Veterinary Medical Faculty, University of Leipzig, Leipzig, Germany

The use of external fixation in the form of casting using rigid, moldable materials has many indications in large animal medicine and surgery. The use of “casts” as a primary means of support and immobilization for fractures in the distal limbs is an obvious indication both for emergency fracture management and as a primary, longer-term method to support the healing process. Luxations may also be handled by application of casts to counteract the tendency of a joint to dislocate as well as to provide added support and protect against unphysiological forces after a luxation has been surgically treated. Wounds in the distal limb region, particularly in horses have a tendency to produce excessive granulation tissue which can result in a disturbance of the wound healing sequence. Casts may be applied with the specific aim of controlling exuberant granulation tissue buildup in some of these instances. Some fractures in large animals treated using internal fixation devices are considered to require further support post-operatively. This is particularly true in the postoperative recovery phase following equine general anesthesia when excessive forces in combination with uncoordinated movements predispose to overloading of implants. The combination of external support in the form of casts may provide adequate support in such critical cases or specific instances. Following soft tissue injury and surgery of joints and tendons, casts may be utilized to prevent over flexion / extension as well as over stressing tendons and ligaments thus preventing reinjury or additional injuries. Following fracture healing and removal of implantation under general anesthesia, casts may be utilized to protect the affected limb in the recovery phase and is particularly indicated in those fractures which have required a long time to heal and thus may be associated with bone and muscle atrophy. Such animals are at increased risk of refracture or fracturing other boney structures which have not been subject to normal physiological stresses during the healing period.

The advantages of cast application must be weighed against the possible disadvantages when considering whether or not to use a cast in each particular case. In general when speaking of cast application we are considering fracture management. It must be remembered that, provided the fracture fragments are rigidly immobilized, the best interests of the animal are served by having some degree of mobility of the animal which implies relatively pain-free limb movement. These conditions reduce the occurrence of complications such as laminitis in horses from over use of the contralateral healthy limb and fracture disease in all species as discussed below. Movement and use of a limb supports blood supply, minimizes edema and supports the healing process in many ways. The major question in using casts in large animal species is whether or not this form of external fixation is sufficient to hold the fragments in place long enough to allow healing by secondary intention without predisposing to complications which can result to the overall detriment of the animal. The ideal situation of controlled, pain-free movement is not always attainable for large animals and thus the application of casts as the primary fracture treatment methodology must be carefully considered in that light of all possible treatment techniques.

Advantages

The major advantage of casts in the various indications listed above is that the initial outlay of investment is minimal particularly when considering plaster of Paris casting material which however may not be adequate for many instances in adult large animal patients. The application of cast material of most types is relatively simple and follows well known principles. Cast material, at least when considering plaster and fiberglass, is readily available and both have a relatively long shelf life. A limited inventory is all that is required in contrast to the inventory of implants and equipment required for fixing the same fracture using internal fixation. A further
advantage is that all materials required are easily transported and do not require sterile methodologies or facilities which is particularly advantageous for on-farm emergency fracture management. Fracture management in young animals, particularly bovines is best obtained using casting methods when distal limbs are affected.

**Disadvantages**

“Fracture disease” is a complex of musculo-skeletal changes associated with and resulting from prolonged immobilization resulting from cast fixation of a limb regardless of the initiating problem. Following prolonged restriction, joints lose the ability to return to full mobility and may lose considerable range-of-motion (ROM) is part due to changes in articular and periarticular tissue structures such as joint capsule and periarticular fibrosis. Muscle adhesions both between different muscles, between muscles and fascia, and also between muscle and bone in the region of the fracture and callus result in impairment of normal muscle and joint activity. Muscular and bony atrophy from disturbances in vascularity and disuse are highly underestimated problems during and following the healing process. Exuberant callus production as a result of trauma or less than optimal fracture immobilization may affect joint movement as well as interfere with nerve tissue in and around the fracture site. Due to problems associated with fracture disease and the necessity to reduce bone and muscle atrophy to a minimum, the post-traumatic period and the healing phase should be accompanied by physiotherapy under controlled conditions whenever conditions permit.

Biomechanical effects resulting from elongating the “lever arm” resulting from cast application to the distal limb must always be kept in mind throughout all phases of the healing period from initial post-operative recovery to removal of the cast device.

Positioning the limb in extension or “equinus” with or without a walking bar to strengthen the cast and provide a beneficial breakover effect, facilitates ambulation and minimizes eccentric forces acting along the length of the cast and the proximal cast/skin junction. Other effects such as altering the tension on tendinous structures should also be considered when selecting limb positioning within a cast.

Problems following cast application are related to cast continuity, development of pressure points and functionality of the cast itself. A broken cast is of major concern and should be immediately remedied by replacing it or at least by “patching” it when possible. The cast should be inspected daily and is best achieved by visual observation as well as palpation. The most common problem in the author's opinion is the presence of pressure sores either under, around the cast ends or on other parts of the body caused by increased recumbency. Pressure points under the cast are difficult to recognize and should be evaluated by the methods described below. Failure of the cast to adequately immobilize the fracture ends results in delayed or non-union or worse malunion. Regular clinical and radiographic evaluation should be considered in all cases where healing problems are suspected.

In general, problems which develop under a cast are difficult to evaluate on a one-time basis. It is always advisable to consider “trends” in daily parameters. Indications of such problems are suggested when the patient begins to spend increasing periods of time in recumbancy or appears to be more quiet (less mobile) than usual. Patients with a cast usually appear lame but when the degree of lameness increases it is cause for concern. Some patients demonstrate more interest in the cast itself by looking at it or attempting to chew or make contact with it. Although not the norm, body temperature may be increased. If appetite or eating habits change a problem under the cast should be considered. Obvious changes at the proximal or distal ends of the cast such as edema, cellulitis, swelling or exudates indicate a significant possibility that a problem exists and the cast should be removed to evaluate the limb.

The question of cast padding relative to pressure sores under and around the cast is an important topic to discuss. In theory at least, padding should function to protect the underlying skin from pressure and rubbing as
well as to optimize the “fit” of the cast by conforming to limb contours. The very first casts used plaster of Paris and a padded “bandage” of cotton was applied to the limb followed by the application plaster of Paris applied as a paste over the bandage. Traditionally large amounts of cotton was used and cast-bandages were bulky and heavy in addition to being less than optimal in achieving long lasting immobilization of the fracture ends. The use of very rigid (thus capable of good immobilization) materials which can be applied with good conformity to the distal limb reduces the need for extra padding and in fact the use of more than minimal padding increases the risk of pressure sores. The problem with compressible cast padding such as cotton wool is that it compresses within a short time under a cast and thus the resulting poor cast fit leads to the movement of the limb under the cast which automatically leads to the increased chance of development of pressure points. This author prefers using minimal (preferably two polyester stockinette) layers of padding and application of a good fitting cast on a limb which has little or no edema to reduce the occurrence of pressure sores and improve the function of the cast.

Fit of a cast in the proximal limb where muscles are more prominent than distally is worthy of discussion because over the course of days and weeks the muscles atrophy and the cast cannot continue to effectively function because it doesn’t fit the proximal limb any more. This leads to the potential for immobilization problems and increases the risk of cast sores both at the proximal end of the cast and under the cast as a result of limb movement under the cast in the area of a nearby contact point or joint location.

Selection of casting material

Plaster of Paris as a casting material is both economical and adequate for younger animals provided that housing and maintenance are consistent with good cast care. Even older, heavier cattle may have plaster as part of the external fixation device if other materials are incorporated into the cast to overcome the shortcomings of excess weight and limited final strength inherent in plaster. The use of an aluminum walking bar or combinations of plaster and fibreglass are two methods of overcoming such limitations. The use of fiberglass cast material is highly recommended for all but very young horses.

Fiberglass cast material alone provides excellent strength with minimum weight. It has had the disadvantage of increased cost and less than optimum conforming and molding characteristics. However these factors are overshadowed by the much stronger resulting cast and the short time in which maximum strength is obtained using modern fiberglass products designed for human and veterinary applications. Innovative modifications in fiberglass casting materials have made significant improvements in conforming qualities while maintaining pre-existing costs is seen as a further advantage. The relative radiolucency of fiberglass combined with its high strength to weight ratio allows radiographic evaluation of bony elements without the need for cast removal in many instances.

Casting as an emergency method of immobilisation uses the same principles and techniques as when used for primary means of immobilisation of fractures and soft tissue support.

The objectives of cast application for treatment of fractures are to immobilize the fracture fragments in order to optimize the healing process. This may be achieved only if axial and rotational forces are controlled so that no forces other than compression act on the fracture site. To immobilize the fracture site the joints proximal to and distal to the fractured bones must be immobilized which means that the cast must extend well beyond these respective joints to achieve the desired effect. The application of casts which are not long enough is one of the most commonly seen errors in the management of fractures in practice – it seems that a high percentage of people tend to underestimate the extent to which casts must be extended in order to stabilize the proximal and distal joints.

Rotational forces also act on the fracture site and must be neutralized in order prevent movement which acts to inhibit the healing process. Irregular contours of the limb proximal and distal to the fracture site should be utilized as much as possible to counteract rotational forces. The shape of the distal limb (hoof for horses and
claws for cattle) provide an excellent possibility to control rotational forces distally. The shape of the carpal, elbow and hock joints in the more proximal locations especially when some degree of joint flexion exists should be utilized whenever possible. Longer casts are more likely to utilize these contours to achieve the original objectives related to effecting stability at the level of the fracture site.

Special consideration for using plaster as a casting material is related to the fact that plaster takes a long time to reach its optimal strength. It takes approximately one week to achieve its maximum strength despite appearing to become hard within a few minutes when conditions are optimal. This factor alone restricts the use of plaster to those situations where limited initial cast strength is required and the animal must not bear weight on the limb for over 30 minutes. Plaster itself remains susceptible to moisture after hardening and is thus not suitable as a material when environmental conditions preclude keeping the cast dry for the complete time it is to function. Plaster achieves its strength from crystal structure formation which occurs in an exothermic reaction in the presence of water. It is critical to optimal crystal formation that the process occurs quickly with the production of maximum heat, long crystals and creation of the full cast thickness as a single layer. This process is not readily achieved without knowledge of the principles and the art of “casting” which is best learned from someone with extensive, successful experience with plaster cast construction.

Special considerations for utilizing fiberglass as the casting material are primarily associated with its cost (approximately 10 X that for plaster), its rapid attainment of high strength, and its tendency to conform less optimally than plaster. Fiberglass sets up quickly and speed is of the essence when applying this material since one objective is to integrate all of the material into a single layer which is much stronger than the same amount of material which is not formed in a single but rather in several non-integrated layers. Shelf-life of fiberglass is of some concern as outdated material does not catalyse properly and will “layer” and dry out when stored past its expiry date. Once the sealed individual packages are opened to the air they must be used and cannot be stored for later use.

Removal of casts is usually more problematic than applying casts. The majority of casts are removed from the standing animal although it is certainly possible to deeply sedate or have the animal under general anesthesia for this procedure. There are several ways to remove a cast regardless of its composition. The biggest problem is that the cast is hard and closely contoured to the limb which is irregularly shaped. Cast padding is usually minimal and there exists little space between the inner limit of the cast and the skin or horny surface of the animal thus leaving minimal working space and / or room for error. Every person has slightly (or significantly) different methods of applying a cast and estimating the optimal cast thickness over the length of the limb. This leads to a potential problem in estimating cast thickness if different people apply and remove the cast. This author recommends that the person who removes the cast should be the same one who applied the cast to minimize the risk of skin wounds to the patient and minimize the time required to remove the cast itself. Most casts are removed when, based on clinical judgement, the fracture has healed enough or the various objectives have been met. Often radiographic evaluation on a one-time or repeated basis is used to assist this decision process.

There are several devices to assist removal of casts. The first choice of the author is an oscillating saw with a blade specifically designed to cut through plaster and fiberglass material. The major advantages of this device is that it has significantly less tendency to cut into skin, is rapid and effective and is easy to control as to depth and direction of cut. It allows the cutting of “cast windows” and the “bivalving” of casts thus reducing costs during the recovery phase and transition phase following cast removal. Care not to overheat or overwork the saw must be observed so as to prolong the life of the device. There are fewer things more frustrating than to have a saw breakdown partway through cast removal on a sedated but fractious horse – a good reason to have an additional saw as backup. The incorporation of a wire saw within the cast or within a tube within the cast has been advocated by some but may also be fraught with problems. The use of plaster cutters is adequate for removing
plaster casts with room between the cast and limb for one jaw of the cutting device but such casts are not always desired. These cutters should always be “on hand” but are not adequate for fibreglass materials in the author's experience. Heavy tongs such as vise grips may be used to remove large chunks of plaster by brute force but are not recommended for fibreglass. The use of rotating grinders or drills with cutting discs has a significant risk of injuring the patient and are not recommended for use on a routine basis. In emergencies when other devices fail, it may be possible to use a hammer and chisel (in the form used by some hoof and claw trimmers) to remove a cast. It must be remembered that the cast is usually removed in two halves and this process is made easier when a cast spreader is used.
INTRAOPERATIVE AND LAPAROSCOPIC ULTRASOUND:
DIAGNOSTIC APPLICATIONS IN THE BOVINE

Ferguson, J.; Gerlach, K.

Clinic for Large Animal Surgery, Faculty of Veterinary Medicine, University of Leipzig, Leipzig, Germany

Diagnosis of abdominal disorders in cattle remains a challenge and is normally restricted to methodologies associated with evaluation of clinical parameters from history and observation of clinical signs, physical evaluation of the animal, collection of samples from blood or other fluids and sometimes from exploratory laparotomy findings. While clinical examination results are obtained immediately, the time from sample collection to reception of results from biopsies, samples for culture and sensitivity, hormone analysis etc. may take considerable time and delay the diagnostic and prognostic processes. In such instances the use of a rapid, non-invasive or at least minimally invasive method may significantly reduce the time and costs incurred in reaching a diagnosis. The collection of biopsies from specific locations in organs deep within the abdominal cavity may also be problematic specifically three dimensional information is required to direct the biopsy instrument. Diagnostic ultrasound in its various forms may be ideally suited to assist diagnoses in such problems.

There are many factors which complicate arrival at a definitive diagnosis of abdominal disease in cattle using standard methodologies, some of which are discussed below.

Stoic attitude and tendency not to demonstrate overt signs of colic may delay the early observation of disease signs and allow for development of secondary associated changes within the abdomen.

Animal size often precludes use of diagnostic modalities such as radiography in the abdomen of adult cattle. Size of the abdomen and location of specific structures within it are often associated with difficulties in the application of diagnostic imaging modalities related to organs located deep within the abdominal cavity and out of reach of traditional transcutaneous ultrasound imaging methods and also not palpable via the rectal route. In such cases the presence of space occupying lesions and location and distribution of tumours within organs are not always available from traditional, non-surgical diagnostic methodologies.

In contrast to companion animal practice, the diagnosis and treatment of cattle diseases usually has a limit to the amount of money which may be spent to successfully diagnose and treat an individual or herd problem. Modern laboratory methodologies are very sophisticated and accurate and readily available to most cattle practitioners. However the price of an individual analysis or a battery of tests may incur significant costs which most practitioners and owners would prefer to keep to a minimum.

Evaluation of haematology and serology samples is not always reliable and specific enough to provide information of a specific disease, the amount of damage to an organ or the location of a lesion within an organ or organ system. This is particularly problematic in the evaluation of paired organs or those organs which have considerable capacity to function despite major involvement of a disease process. Such organs as the liver and kidneys may only demonstrate serum changes in the later stages of the disease process.

Transcutaneous and transrectal sonographic examination have been standard procedures in large animal practice for many years. While these techniques have been developed and refined to optimize their use, detailed image acquisition from structures lying deep within the abdominal cavity remain difficult and sometimes impossible to attain.

The general limitations of transcutaneous ultrasound for abdominal diagnosis in large animals are particularly problematic for those organs which lie within the thoracic and pelvic regions and are difficult to image due to spatial interference of the ribs, lung tissue, gas-filled bowel and the presence of overlying structures deep within the cavities in question. Imaging of structures lying distant from the abdominal wall is a compromise between penetration of energy waves (3-5 MHz) and image quality (5-8 MHz). Penetration being not only limited in depth but also in quality ultrasound probes of a lower frequency are used. Higher frequency probes provide for higher image resolution but cannot penetrate much beyond the abdominal wall musculature. Evaluation of structures lying within the abdomen is obviously not possible to evaluate in all three planes using the transcutaneous method. Intra-operative or laparoscopic direct application of an ultrasound probe to the organ in question without an offset pad facilitates rapid examination in all three planes (dimensions) and provides optimal image quality. The option of using the colour Doppler modality in combination with higher frequency probes further facilitates acquisition of detailed images and arriving at diagnostic conclusions.

Direct application of an ultrasound probe can be achieved by laparoscopic or direct intra-operative methods and
provides detailed information with respect to small, defined areas in contrast to the transcutaneous method which provides images representing larger organ dimensions but cannot produce detailed images sometimes required for diagnosis. Intra-operative ultrasonography (IOUS) has been performed in diagnostic and therapeutic procedures for liver, kidney, pancreas, spleen, abomasum, and reticulum. Rumen and small intestine. Results of these studies demonstrate an improvement in imaging for all organs. Images presented demonstrate the following ultrasound characteristics of IOUS obtained from standing, mature cattle (results of kidney and liver have previously been presented, (WBC Hannover, 2002).

Methodology For normal transcutaneous ultrasonic evaluation of abdominal structures, the animal is prepared by clipping or shaving the skin to optimize image quality, the animal may be sedated depending on the preference of the clinician. For laparoscopic or intra-operative procedures the skin receives a surgical preparation and local or regional anesthesia depending on the method of choice. Laparoscopic procedures only require local infusion of anesthetic at the trochar sites, while intra-operative evaluations are carried out under regional anesthesia such as paravertebral. The rumen, reticulum and spleen are evaluated via the left flank while the pancreas, liver and abomasum are reached through the right flank approach.

While standard ultrasound probes varying from 3 to 6 MHz are standard in transcutaneous evaluations, intra-operative probes range in frequency from 5 to 8 MHz or even higher. We utilized both a microconvex as well as a linear probe to obtain our intra-operative images. For laparoscopic ultrasound examinations, a specific transducer is required which is compatible with insertion through an existing trochar system (it must be round in profile) and long enough to reach most organs of interest within the abdominal cavity given a certain flexibility in trochar placement. We used a 40 cm working length linear probe with frequencies varying from 5 to 8 MHz which was compatible to our Toshiba Eccocce SSA-34A/3E ultrasound machine. The probe had a flexible distal segment mounted which supported movement in all three planes. The laparoscopic equipment was mounted on a standard tower and included colour monitor, high flow CO2 insufflator, a 300 watt xenon light source and a camera with twin video, still recorder and SVHS-video capabilities. We used standard laparoscopic trochars and cannulae and a basic surgery set. The software in use with the Twinvideo system allowed the simultaneous production of both laparoscopic and ultrasound images on the monitor which greatly facilitated probe placement in the correct plane and optimal contact point under direct visual control.

Body condition score plays a greater role in transcutaneous evaluations than in intra-operative examinations due the presence of thicker muscle and fatty tissues between the ultrasound probe and the organ in question. This factor does not significantly affect image acquisition in laparoscopic or intra-operative methods.

Pancreas: examination through a right flank approach, high quality images were obtained without difficulty from all animals examined. Good quality transcutaneous images were difficult to obtain from fat cows and in those cases when intestinal structures were located between the abdominal wall and the pancreas.

Spleen, Rumen and Reticulum: the spleen may be readily examined both intra-operatively and transcutaneously. Intra-operative examination of the rumen and reticulum are facilitated by using the spleen as an “off-set pad” to better visualize their wall features.

Abomasum: High quality images are readily obtained from the abomasum using a left flank approach without the necessity of “off-set” techniques. The addition of large volumes of physiological saline to the abdominal cavity further improves the diagnostic image quality.

Comparison of IOUS techniques with examination of post-mortem specimens in a water bath environment may be used to confirm the accuracy and reliability of the intra-operative methodology.

Summary
Sonographic experience is required to acquire good images in both transcutaneous and intra-operative techniques but the learning curve is not too steep. Laparoscopic ultrasound is more complicated because it requires some facility with minimal invasive techniques and technology both of which requires more time to learn than the other two methods. The equipment for intra-operative procedures may be already available in many practices but few practices have laparoscopic ultrasound probes and purchase prices are relatively high. It is possible however to use much of the equipment required for arthroscopy for laparoscopic procedures. We recommend a microconvex ultrasound probe for intra-operative procedures.

The majority of the forestomachs plus the body and right lobe of the pancreas are available using the intra-operative approach. It is also noteworthy that the intra-operative approach always provides further information as to the condition of other structures within the abdomen which may be noted to be normal or abnormal (both of which are important to recognize). The significance of ultrasonically visible changes found in the pancreas has not yet been established relative to
bovine clinical disease. While these techniques are applicable to virtually all cows, we are currently recommending them for individual valuable animals which require further workup to improve diagnostic, therapeutic and prognostic information. For such animals these procedures are informative, readily performed and may help to reduce extensive, time consuming laboratory investigations.

References


FLAP RECONSTRUCTION OF LARGE SKIN DEFECTS IN DOGS AND CATS

Professor D. REMY
Ecole Nationale Vétérinaire de Lyon France

Large skin defects in dogs and cats are frequent in veterinary traumatology or following tumor resection. Second intention healing is long and does not always make it possible to obtain a satisfactory result (excessive scarring, contracture). Skin flaps make it possible to avoid most of these problems and are very useful to protect and “cover” important tissue such as bone, joint, ligaments, vessels, nerves and tendons exposed by the wound. Skin flaps do not require the need for a vascular bed contrary to skin grafts.

Skin flaps (also called skin pedicle flaps) are “tongues” of epidermis and dermis that are partially detached from donor sites and used to cover defects. They can be classified in various ways based on location and blood supply. Flaps created adjacent to the defect are local flaps. Those created at a distance from the defect are distant flaps and usually require multiple stage reconstruction. As for blood supply, most flaps, constructed in loose elastic skin without any anatomic reference to a cutaneous vessel, are called subdermal plexus flaps (circulation is derived from the subdermal plexus alone). Axial pattern flaps (figure 1) incorporate a direct cutaneous artery and vein (the terminal branches of which supply blood to the subdermal plexus) into their base and, as a result, have better perfusion compared with subdermal plexus flaps.

Island flaps (figure 2) can be developed from axial pattern flaps by dividing the cutaneous pedicle but preserving the direct cutaneous vessels (with some surrounding subcutaneous tissue) entering the newly created “skin island”.

Our lecture will focus on axial pattern flaps (and island flaps), which are most useful in the treatment of large skin defects in dogs and cats. We shall also shortly describe distant flaps.

Axial pattern flaps (and island flaps)
Experimental studies and clinical trials have demonstrated that large axial pattern flaps can be safely elevated and transferred in a single stage for closure of major cutaneous defects within their general radius. They are usually rectangular or L-shaped flaps. They are most commonly used to close wounds following tumor resection or trauma. They do not require postoperative immobilization.

Complications include wound drainage, partial dehiscence, distal flap necrosis, infections and seroma formation. Flap survival is nevertheless approximately twice the survival rate of subdermal plexus flaps of comparable size.

Several axial pattern flaps have been formally researched and designed for clinical use in the dog, based on the following direct cutaneous arteries: the omocervical artery, thoracodorsal artery, superficial brachial artery, caudal superficial epigastric artery, cranial superficial epigastric artery, deep circumflex iliac artery, genicular artery, caudal auricular artery and lateral caudal (tail) artery. Although similar flaps can be created in cats, only the thoracodorsal and caudal superficial epigastric axial pattern flaps have been evaluated. These two flaps have the greatest clinical use in both dogs and cats. The thoracodorsal axial pattern flap is illustrated in figure 3 and the caudal superficial epigastric axial pattern flap in figure 4.

It is absolutely necessary to perfectly know the anatomy of the direct cutaneous vessels as well as their anatomic landmarks in order to carry out successful surgery. Axial pattern flap development and transfer also require careful planning. Measuring and drawing the flap on the patient’s skin prior to surgery minimizes errors. Great care must be taken to avoid injury to the direct cutaneous vessels during surgery.

![Diagram showing the thoracodorsal axial pattern flap](image)

**Figure 3: The thoracodorsal axial pattern flap (first described by PAVLETIC)**

- **a:** thoracodorsal vessels, cranial and caudal borders of the flap
- **b1:** standard rectangular (“peninsular”) configuration of the flap
- **b2:** L (“hockey-stick”) configuration of the flap
- **c:** elevation of the flap which can subsequently be pivoted into a variety of defects (arrows)
The borders of the flap are: a midline abdominal incision beginning just behind the last mammary teat and a lateral incision parallel to the medial one, at an equal distance from the mammary teats. In male dogs, the midline incision must incorporate the base of the prepuce to preserve the epigastric vasculature. The length of the flap depends on the wound to be treated. The flap can extend cranially to a line between glands one and two. Because mammary tissue is functional in its new location, ovariohysterectomy is recommended. The caudal superficial epigastric axial pattern flap is used for closure of major skin defects of the caudal abdomen, flank, inguinal area, prepuce, perineum, thigh, and rear limbs.

A variation of the axial pattern flap, the reverse saphenous flap, has clinical application for wounds involving the tarsal and metatarsal areas of the dog. This flap is based over the saphenous artery and medial saphenous vein, which supply small direct cutaneous vessels to the overlying skin. Upon division from the femoral artery and vein, circulation flows in reverse fashion through the saphenous vessels via anastomoses with collateral vascular tributaries.

Axial pattern flaps can be modified to create island (arterial) flaps, which have considerable mobility tethered to the direct cutaneous vessels and which also have the potential for use as free flap for transfer and microvascular anastomosis. Nevertheless their routine clinical use is unnecessary. One exception involves large skin defects that encroach on the origin of a direct cutaneous artery and vein. Under these circumstances, the base of the flap shares a common border with the wound and it is possible to rotate the island flap 180 degrees (maximum) over the defect. As for their use as free flaps, it is restricted to the largest academic institutions because of the surgical training, skill, equipment and cost associated with microvascular surgery. Fortunately, most wounds can be treated more easily.

**Distant flaps**

Distant flaps are constructed at a distant location from a skin defect and are used almost exclusively for wounds that involve the lower extremities. The skin of the lateral thorax and abdomen are the most frequently used donor sites. Distant flaps are subdivided into direct flaps and indirect flaps depending on the method used to transfer the distant flap to the recipient bed. In the case of direct flaps the affected limb is immobilized against the chest or abdomen for an extended period of time. In the case of indirect flaps, the distant flap is tubed and, after a delay procedure, is “walked” to the recipient site. The use of
distant flaps require multistaged surgical procedures, is time-consuming and expensive. These techniques were originally developed in human patients and subsequently modified for use in the dog and cat. The axial pattern flaps, above described, have largely replaced the need for distant flaps. Yet there are occasional cases in which these procedures can be used effectively.

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While optimum bone reconstruction and stable reduction remain of paramount importance with fractures at or near a joint, shaft fractures can tolerate fragment displacement provided that the long axis and the alignment of the bone has been restored. In the 1970s and 1980s, precise apposition, under mechanical conditions was the goal, even in diaphyseal fractures. But nowadays one is more prepared to accept the displacement of fragments and a slight loss of stability in favour of an optimum biological response. The aim is to minimize derangement of fracture healing. Therefore, the bone is exposed just sufficiently to allow assessment of the fragment position and realignment while, at the same time, sparing soft tissue structures. Axial or interfragmentary compression is omitted and the damaged bone is repositioned so that its long axis is correct. Fractures and bone are then supported with a bridging plate, an internal or external fixator and/or an intramedullary nail. Direct primary union is no longer the aim. Consolidation occurs by indirect secondary union; callus forms rapidly around a well vascularized bone, which soon stabilizes making cancellous bone grafting unnecessary.

The decision in favour of the biological treatment regime was taken on the basis of the results of a number of follow-up studies of plated fractures which looked good on radiographs, but which were frequently shown to have long-lasting impairment of vascularization after accurate reduction of the fracture. Fragments are denuded when they are forced into a precise reduction and they lose vitality, which in the end slows healing and lowers the bone’s resistance to infection. Stabilization may fail if implants become fatigued under high bending load and break as a consequence of retarded fracture healing. Using stronger implants does not solve these problems but rather promotes the development of intra-cortical osteoporosis, which in turn weakens the bone and predisposes it to refracture after implant removal.

Local bone loss has long been interpreted as a biomechanical phenomenon. It is now known that it is based not only on the diversion of force flow through the implant, but also on interference with intracortical circulation. Healing of the vessels involves an osteoclastic expansion of the bone canals. In addition to this first biological remodelling, a second subsequent remodelling process associated with weakening of the bone occurs, if the plate is very rigid. This is a biomechanical situation (stress protection). Implants should therefore have as small a contact area as possible and rigidity suitable for their purpose.

Alignment: Biological fracture repair does not entail any new principles. It is in line with the strategy of every experienced surgeon, who is able to balance the disadvantages of a surgical intervention against the advantages of bone reconstruction.

With the aim of putting as little stress as possible on fracture healing, the fragments are not exactly replaced, but are only reduced indirectly with distraction of the main fragments by muscle tension. The use of a fracture distractor may facilitate restoration of normal bone length. Intramedullary pins can also be used to distract fractures. The pin is introduced into the proximal fragment by the normograde route and is then driven distally across the fracture lines until it engages metaphyseal bone. While the proximal fragment is steadied with bone-holding forceps, the pin is advanced distally until appropriate distraction is achieved.

The fracture zone remains untouched in the soft tissue envelope. Alignment can only be correspondingly oriented by peripheral structures; for this, a sound anatomical expertise and excellent three-dimensional perception are prerequisites. The most frequent problems are due to incorrect rotational alignment achieved during reduction. The limb must therefore be correctly positioned and an adequate approach has to be used to visualize the fracture ends and assess the axis of the bone closest to the joints.
Fixation techniques

Fixation is limited to splinting the bone. Compression of the fragments is not mandatory. The main fragments are stabilized by a buttress plate, the Clamp Rod Internal Fixator (CRIF), an intramedullary nail and/or an external skeletal fixation device.

**Buttress plate**

Close to the fracture, as few screws as possible are placed. Larger fragments are only brought into the repair site by means of lag screws in those cases, where this can be done without detaching the bone pieces from surrounding muscles. A long plate, which reaches to the joint, is employed and is attached peripherally to the main fragments using two, or preferably three or four screws. Any screw holes remaining in the middle are not deleterious to the implant construct. They distribute bending forces and allow slight movement in the fracture zone, which is a good stimulus for callus formation. However, the plate must be sufficiently strong, as it has a weight-bearing role until the callus is adequately developed. In cats and small dogs, plates of 2.4 or 2.7 mm screw size have proven successful, while 3.5 mm are good for medium sized dogs, and 4.5 mm plates are used for larger breeds. For very large, heavy dogs, 4.5 lengthening plates, without any screw holes in the middle section, provide the required stability. Whenever it has to be assumed that the available plate might not resist the high stress levels to be expected, a plate/rod combination can be used to bear the load.

In order to minimize perfusion interference of the bone in the plate-bearing position, narrow or special plates with limited bone contact are preferred.

**Clamp Rod Internal Fixator**

The CRIF system is also known as VetFix. It consists of round stainless steel bars, which are contoured and screwed to the bone using special clamps that are slid on to the rod to any desired position. By tightening the screws, the clamps become compressed fixing them firmly to the bar and the system to the bone. Clamp sizes fit for 2.0, 2.7, 3.5 and 4.5/5.5 mm standard conventional bone screws and rod diameters vary between 2, 3, 5 and 8 mm. As a simplified version of similar systems from human spine surgery, the CRIF offers a variability of length comparable to cuttable veterinary plates and also to reconstruction plates. By contrast with the other systems the superior stiffness characteristics of the CRIF even ensure good support of comminuted long bone fractures. The CRIF system offers outstanding contouring properties which makes it suitable for curved bone. Beyond that, it does not need to be adapted perfectly to the bone as the clamps, which can be diverted freely, may compensate insufficient contouring. This property permits minimal invasive fracture treatment of the long bones via short incisions at the proximal and distal ends. The reduced contact area, limited to the clamp surfaces only, enables the maintenance of good blood supply to the periosteum which makes this implant superior to conventional bone plates.

**Interlocking nail**

As an alternative to plate or CRIF reconstruction, the medullary cavity may be splinted by a pin. Here, the biological principle is maintained by not reaming the medullary cavity and using a small diameter pin. Interlocking nails prevent rotation, changes in the axis and bone shortening. Callus formation is more pronounced than after plate fixation.

In this procedure if open reduction is entailed the fragments must also be left in the envelope of soft tissue. The pin is usually locked distally with two transverse screws and proximally by one screw placed transversely or obliquely. For dynamization the locking screw is removed on one side.

When Steinmann pins are used, support and rotational stability can be achieved by combination with an external skeletal fixator. For this a threaded Kirschner wire is placed peripherally in each main fragment and then fastened to a connecting bar with clamps. Dynamization is produced by removing the external fixation device before the fracture callus has consolidated to bone.

**External skeletal fixation**

Multiple fragments fractures, distal to the elbow and stifle joints, are also suitable for external skeletal
fixation. External fixators may also be used for segment displacement when dealing with major bone deficits. In this technique, the bone is transected at a distance from the defect and the callus forming at this place is distracted until the bone ends make contact.

**Callus distraction**

By callus distraction, with only one operation bone shortenings and large deficits can be remedied. Unlike conventional techniques which sometimes require multiple bone transplantations. The rate of distraction is crucial and must not exceed 1 mm per day. It should be continuous (0.017 mm/24 min) or distributed over four extensions of 0.25 mm each. In order to conserve the medullary vasculature a corticotomy is performed; although an intact nutrient artery is not an absolute prerequisite for the development of distraction callus regenerate.

In all procedures it is mandatory that exposed tissues should be protected against drying out during the operation and from thermal bone damage during drilling, which is preempted by irrigation. The surgeon must not succumb to the temptation for that of perfect reconstruction, even when suturing tissues. Multiple fragment fractures are predisposed to a compartment syndrome and hence only layers which can be adapted without tension may be closed.

After biological osteosynthesis a structure which is heterogenous to x-rays persists. Even years later, fragments enclosed in callus remain radiographically opaque. They are less important for the stability of the fracture than is the callus, the latter having a lower degree of mineralization. This phenomenon does not detract from function of the local structure.

In conclusion, it should be emphasized, that the quality of an osteosynthesis, even those employing biological techniques, cannot be assessed by radiography alone. Bone vascularity, which is crucial for the progress of healing, cannot be seen on conventional radiographs.
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SOME FACTORS ASSOCIATED WITH FOOT SHAPE AND LAMENESS IN DAIRY CATTLE

R. D. Murray

University of Liverpool Veterinary Teaching Hospital, Leahurst, NESTON, Wirral, UK. CH64 7TE

Abstract

Several factors affect foot shape in dairy cattle. Factors related to the cow itself may include genetic control of horn growth, season and endocrine changes around the time of calving. Other factors are associated with interactions between the cow and her environment such as horn growth rates relative to wear, nutrition, and the effects of poor cow comfort through prolonging standing times. Some factors may be imposed on the cow, such as poor claw trimming. These risk factors will be discussed in the context of minimising their effects and promoting better welfare in dairy cattle.

Introduction

Lameness in dairy cattle is an important cause of economic loss to dairy farmers worldwide and poor welfare for affected cattle (Broom 1988). In the United Kingdom the annual cost to the national dairy herd is approximately £83 million (€120 million); the equivalent loss in the Netherlands is around £24 million (€35 million) (Enting et al., 1997). In dairy herds farmed in Middle Eastern countries the economic losses and welfare issues associated with cattle lameness have not been reported.

The issue of poor welfare for lame cows transcends geographical boundaries. Lame cows lie down for longer (Singh et al., 1993), do not show normal oestrus behaviour, and have more rapid bite rates but lower dry matter intakes (Hassall et al., 1993). The overall effect is for them to lose excessive body condition score that contributes further to the adverse economic impact of lameness, for example by increasing the culling rate (Mgasa et al., 1990).

Poor foot shape is an important risk factor for lameness and some of the causes of this are discussed below (Ral 1990).

Risk factors associated with poor foot shape

These may be subdivided into independent variables related only to the cow herself such as genetic traits, and variables interacting with the cow such as its environment and nutrition. Finally, other factors may be superimposed on the cow unnecessarily such as poor foot trimming.

Individual cow factors

Genetics related to horn growth

Parturition

Factors interacting with the cow

Nutrition

Environment

Factors superimposed on the cow

Claw trimming

Lack of training in claw trimming skills

In the UK, only 3.4% of its 14,000 dairy farms employ stockpersons trained adequately in the skill of cattle claw trimming. It is the opinion of many stockpersons untrained in this skill that they are competent trimmers because they can return an overgrown hind claw to a more normal foot shape; this is reflected in Table .
**Table.** Proportion of 320 cows with normal and abnormal hind claw foot shape 30 days before and after routine trimming on 14 large Cheshire dairy herds.

<table>
<thead>
<tr>
<th>Variable describing footshape</th>
<th>Percentage of cows</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30 days before trimming</td>
</tr>
<tr>
<td>Axial wall deviation: none severe</td>
<td>88</td>
</tr>
<tr>
<td>Heel height: low/medium high</td>
<td>78</td>
</tr>
<tr>
<td>Toe length: correct length excessively long</td>
<td>83</td>
</tr>
</tbody>
</table>

However, a proper functional trim should not only restore normal shape to an abnormal claw but also improve the cow’s locomotion; this is functional claw trimming. Table shows that this objective is seldom achieved. In fact, in this study a significantly greater proportion of cows had worse locomotion after routine claw trimming than before. There is a major welfare issue here. It is unacceptable that UK dairy farmers refuse to employ paraprofessional claw trimmers on a regular basis because of the cost implications. Instead, they try to carry out the task themselves at no cost, other than for time, and in so doing create poorer welfare for the cows whose feet they trim. The same is probably true in other countries where dairy cattle are farmed and managed intensively.

**Table.** Proportion of 542 cows walking normally (score 1 or 2) or lame (score >3) 30 days before and after routine trimming on 14 large Cheshire dairy herds.

<table>
<thead>
<tr>
<th>Variable describing locomotion</th>
<th>Percentage of cows</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30 days before trimming</td>
</tr>
<tr>
<td>Locomotion score: 1 or 2</td>
<td>68</td>
</tr>
<tr>
<td>&gt;3</td>
<td>31</td>
</tr>
</tbody>
</table>

**Improper use of power tools**

Kloosterman (1997) has described the motorised tools used commonly to trim the claws of cattle. He states clearly that their use is extremely dangerous if used by inexperienced operators. Horn, especially at the toe and sole, is removed so rapidly that the corium is easily exposed in a short period of time. Furthermore, if sanding discs are used they generate large amounts of heat and this causes necrosis of underlying soft tissues.
References


BOVINE LAMINITIS

Christian STANEK

Univ.Prof. Dr., University of Veterinary Medicine Vienna, Veterinaerplatz 1A 1210 Wien, christian.stanek@vuwien.ac.at

Laminitis (Pododermatitis aseptica diffusa) is one of the most important metabolic disorders in cattle and one of the large problems in high yielding dairy cows. Basically it is a disease with disturbances of the microcirculation and following reactive inflammation and degenerations at the level of keratinocytes with a multifactorial cause, inducing severe disturbances of the bovine claw horn production. According to the clinical symptomatology, an acute, a subacute a chronic and a subclinical form is differentiated. The acute and the subacute form exhibit a disturbed general condition with severe to low grade locomotor disturbances. In the chronic form, one can find typical morphological changes of the claws, with the recurrence of a number of acute relapses. The subclinical laminitis is characterized by a bad quality of the claw horn, hemorrhages in the claw region and by an increasing number of complicating diseases of the claws, whilst general symptoms cannot be found.

Despite the importance of the disease a model for experimental induction of the bovine laminitis could not be established for studies of etiology and pathogenesis, comparable to the starch model in the horse. The role of various defined factors could not be established until now.

Occurrence, etiology and pathogenesis

The frequency of the various types of laminitis differs. The acute and subacute form is occurring sporadically, mainly single adult animals are affected, with primiparous cows as the main group of risk. As etiologic factors massive failures of the feeding regime and quality, like overfeeding of cows in a maize field, intoxications, partially following a retention secundinarium. Overall, acute laminits after retentio oder puerperal diseases is followed by laminitis only in a restricted number.

The subacute laminitis is diagnosed not only in dairy cattle, but also in fattening bulls with troubles in the feeding regime (To high energy ration or to high protein content, mykotoxin intoxication). Laminits is also observed in older calves with high protein intake (SVENSSON and BERGSTEN, 1997). Judging the percentage of severely deformed claws, a large percentage of old high yielding dairy cows suffers from chronic laminitis. The development of the severe deformation of the claws in chronic laminitis often inapparent. In Jersey cows, a hereditary form of laminitis was decribed, affecting mainly animals up to 2 years. The disease is developing without any obvious reasons, a severe deformation of the horny capsule with a massive atrophy of the pedal bone is prominent. Independent from this defined disease, genetical factors for the occurrence of laminitis are evident. An overview of the large number of various factors is given by VERMUNT and GREENOUGH (1995).

The etiology of bovine laminitis is not clear in several points, several experimental results are contradictory. A central point of the acute and the subacute laminitis is the disturbance of the ruminal digestion. Following an overwhelming uptake of easily digestable carbohydrates/proteins, a decrease of the ruminal pH leads to a pathological change of the ruminal bacterial flora, associated with an increase of Streptococci, Lactobacilli and lactic acid. Predisposing factors are ketosis, acetonemia, hepatic steatosis and dystrophy and abomasal displacement. Due to the ruminal acidosis, endotoxins are released out of gramnegativ bacteria and resorped through the damaged wall of the rumen. Detoxification in the disturbed liver is impaired. In contrast to this theory, neither the experimental intraruminal application of endotoxins nor the intravasal application of histamin was effective in inducing acute laminitis. As primary disease, also parenchymatous mastitis, eg by E. coli, plays an important role. In contrast, endometritis is of minor importance.

As nutritional failures, the insufficient supply with crude structurized roughhage, inducing salivation and increased ruminal buffering capacity, must be mentioned. Also with enough roughhage, an
overdosage of concentrate can induce laminitis, especially if this concentrate is fed in few large portions. Excessive uptake of raw protein must be mentioned as well in combination with reduced crude fibre content, either due to concentrate feeding or pasturing on intensive green. An overdosage of nitrogen on pasture can induce laminitis in a high percentage of the grazing animals.

Despite other predisposing factors, a high level of protein supply is proven regularly in calves with laminitis. It is remarkable, that younger calves with a lot of gastrointestinal problems rarely suffer from laminitis. A certain role of biochemical factors is evident, but it is difficult to define, whether these are predisposing conditions or factors inducing laminitis directly. Here should be mentioned: high daily weight gain in heifers and fattening bulls, soft claw horn, hard concrete floors, marches on stony roads, long transport on trucks, if this can be differentiated from gastrointestinal affections on long transports. Furthermore problems after excessive claw trimming, introduction of animals on slatted floor systems. On hard floors, an increasing number of hemorrhages of the solear area can be found (BERGSTEN, 1994).

Also social factors play an important role, especially in heifers introduced to a large herd. Overcrowding in a stable induces a higher frequency of pathological changes in the claws (LEONARD et al., 1996). In housed cows, the lying time is reduced compared with animals kept on pasture. Animals with restricted lying time had a higher frequency and severity of hemorrhages (SINGH et al., 1993). As risk factors for heifers, in addition to social conflicts also reduced time for food uptake and the existing pregnancy are important. Among various breeds predisposition for laminitis is different, with HF being more susceptible than RHF, Simmenthal or Jersey (BERGSTEN, 1994).

From a variety of pathological conditions, the sinking of the pedal bone is of greater importance than the pedal bone rotation, the sole is thin and flattened, the white line widened and of poor horn quality, leading to local infections. Hemorrhages of different extent can be found on the sole and in the white line. The laminitic claw shows a concave dorsal wall and v-shaped grooves diverging in dorsoplantar direction. The surface of the claw has an appearance like the bark of a tree, the hairs in the coronary region show an irregular pattern. After post mortem exungulation, edema formation and necrosis of the pododerm are visible. In many cases, a remarkable difference between both claws of one limb is evident. It remains unclear, whether this is caused by biomechanical factors like overloading.

From the histopathological point, the laminae choriales and the epidermal structures of the wall are involved both, the pododerm of the sole is involved in second place. In the subcoronary region, vessels of the corium are involved with opening of arteriovenous shunts, inducing a speed reduction of the blood capillary flow. Another factor is the primary disturbance at the basal membrane. The vascular changes induce a local hypoxia, a damage of the vascular wall and a local compartment syndrome in the restricted space between the pedal bone and the rigid horny capsule. The role of the epidermal growth factor in this cascade of disturbance of horn production needs further evaluation. The infiltration by inflammatory cells is a second, a reactive step.

Clinical symptomatology

Animals with acute laminitis offer a typical clinical picture: bilateral lameness of medium to severe grade, mainly all four limbs, less frequently only hind limbs are involved. Unilateral laminitis caused by overloading of one limb is rare. Animals are lying prolonged time, remain kneeling on the carpal joints whilst getting up, fall nearly whilst getting down. In severe cases the cow is lying on her side. In standing position weight shifting is obvious. In contrast to the horse, cattle do not prefer the position with their back legs standing under the abdomen. On examination of the limbs, a slight edema formation is visible up to the fetlock joint, sometimes an extension of the superficial veins, the hairs in the coronary region stand like a bristle, on palpation of the coronary region the examining person gets the feeling to palpate behind the horny capsule, an indication of the pedal bone depression. Another important clinical sign is the increased pulsation of the main artery on front and hind limbs.

One important symptom is the pain in the claw, which can be provoked also in the weight bearing limb through percussion using a hoof tester. Lifting of one extremity is difficult. The subacute form shows a reduced clinical symptomatology, the animals lay down prolonged time and avoid rising. The beginn of the disease is not clearly defined. Morphological changes at the claws are missing.
Summarizing all cases lasting longer than 10 days as subacute laminitis does not seem justified.

Cases of chronic laminitis show a mild to medium lameness, the general condition is impaired. Raising is troublesome for the animal, claws show an increase of temperature, the wall of the main artery is thickened. Morphological changes of the claw are dominating. Claws are wide, with a flat and thin sole, a wax-like appearance of the sole horn, a concave dorsal contour, rims divergent toward the bulb, widened white line.

In cases of subclinical laminitis, one can find solear hemorrhages, a poor hoof horn quality, an irregular horn structure. The disease is linked to a high percentage of complications, like sole ulcers or white line infections. Not every solear hemorrhage indicates laminitis. The general condition of the cows is not impaired, the form of the claw is within the physiological range in many cases.

**Differential diagnosis**

Acute or subacute laminitis sometimes is found associated with displaced abomasum, lipomobilisation syndrome, ketosis and/or keturia, endometritis or traumatic reticuloperitonitis. In chronic laminitis, complications like sole ulcers are dominating. The internal diseases mentioned above should be considered as differential diagnosis (LISCHER et al., 1994). Lameness in laminitis cases should not be misinterpreted as ataxia.

**Therapy**

Therapy of acute laminitis is an urgent task. Especially in the peripartal phase, locomotor problems are referred to problems caused by the parturition and not by the pain in the digital area. Despite the enormous economical importance, few relevant data on the optimal therapy are available. In Europe, also the logistical situation plays an important role. Therapy is depending on the primary disease. In cases of ruminal acidosis, changes of the nutritional regime, transfer of ruminal content, antiacidotical infusions, antibiotics in cases of retained plazenta or mastitis. In early cases antihistaminic therapy is recommended. The use of heparin was not advantageous in the horse in spontaneous cases. No proven evidence on the use of corticosteroids is available, in horses their use is contraindicated as corticosteroids increase the sensitivity of precapillar sphincters against neurotransmitters. Anecdotal, the successful therapeutic use of blood withdrawal connected with volume substitution is reported, even if contradictory to histological results. Pain therapy is an important part. Phenylbutazone is preferable to Flunixin meglumine. Phenylbutazon 4 - 10 mg/ kg KM IM, IV or per os; Half life period 36 to 72 hrs. Flunixin meglumine in a dosage of 1.1 to 2.2 mg/kg BM IM or IV. Supporting help can be found in the use of cold foot bates inducing an anti-pain effect, an increased blood flow is achieved through reflectory vasodilation after the end of the cold application.

In experimental studies, in HF cows an improved claw condition was found after nutritional application of 20 mg Biotin /day (SCHMID, 1995). The painful contact with the ground is relieved through soft bedding or through soft bandages using polystyrol. Applying a wooden or rubber block with methyl-methacrylat in laminitic claws can be desastrous, if the claw where the block is fixed, has a hidden problem. The gait is impaired immediately; solear necrosis or subungular pus formation can be provoked.

The most important therapeutic step is the repeated claw trimming performed by an educated claw trimmer (HUBER et al, 2004). This person has to remind that the claw trimming is carried out in diseased claws. It is easy to perforate the horn sole in the area towards the tip of the sole in cases with a sunken pedal bone. Claw trimming is also important in the prophylaxis of acute laminitis.

**Feeding guidelines for reduction of laminitis** (SHAVER, 1997)

Avoid sudden changes of the feeding regime; slowly increase the concentrate amount in the last 2 – 3 wks prior to parturition. Postpartal slow (6 wks) rise of concentrate, high quality ratio with low mykotoxin content of the concentrate and the silage. A mixed ratio with a defined concentrate – roughhage correlation offered throughout the day is preferable. The composition must be adapted to the milk yield. In small herds transponder controlled feeding regime. Concentrate not above 4kg/one session. 27 – 30% not digestible crude fiber, with a minimum of 18 – 21 % neutral detergent fibre NDF in roughhage, roughhage not below 40 – 45%, a minimum of 25% of crude strucuted roughhage; the role of
the protein content in the ratio remains open, an increase from 16% to 20% induced a significant increase of lameness cases (Manson u. Leaver, 1988). The additional supply with Methionine analogues induced no positive effect with respect to claw health. Supplementary supply with 0, 75 to 1% of Sodium-bicarbonate /DM.
References


The diagnosis and treatment of joint disorders are becoming increasingly more important in the practice of veterinary orthopaedics. Traditionally arthrotomy has been the most useful tool for joint exploration, however whilst effective arthrotomy has significant disadvantages. Arthrotomy requires a large incision, with the attendant risks of infection, damage to underlying articular and periarticular structures, tissue drying, blood loss and joint instability. Arthrotomy is also time-consuming and creates a limited but appreciable amount of synovitis and consequently, degenerative joint disease. Finally, recovery from arthrotomy can be a prolonged process that further limits recovery of joint function and the animal’s return to normal activity.

Endoscopic assisted joint surgery has been the standard in human orthopedics and equine orthopedics for the past two decades. Excellent visualization, minimal joint trauma, decreased operative time, and lower patient morbidity are all cited as positive aspects of arthroscopy. As with any surgical procedure significant skill is required to master the process and achieve positive outcomes. Arthroscopy has been described as the most difficult of endoscopic surgeries, because the intra-articular space is small and the instrumentation delicate and easily damaged. Even very experienced surgeons may find the learning curve steep, although through practice (cadavers) and the understanding and selection of arthroscopy equipment, proficiency can be achieved. The understanding of many poorly understood joint pathologies has been revolutionized by the information now available to the orthopaedic surgeon by use of arthroscopy and the understanding of progression of disease by the use of “second look” arthroscopy.

**Equipment**

Of primary importance is the quality of the optical system. The optical system encompasses the arthroscope, light source, and camera. To aid visualisation a constant flow of appropriate fluid is maintained throughout the procedure. Fluid flow requires establishment and maintenance of ingress and egress (inflow/outflow) portals and the administration of fluid by gravity or with a fluid pump system. Finally, successful surgical intervention requires small, high quality hand instruments and on occasion, special motorized instrumentation or electrothermal units.

An arthroscope is made of an outer series of high quality fiberoptics for light transmission; it illuminates the joint and then transfers the image by a series of lenses to an eyepiece or camera. They are commonly described by three measurements: diameter, lens angle, and working length. The arthroscope diameter is the outer diameter of the tubular portion of the arthroscope without the accompanying cannula. Arthroscope diameters commonly employed in canine arthroscopy include 1.9mm, 2.3 mm, and 2.7 mm.

The advantage of smaller arthroscopes in canine joints is the minimisation of joint trauma and greater mobility in joints such as the elbow and tarsus. The disadvantage of the small arthroscopes (in particular the 1.9mm arthroscope) is their fragility and ease with which they can be damaged. The smaller diameter arthroscopes also have a smaller field of view. Larger diameter arthroscopes on the other hand have increased durability because of their resistance to bending and a larger field of view. However, the advantages of a larger arthroscope must be weighed against the risk of increased joint trauma in small canine joints.

Lens angle refers to the angle between the long axis of the telescope and the center of the viewing range.
angles commonly used in arthroscopy are 0°, 30°, and 70°. The 30° fore-oblique arthroscope, the instrument most commonly used in canine arthroscopy, allows a wide field of view simply by rotating the Arthroscope on its longitudinal axis; thus, a combination of axial rotation and angular movement of the arthroscope allows a large percentage of the joint to be examined through a single portal.

Working length refers to the overall length of the arthroscope and is usually designated as short or long. Both short (8.5cms) and long (13cms) arthroscopes have applications in small animal orthopedics. Short arthroscopes have the advantage of ease of handling in smaller joints such as the elbow and these scopes may be less susceptible to damage from bending. Longer arthroscopes have the advantage of increased depth of focus compared to the same diameter “short” arthroscope. In general, arthroscopy of the shoulder is performed with a 2.7mm arthroscope, arthroscopy of the elbow with a 1.9 mm or a 2.3mm arthroscope, and arthroscopy of the stifle with a 2.7mm “long” arthroscope.

The external part of the scope ends in an eyepiece but has an attachment for a fibreoptic light cable and a locking system to secure it within a metal cannula. The arthroscope is inserted into the joint through a cannula or
steel sheath that serves multiple functions. The cannula diameter is slightly larger than the arthroscope, permitting fluid enter the joint by flowing down the space between the telescope and the cannula. The open end of the cannula is beveled to the angle of the arthroscope. The external end has an interlock mechanism for connecting to the arthroscope and tap mechanism for attachment of a fluid line. The cannula and arthroscope interlocks must be compatible and the length and diameter of the cannula must be appropriate for the arthroscope as well. Because cannulas are specifically designed for their accompanying arthroscope there are few options in their selection; however, manufacturers have cannula diameter variations that affect ingress fluid flow. A “high flow” cannula or sheath is available from some manufacturers for smaller diameter arthroscopes. The cannula is introduced into the joint space using a stylet (blunt, conical, and trocar tipped) once placed the stylet is replaced by the telescope. The conical tipped stylet is preferred, as both the stylet and cannula diameter are influential in determining the degree of joint trauma during insertion.

The image from the arthroscope is projected onto a monitor by means of a digital camera system. The camera system is comprised of a control unit and a camera head. The head includes the digital chip lens head that clips onto the eyepiece of the arthroscope and connected to the control box by means of a cable. The camera head contains a chip that converts the image to a digital signal. Most cameras contain either one or three digital conversion chips. Three chip cameras give greater resolution than do single chip cameras. Costs on camera systems (head and control box) vary primarily based on the number of digital chips and functions. Simple one-chip cameras and boxes begin at approximately $10,000.00 list price while more expensive units may cost close to $30,000.00.

The final arthroscopic image is visualized on a standard colour monitor. These monitors may be purchased independently or in combination with an entire arthroscopy package. Monitors for arthroscopy should have a high horizontal resolution of at least 450 lines and tube size should be 33cm or larger. Most monitors will have S-VHS sockets which enable higher quality video recording. New medical grade monitors list for two to four thousand dollars each. Image recording can be achieved by video tape recording, digital still image capture, and colour printing.
Illumination within the joint is provided by a light source. Tungsten, halogen or xenon bulbs are usually housed within a light box and the light is carried to the scope by means of a fiberoptic cable. Care should be used in handling this cable as the fibres are easily damaged resulting in “blind spots”. Most new light sources use xenon bulbs, as they provide a brighter and whiter light, ensuring higher visual clarity and colour rendition. This clarity and colour definition come at a higher price but is generally recommended for superior image quality.

The intensity of the light may be controlled manually or by an automatic feedback system to maintain appropriate image intensity throughout an arthroscopic procedure. Lamp wattage may vary from 175 to 400 depending on the manufacturer and lamps may last up to a year or more depending on usage. Newer units may provide lamp hour displays and it is important to have spare lamps on hand in case of burn out during a procedure. Light sources vary in price from $5000.00 to close to $10,000.00. The fiberoptic cable will also heat up significantly and should never be placed directly against the patient as it may cause burning.

Optimal visualization is enhanced by joint distension and flushing of the joint with a constant flow of fluid. Distension of the joint is necessary to observe the interior of the joint without interference from the synovium. Ingress and egress (inflow/outflow) portals are established and maintained throughout surgery. Lactated Ringer’s solution is considered by many to be the fluid of choice for joint irrigation, although no adverse effects have been seen with the use of normal saline. The administration of fluid is assisted by gravity or by a fluid pump system. Gravity flow refers to administration of fluid directly from the fluid bag to the cannula with a simple administration set. The diameter of the administration set will influence fluid flow rate and large diameter tubing for arthroscopy is available. Rate of fluid flow may also be increased by placing the fluid bag in a pressure bag. Advantages of gravity flow include the relative simplicity of the system, low costs, and safety against over pressurization. Disadvantages include poorer control of pressure, relatively lower maximum pressures, and the inability to maintain high fluid pressures and flow over longer surgical procedures. Advantages of fluid pumps include precise control over inflow rate, inflow pressure, and in some cases outflow rate. Fluid pumps permit selection of both fluid flow rate and fluid pressure rate. Most are pressure priority meaning that the selected pressure in the joint will be maintained and
when the pressure drops below this level the fluid will be pumped in at the selected flow rate. Fluid pumps are superior to gravity at maintaining pressure when suction or shaver systems are in use. The use of gas (carbon dioxide or nitrous oxide) to distend the joint is not used as it requires special equipment, periarticular emphysema can result, and intra-articular haemorrhage can obscure the operative field.

Small portable arthroscope and monitor  
1-egress needle, 2-arthroscope portal, 3- instrument portal, 4-portal for access to biceps tendon

Medial glenohumeral ligament tear  
Cartilage erosion Eburnation
Hand instruments for small joint arthroscopy must combine small diameter with excellent mechanics to provide high accuracy and reliability while minimizing iatrogenic trauma and instrument failure. Basic recommended arthroscopic hand tools include probes, grasping forceps, and biting forceps. Probes are used to palpate surfaces and manipulate tissues within the joint and are usually right angle design with a tip of approximately 3mm in length. In small animal arthroscopy right angle probes are used to palpate articular cartilage for pathology and to manipulate OCD flaps, meniscal injuries, and bone fragments. Grasping forceps are available as locking and non-locking types. Non-locking grasping forceps include standard alligator forceps and those designed specifically for use in arthroscopic procedures. Most grasping forceps designed specifically for arthroscopic use have an enclosed operating mechanism that avoids interference between the mechanism and surrounding tissues. Graspers vary in size and selection depends upon the joint being operated, the specific procedure being performed, and surgeon preference. Arthroscopic graspers tend to be larger than surgical alligator forceps due to the need for larger size for an enclosed mechanism and the fact that most arthroscopic instruments are designed for human use although newer designs of arthroscopic graspers for veterinary and human wrist surgery have outer diameters as narrow as 2mm. The smaller size diameter forceps have distinct advantages in operation of small animal joints; however, it is possible to bend or break these instruments within the joint and the smaller mechanism results in less grasping power. It is therefore recommended that a basic arthroscopic surgery pack include a very narrow alligator forceps and a slightly larger and sturdier arthroscopic grasping forceps. The grasping surface may be with or without teeth and blunted or pointed. For most small animal applications pointed forceps without teeth are recommended. Small diameter curettes, arthroscopy knives, and hand burrs are very useful in small joint arthroscopy for elevation of bone fragments and debridement of cartilage and bone. In most cases a small (5-0) surgical curette will work although the large diameter of shaft will limit its use to portals without a cannula. Smaller diameter (2.5 mm) arthroscopic curettes are available that may fit through larger cannulas. Generally, a straight curette will be easier to insert into the joint and will be adequate for most applications. An angled curette is more difficult to insert through the portal but maybe useful for working at difficult angles.

Power shavers are designed to rapidly debride soft and hard tissues. Power shavers are generally separated into small and large joint instruments.
1-egress needle,  
2-arthroscope portal,  
3- instrument portal  

1 or 3-arthroscope portal,  
1 or 3- instrument portal  
2-egress needle,  

FCP  

Chondromalacia  

Eburnation  

Cruciate ligaments  

Medial meniscal fraying
Shavers are appropriate for small animal elbow, shoulder and knee. Large joint shavers may be used in the canine knee for debridement of the fat pad. Most shavers permit variation of speed and direction including forward, reverse, and oscillation. Speed control is important as debridement of different tissues with different shavers is optimal at different speeds. Shaver tips come in numerous varieties that are designed for either soft tissue or hard tissue debridement. Soft tissue shavers include guarded sharp cutters and aggressive cutters. Sharp cutters have a simple sharp edged cup while aggressive cutters have a toothed cup. The latter is generally more useful for debridement of fat or synovium in small joints. Shaver systems are readily available either new or used. Many manufacturers will supply the hand piece and control box free of charge with a minimum contract for purchase of the shaver tips. The shaver tips can cost from $50.00 to over $100.00 each and although intended for single use is reusable with resterilisation by gas. The shaver tips come as two piece units that should be separated for cleaning.

Electrocautery and radio-frequency are used to generate heat for cauterization of vessels, debridement of tissues, or shrinking of collagen. Electrosurgical tips specifically designed for underwater arthroscopic application are available for use with standard electrosurgery generators. These instruments may be used for cautery of small vessels and special tips are designed for cutting soft tissues. Radiofrequency devices transfer energy by using electromagnetics to produce molecular friction in the intracellular and extracellular environment. Monopolar units generate an alternating current that runs from the tip of the probe to the joint capsule or other surface, through the body, to a grounding plate. Heat is generated in the tissues due to the higher resistance of the tissues. Bipolar units create an arc of energy through the arthroscopic fluid that can be directed through tissues. Radiofrequency probes have only been recently introduced into veterinary arthroscopy and orthopaedics; however, several useful applications have been identified and numerous experimental applications are being considered. In the stifle joint, radio-frequency is used in combination with power shavers to rapidly remove the fat pad to permit evaluation of the joint. The RF probes have also been used to perform partial meniscectomy of torn meniscus and to debride or remove damaged cranial cruciate ligaments. Radiofrequency units are comprised of a control box, connecting able, and tip. Most manufacturers will supply the control box with a contract to purchase a minimum number of tips. Tips cost approximately $100-125.00 each and variations in design include shrink tips versus ablation tips and differences in tip shape, size, and angle. Tips can be resterilised although damage to the insulating cover limit their ability to be reused.

**Basic Arthroscopic Technique**

The basic principles of aseptic surgery are observed during arthroscopy. Steam sterilization is used on all instruments where possible, however the delicate scopes and fibreoptic cables are generally prepared by use of cold chemical preparation (disinfection). Glutaraldehyde solutions are used to decrease microorganism levels to an acceptable point but can not be considered to sterilize this equipment. Some camera systems can be steam sterilized, however others are isolated and draped out by means of specialised sterile plastic sleeves which attach to the arthroscope and seal the eyepiece and camera out of the surgery field. The perioperative administration of antibiotics is controversial as most surgeons believe that this is unwarranted and unnecessary.

General anaesthesia is required for procedures in companion animals. This may be combined with regional anaesthesia such as brachial plexus blocks or the use of per-operative intra-articular analgesia. The patient is clipped and prepared in a similar fashion as for arthrotomy. Supportive care and monitoring such as warmed intravenous fluids, warm water circulating blankets and anaesthetic monitoring equipment should be used as per good operative practice. Positioning of the patient is crucial to a successful surgery, the use of specialized braces, sand bags, vacuum bean bags and ties all help. Once positioned and a final preparation is applied the surgical site is draped, some surgeons prefer a free-drape technique others are happy just to isolate the surgical
The surgeon begins by palpating the regional landmarks of the joint, as these are critical to correct positioning of the portals for the arthroscope and instruments. The difference between successful surgery and failure to gain adequate access is small, a matter of 2-3mm can serious affect the outcome. A 1.5 -2 inch 18-gauge hypodermic needle and a 5-10 ml syringe is used to aspirate some synovial fluid from the joint. This syringe is removed and another containing 10-15mls of lactated ringer’s solution is attached and used to distend the joint. Some surgeons use 0.5% bupivacaine at this stage to achieve some degree of joint analgesia. Theoretically this dose of bupivacaine will cause seizures or even be fatal if given intravenously, however most of this will flow out of the joint once the cannula is placed and the remainder is flushed from the joint during the procedure. Personally I am inclined to place a small dose of 0.5% bupivacaine (up to 1mg/kg) intra-articularly during patient preparation. A second needle is use to locate the portal for the arthroscope, once the needle is felt to “drop” into the joint a number 11 scalpel blade is used to create a stab incision along the line of the needle ensuring that the incision enters the joint. The arthroscopic cannula and conical obturator are coupled and inserted through the joint capsule into the joint space. Once the obturator is removed the fluid that was used to distend the joint rushes out, confirming the intra-articular position of the cannula. The arthroscope is introduced into the cannula and secured in place. The light source and fluid line are attached to the arthroscope and cannula respectively. A fluid flow is established using a pressure of between 50 and 150mm Hg if using a pressurized system. The syringe is disconnected from the original needle and this needle can be used as an egress portal whilst the joint is explored.

When the joint has been systematically explored and any pathological changes are identified, an instrument portal is created by use of the triangulation technique. Triangulation is achieved by passing an 18-gauge needle at an angle such that the tip of the needle intersects with the tip of the arthroscope. Care should be taken to ensure sufficient room between the arthroscope portal and the instrument Portal to allow manipulation of both. Once the needle is correctly positioned a stab incision is created along the line of the needle, visualisation of the tip of the blade ensure the incision has entered the joint. A blunt probe called a switching stick can be placed into the joint and the instrument cannula slipped into position over this stick or alternatively the cannula may be placed with the aid of an obturator or stylet. It is not acceptable just to be able to see the instrument with the scope. The instrument must be oriented at an angle that will permit adequate access and manipulation to accomplish the intended task. Triangulation is a lesson in hand-eye coordination and is quickly learned with practice. Most beginners have difficulty with triangulation due to a tendency to insert the instrument at an angle that is too acute. The instrument crosses above the tip of the scope. The reason for this is the inability to take into account the oblique nature of the lens. When the scope is inserted, the image viewed is actually to the side of the scope. More specifically, the image is to the side of the scope that is opposite the position of the light handle. Triangulation is more difficult in joints covered with heavy muscle such as the shoulder. If difficulty is encountered, consider use of an aiming device. An aiming device that attaches to the scope is available to assist proper placement of working instruments.

The surgeon needs to develop the ability to watch the monitor while working the scope and hand instruments. It is difficult to watch your hands and perform arthroscopy effectively. Treatment may involve retrieval of loose bodies (“joint mice”), removal of cartilage or osteochondral flaps, curettage or micropicking
of exposed subchondral bone, excision of torn portions of menisci or cruciate ligaments, or mechanical debridement of diseased articular cartilage. Visualisation of intra-articular fractures and reduction and stabilisation as well as ligament reconstruction have been reported. More recently arthroscopic technique to treat unstable joints has been described (capsular shrinkage).

When the procedure is finished, the arthroscope, instrument cannula and fluid egress needle are removed. The skin incisions are closed with a single interrupted suture (3-0 nylon).

**Complications of Arthroscopy**

Complications encountered with arthroscopy include failure to properly create portals and hence failure of the procedure, damage to intra-articular structures, premature dislodgement of the arthroscope, collapse of the joint capsule secondary to excessive fluid extravasation, haemorrhage from inadvertent puncture or injury of periarticular vessels, damage to the arthroscope from excessive bending forces applied to the arthroscope, neurological injury, infection, and an inability to adequately explore or treat the joint disease. The level of complications seen is related to the experience of the surgeon with arthroscopy. Proper positioning of the equipment and adherence to the basic principles helps avoid most of these complications.

Excessive fluid extravasation results in distortion of tissue planes, loss of anatomic landmarks and collapse of the joint capsule leading to an inability to properly visualize the joint. Extension of the skin incision may allow this fluid to drain away, however prevention is always the best policy. If the extravasation becomes excessive then it may be necessary to abandon the procedure and revert to an arthrotomy (landmarks distorted) or the joint must be re-examined during another anaesthetic episode. The presence of extensive periarticular fibrosis secondary to chronic osteoarthritis may prevent adequate exploration and treatment within a joint. Neurovascular injury has been reported during creation of the portals and positioning of the egress needle or as a result of traction during positioning of the patient however this is unusual if correct procedure is followed.

**Arthroscopy of the Shoulder**

As with all joint there are an increasing number of portals being described in order to allow adequate visualization and treatment of many conditions of the shoulder. Osteochondritis Dissecans is the most common indication for diagnostic and surgical arthroscopy of the shoulder joint. More recently reports have centered on the concept of shoulder joint instability and its correction. Excellent visualization is obtained with limited tissue trauma and because of the minimally invasive character a bilateral treatment is well tolerated.

The most common approach uses lateral portals as this offers the best opportunity to inspect both the cranial and caudal compartment of the joint. The long 2.7mm arthroscope is well suited to use in the shoulder. The animal is positioned in lateral recumbency with the affected limb uppermost. The leg is extended and supported in a horizontal plane. The limb should be freely Muscle, while the caudal portal is located at the same level but caudal to the acromial head of deltoideus muscle. If one of these portals is used for the arthroscope the other may be used for instrumentation, however for removal of OCD flaps a more caudal instrument portal is suggested.

More recently a hanging limb position has been described to allow for medial placement of the arthroscopy to allow for better visualization of the lateral collateral ligament and joint structures.

**Arthroscopy of the Elbow**

The most important disorders of the elbow joint are often described as the elbow dysplasia complex, including medial coronoid disease (fragmented coronoid process or FCP), osteochondritis dissecans of the medial humeral condyle (OCD) and ununited anconeal process (UAP). Except for UAP, radiographic evidence of primary or even secondary lesions is minimal or absent. Arthroscopy can then be used to demonstrate the
primary lesions. If lesions (OCD, FCP) are present, diagnostic and surgical arthroscopy can be combined. In case of UAP, arthroscopic inspection of the joint and treatment concomitant coronoid lesions can be performed. At least 6 different portals have been described, however using a medial approach a nearly complete inspection of the joint can be combined with the arthroscopic treatment of the lesions of the medial coronoid process and of the medial humeral condyle. Routinely a 2.4mm arthroscope can be used in most elbows however occasionally a 1.9mm arthroscope may be necessary.

The dog is positioned in lateral recumbency with the affected limb closest to the table. The unaffected limb is drawn back and restrained in this position along the animal’s flank. The elbow is placed over a sandbag or over the edge of the table to allow further abduction and examination of the joint. The medial side of the elbow joint is prepared for surgery. The egress needle is placed in the caudodorsal portion of the joint between the anconeal process and the olecranon fossa. The arthroscopic portal is midway along the arc of the trochlear notch approximately 1cm distal to the prominence of the epicondyle. The instrument portal is on the same level as the arthroscope but 1.5-3cm cranial to it yet still caudal to the medial collateral ligament. This avoids the neurovascular bundle that may be found just cranial to the collateral ligament.

**Arthroscopy of the Carpus**

Although arthroscopy of the human carpus is commonplace especially for treatment of carpal tunnel syndrome no such disease is recognised in dogs. Exploration of the joint is possible to identify fractures, synovial disease and to aid arthrodesis but is rarely preformed. The portal for the arthroscope lies medial to the common digital extensor tendon while the egress needle and instrument portal are located lateral to this tendon.

**Arthroscopy of the Hip**

Whilst technically possible there are few conditions in the canine hip that warrant the use of arthroscopy. The primary indication reported is the examination of the acetabulum, labrum, and femoral head of dysplastic dogs.

Lateral portals are used with the arthroscope positioned dorsal to the greater trochanter and the egress needle positioned craniodorsal or caudodorsal to the arthroscope.

**Arthroscopy of the Stifle**

Arthroscopy of the stifle has revolutionized the treatment of knee injury in man. The use of arthroscopic-assisted surgical techniques for tears of the menisci and cruciate ligaments has dramatically reduced postoperative pain, the length of hospital stay and shortened the time required for return to function. As in man, cruciate disease and meniscal injury are common injuries seen in dogs and cats. Important advantages of arthroscopy compared to arthrootomy include decreased pain, earlier return to function, improved visualization and more precise and accurate treatment. Other potential advantages include reduced scarring of the skin, decreased periarticular fibrosis and improved long term function.

The patient is positioned in dorsal recumbency with the stifle hanging off the back of the table. A vacuum beanbag is used to stabilize the patient and allow both legs to hang from the end of the table. This allows unobstructed access to both sides of the stifle. The arthroscopic portal is either in the medial or lateral parapatellar fossa, 1cm medial or lateral to the straight patellar ligament and midway between the tibial crest and the patella. The needle egress portal is in the proximopatellar joint space parallel to the patella. The instrument portal is placed in the parapatellar fossa opposite the arthroscope. Visualisation of the cranial portion of the femorotibial joint is often impeded by the proportionally large fat pad. This fat pad can be removed with a motorized shaver. A combination of varus and valgus stresses combined with flexion, extension and rotation of the limb improves visualization. Stabilisation of the cranial cruciate-deficient stifle has been described and autologous or synthetic materials can be used. Treatment of meniscal injury can be treated by excision or
precise use of radiofrequency to ablate the damaged tissues.

**Arthroscopy of the Hock**

Exploration and treatment of the hock is done through craniomedial, craniolateral or caudolateral portals depending on which portion of the joint is to be examined. Both lateral portals can be accessed from a lateral position with the affected limb uppermost, however a dorsal recumbency allow access to all 3 sites. Palpable landmarks for determining the portals are the extensor tendons and malleoli for the cranial portals and the calcaneus and lateral malleolus for the caudolateral portal. Most of the joint can be explored by flexion and extension, however a combine approach if often necessary to complete explore the joint.

The future of arthroscopy is only limited by our imagination.
RECEPTION AND EXAMINATION OF THE COLIC CASE

Richard Coomer
MA Vet MB MRCVS

HBLB Resident in Equine Gastroenterology and Soft Tissue Surgery
Equine Division, University of Liverpool, Leahurst, Chester High Road,
Neston, South Wirral, CH64 7TE, United Kingdom.

Having horse colic is stressful to horse owners. One so serious as to need to be referred to a hospital is even worse. The key to managing this stress is by preparation and teamwork, allowing owners to be met with calm efficiency. All members of the team should be well practised in the diagnostic procedures that are to be carried out.

Colic cases are often referred at unsociable times. In office hours it is possible to unload the horse and start the examination whilst office staff takes care of paper work. Clearly, out of hours this is not possible. It is important to assess the level of pain being demonstrated by the horse before completing paperwork; if the horse is recumbent or violently painful then immediate veterinary attention is required. It is rarely necessary to take horses directly to the induction box but remember to prepare for these cases. Collapsed horses should be taken directly to the induction box. Have an emergency tool box at hand containing hacksaw and crowbar etc in order to be able to remove bent trailer partitions quickly.

More often horses are taken to examination stocks. Usually one person takes the history (see attached history worksheet) whilst others start clinical examination. The colic worksheet allows us to take a full history in every case, remembering also other pertinent history which may affect the anaesthetic risk e.g. concurrent pregnancy, laminitis, respiratory disease, drug allergies, and history of rhabdomyolysis. The primary aim of the examination is to distinguish horses with a mild or uncomplicated disease process from those with potentially life-threatening disease requiring surgical correction or euthanasia.

A full stepwise clinical examination should be carried out. If pain limits this or makes it dangerous, the horse should be sedated in stocks using xylazine (0.4 mg/kg useful dose). Within the clinical examination, 5 factors may indicate necessary surgical treatment independent of all other measurements. These are:

1. Pain exhibited
2. Cardiovascular system
3. Rectal examination
4. Paracentesis abdominis
5. Nasogastric intubation

Pain

Ongoing pain, unresponsive to appropriate analgesics, is indication for surgery. This is why horses collapsed in transport or demonstrating signs of violent pain are taken directly to surgery. Regardless of the pain displayed on arrival, any signs of previous violent pain such as trauma around the eyes should immediately alert the clinician to the likely presence of a strangulating lesion. Donkeys and mules with severe intestinal disease may show few or no signs of abdominal pain; these cases require special care and close observation.

Appropriate analgesics used in equine gastroenterology include spasmylytics, NSAIDs, alpha-2 adrenoeceptor agonists and opioids. Phentothiazine sedatives (e.g. acepromazine) provide no analgesia and induce profound cardiovascular depression. They should not be used.

Amongst NSAIDs available, ketofen and flunixin can mask significant visceral pain. They should not be used unless surgical treatment is already certain – i.e. after arrival at the referral hospital. Flunixin does not have direct anti-endotoxin effect; the beneficial effects seen are due to the anti-prostaglandin action, which is no different to phenylbutazone or ketofen.

Alpha-2 agonists are very useful for colics, not least because of their relatively short duration of
action. Romifidine is the longest acting drug (effect <90 minutes), followed by detomidine (<60 minutes) and xylazine (<15 minutes). Butorphanol provides reasonable analgesia for <90 minutes.

Horses demonstrating significant pain without other indication for surgery should be sedated (alpha-2 plus opioid) prior to transport, and given a less effective NSAID such as phenylbutazone if necessary. Remember also to pass a stomach tube prior to transport, as this can provide significant analgesia and reduce the risk of gastric rupture.

**Cardiovascular system**

- Mucous membrane colour: reddening indicates increasing haemoconcentration. When in shock, peripheral vasodilatation increases the reddening. This phase is proceeded by pale mucous membranes as cardiovascular collapse develops. A so-called ‘toxic line’ can be seen around the margins of the incisor teeth in these cases. Horses with cyanotic membranes inevitably carry a very poor prognosis.
- Capillary refill time: direct assessment of peripheral perfusion, indirect assessment of hydration and vascular tone.
- Heart rate: pain only has minor effect, more a consequence of haemoconcentration and diminished venous return as a result of toxins absorbed from the intestine. Alpha-2 drugs decrease heart rate.
- Pulse characteristic: in shock, a bounding pulse accompanies the peripheral vasodilatatory phase. As cardiovascular collapse develops, pulses become weak and impalpable.
- Skin palpation: extremities feel cold to the touch e.g. ears, muzzle, legs. Skin tent over the shoulder rough assessment of hydration status.
- Haematocrit: wide range of normal therefore single measurement insignificant unless >40 %, above which the prognosis becomes increasingly poor. Progressively increasing value also significant; therefore, need to measure more than once. Considered with total protein (ref. 60 – 80 g/L) it provides a useful measurement of intravascular hydration. Increased PCV and TP indicate dehydration.

**Abdomen**

- Auscultation: auscultation in 4 quadrants. Sounds are classified as absent (-), present but reduced (+), normal (+++) and hypermotile (+++). Sounds are increased in simple cases of spasmodic or tympanic colic, sometimes preceding diarrhoea. They can also be increased in some cases of partial small intestinal obstruction. In all other cases sounds are reduced. In severe cases such as strangulations, sounds will be absent from within a few hours of the obstruction occurring.
- Palpation: external palpation of the abdominal wall can identify ‘boarding’ in response to generalised peritonitis.
- Rectal temperature: Increased in infectious cases. Normal, progressing to deceased as shock develops (infectious and endotoxic causes). A peripheral white blood cell (WBC) count should also be obtained wherever there is suspicion of an infectious process e.g. Salmonellosis, enteritis, severe acute peritonitis or intra-abdominal abscess.

**Rectal examination**

This the most important part of the clinical examination, caudal 40 % abdomen within reach. Ensure adequate restraint before attempting rectal examination (sedation) and be sure of normal anatomy (avoid ‘rectal tourism’). Large intestinal obstructions which can be recognised include pelvic flexure impaction, caecal or large colon tympany, caecal impaction, left and right dorsal displacement of the large colon, large colon volvulus.

The cause of small intestinal obstructions is rarely identified; usually the accompanying ileus results in distended loops of bowel which can reach into the pelvic inlet. This finding almost always indicates a problem requiring surgical correction.

**Paracentesis abdominis**

This should be carried out after rectal examination. It is contraindicated in cases where severe abdominal distension is present due to the risk of inadvertent intestinal puncture. A site at the most
dependent part of the ventral abdominal wall should be clipped and prepared aseptically. A 19G 35mm or 50mm needle should be inserted approximately 3cm to the right of midline. Avoid twisting the needle as this may traumatis the gut wall. If fluid is obtained it should be collected in an EDTA tube. If none is obtained, the procedure can be repeated at a site further caudal or cranial from the first. If dark blood is obtained this may indicate a splenic tap. In this case, further samples will be contaminated and therefore unrepresentative. Occasionally enterocentesis occurs due to puncture of gut; this can normally be diagnosis from gross appearance and smell. Further attempts should not be carried out.

Abdominal fluid obtained should be analysed; grossly for colour (normal – straw-coloured and clear), for total protein content (normal <2.5g/L), for white blood cell count (normal <5.0 x 10⁹/L) and for cytology (normal ratio of neutrophils:macrophages, 2:1). Alterations in colour, TP content, WBC count and cytology can give an accurate indicator of certain disease processes, particularly strangulating obstructions and peritonitis.

Nasogastric intubation.
- Diagnostic value in diagnosing small intestinal obstruction.
- Gastric decompression provides immediate pain relief and reduces risk of rupture.
- More that 2 Litres considered significant
- Normal pH 3 – 5. In cases of small intestinal obstruction pH rises to 6 – 8 due to buffering action of SI contents.
- Gastric reflux can develop rapidly with proximal obstructions, but can take up to 16 hours with a distal ileal obstruction.

Other tests
- Ultrasonography is a useful adjunctive diagnostic technique, but is not necessary in the examination of all colic cases. It is particularly useful in those cases where rectal examination is not possible, i.e. foals and small ponies. Ultrasonography allows detection of small intestinal distension, reduced motility, left dorsal displacement of the large colon (‘nephrosplenic entrapment’) and thickening of the large colon.
- Radiography is generally not required and is not technically possible in adult horses due to their large size. However, in foals radiographs of the abdomen can be obtained and are sometimes useful.
- Endoscopy can be useful in order to visualise the gastric lining and exclude gastric ulceration as a source of pain. Note that horses must be starved for 24 hours prior to gastroscopy in order to empty the stomach.

Key Differential diagnosis for colics requiring surgical correction

Around 7 % of colic cases require surgical intervention, the rest respond to medical or no treatment alone.

“The differentiation of medical and surgical colic cases is critical but is sometimes difficult; it requires clinical acumen, patience, attention to detail and determination. The benefit of repeated examination cannot be overstated” Derek Knottenbelt.

The principle differential diagnoses for medical versus surgical colics are listed below.

“True” colics due to gastrointestinal disease:
- Hypermotile ‘spasmodic’ colic
- Impactions – large colon, meconium in foals
- Large colon tympany
- Gastric ulceration
- Equine grass sickness – definitive diagnosis ileal biopsy (exlap).
- Neoplasia – rare, including lymphosarcoma, gastric carcinoma, leomyoma. These can be diagnosed during exploratory laparotomy.
- Peritonitis – source and treatment may require exploratory laparotomy
- Enteritis – definitive diagnosis at exploratory laparotomy
“False” colics due to other disease:

- Hepato-biliary disease
- Reno-urinary disease
- Exertional rhabdomyolysis
- Hypocalcaemia
- Parturition
- Uterine torsion
- Laminitis – clinical examination

The decision to go to surgery may be clear. If none of the 5 factors indicate immediate surgical intervention then do not be afraid of simply observing the animal in a stable. Do not feed or give any analgesics. Repeat the clinical examination in 2 hours. Ongoing discomfort or deterioration of other parameters can make the decision much more clear. If the animal was dehydrated without indication for surgery, then patient stabilisation (oral or intravenous fluids) can be carried out at this time. If surgery is required later, the anaesthetic risk will be reduced due to the improved hydration status.

Colics in this situation are monitored every 2 hours. Improvement in signs accompanies a reduction in monitoring to every 4 hours. Feed is gradually re-introduced only when we are sure that the animal is normal. The speed of re-introduction of feed depends on the severity of the colic and clinical signs shown; a minimum of 48 hours is taken.

QUINE COLIC ADMISSION FORM

Owners name: ……………….Referring vet: …………Case number: ……………

GENERAL HISTORY

B.I.O.P. : ……………………………… Pre-Purchase examination? Y/N

Horse used for: general riding / racing / eventing / showjumping / breeding / other

Level of work: hours/day ………… novice / intermediate / advanced

Management: private stable / livery stable / racing yard / grass livery / other

Who cares for horse: owner / private groom / professional yard staff / friend

Bedding: shavings / straw / paper / other

Feeding: coarse mix / chaff/ mollychop / alfalfa / bran / barley / oats / pellets or cubes / hay / soaked hay / silage or horsehage / grass

Worming: frequency: every ………..wks / months

PRODUCT used last time: ……………………..

Horse wormed in synchrony with others Y/N

Routine dental care? Y / N by whom: veterinary surgeon / horse dentist

Vices? None / crib-biting / windsucking / weaving / box-walking

Recent changes in routine or feeding (e.g. sedation for clipping, new hay, box rest, medication started)

…………………………………………………………………….

How long since change occurred? ……………….hrs / days

Previous major disease or episodes of colic? Y/N

If "YES" please specify: …………………………………………………………..

SHORT-TERM HISTORY

Date and time when colic first observed: ……………………..

Duration of colic (hours since last seen normal ie no colic symptoms)……….. hrs

Signs of colic: flank watching / pawing / lying still / kicking belly / rolling / violent

rolling / sweating / muscle tremors / salivation / flatulence

Droppings over previous 12 hours: none / scant / normal / diarrhoea

Time of first visit by referring vet: …………………………………..

Response to treatment: none / improved / deteriorated / unknown

Time of subsequent visits by referring vet: ………………………………

Decision to refer (approx. time): ………………………………..

CLINICAL EXAMINATION Case number: …………………..
Attitude: normal / painful / violent / dull and depressed / unwilling to move
Pain: none / mild / moderate / severe
Body condition: normal / fit / poor / overweight
Other signs: sweating / salivation / muscle fasciculation
Cleanliness of horse: clean clipped / clean unclipped / moderate / filthy

Cardiovascular system
Heart rate: .................. Beats/min  Pulse quality: normal / weak / bounding
Mucous membranes: normal / congested / cyanotic / pale / jaundiced / other
Extremities cold? Y/N  CRT: .................. secs
PCV ................. %  Total protein: ....... g/litre

Gastrointestinal system
Abdominal distension? Y/N  Auscultation:
Rectal temperature: ...........................................°C
Rectal examination: ...........................................................
...........................................................

Gastric reflux: Y/N/not performed  Volume: ............ litres

Paracentesis: gross appearance: normal / turbid / sanguinous / gut contents / chylous / no fluid obtained / not performed
WBC: ........ x10^9/litre  T.P.: ........ g/litre

Diagnostic imaging
Interpretation of any procedures performed: ...........................................................
........................................................................................................................................

PRE_SURGICAL DIAGNOSIS:
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................

Medical management: Y/N  Surgical management: Y/N

Outcome (if known at this time) survived/died/ Euthanased before surgery/at surgery/after surgery/without surgery
MANAGEMENT OF JAW FRACTURES IN SMALL ANIMALS

R. Köstlin

Professor of Surgery and Ophthalmology, Dipl. ECVS, Surgical Department of Small Animals
University of Munich, Germany, koestlin@lmu.de

Introduction

Because of its exposed position relative to the rest of the body, the head is particularly prone to trauma. Fractures usually involve the mandible and result mainly from car accidents and falls; pathological lesions or iatrogenic causes lead to jaw fractures in a small number of cases. Gunshot fractures are seen in hunting dogs from time to time.

The goal of treatment is to restore the normal anatomy and function of the fractured bones and to ensure perfect dental occlusion.

Anatomy and Biomechanics of the Mandible

The horizontal body of the mandible (corpus mandibulae) contains the alveolar process (processus alveolaris mandibulae), which bears the teeth. The teeth sit in the dental alveoli (alveoli dentales) and are anchored by ligaments. Caudally, the body of the mandible continues into the ramus of the mandible (ramus mandibulae), which is the non-tooth-bearing vertical part of the mandible. Dorsally, the ramus continues as the coronoid process (processus coronoides) and caudo-ventrally, as the condyloid or articular process (processus condylaris seu articularis). Between these two processes is the mandibular notch (incisura mandibulae). Like other bones of the skull, the mandible consists of periosteum-covered cortical parts axially and abaxially and of cancellous bone centrally.

Movement of the mandible is controlled by the coordinated actions of a multitude of muscles, primarily those of mastication (m. temporalis, m. masseter, m. pterygoideus lateralis et medialis). When a load is applied to the mandible, for instance during normal mastication, varying lines of stress are created, which continue along the body and ramus as well as along the condyloid process and the zygomatic arch and are transferred onto the skull. These lines of stress can be analysed and shown graphically with proper techniques. Not surprisingly, the trabeculae of cancellous bone are arranged in the direction of the major lines of stress that result from tractional and compression forces. These major lines of stress are referred to as trajectories.

If a bone is subjected to a sufficiently high force, even if only for a very short period of time, a fracture can result. Most commonly, the fracture line runs perpendicular to the trajectories, although less commonly, it may run in the direction of the trajectories. Obviously, knowledge of the trajectories and particularly of their orientation is very important for the surgical management of fractures.

Classification of fractures

Mandibular fractures can be classified in various ways. A descriptive classification includes transverse, oblique, longitudinal and comminuted fractures. An open fracture occurs when the fracture line communicates with the oral cavity through the dental arcade and the desmodontal gap or when there is free bony material due to soft tissue trauma. Dislocation of the fractured bone fragments frequently occurs indirectly due to muscle action.

There are three groups of fractures classified according to the state of occlusion:

1. Fractures of that part of the mandible that contains teeth
2. Fractures of the that part of the mandible that contains few or no teeth
3. Fractures of that part of the mandible that contains erupting permanent teeth
Based on this classification, a further classification can be made according to the location of the fracture:

**Location of the fracture:**

I. Fractures within the dental arcade:
   - Median or paramedian fractures
   - Fractures of the corner incisor region
   - Fractures in the region of the cheek teeth

II. Fractures at the angle of the mandible

III. Fractures of the mandible without fracture of the condyloid process
   - Longitudinal fractures
   - Transverse fractures
   - Fracture of the coronoid process

IV. Fractures of the condyloid process
   - Fractures without luxation of the condyloid process
   - Fractures with luxation of the condyloid process

V. Multiple fractures

**Diagnosis of fractures**

Most mandibular fractures can be diagnosed by careful examination of the face and oral cavity and by the presence of characteristic symptoms. The history of the patient is taken, followed by a thorough physical examination, including inspection, palpation, and a neurological examination. Radiology of the affected area as well as other imaging modalities are used to make a definitive diagnosis.

a) **Clinical examination**

As with fractures in other areas, the signs may or may not be specific for a fracture. Dislocations of the mandible are often difficult to diagnose during a physical examination because of soft tissue swelling. Even in patients with minimal mandibular dislocation, visual examination of the oral cavity reveals malocclusion and a step-like configuration of the teeth, often accompanied by gingival tears. Haemorrhage, haematomas, swelling, pain elicited by palpation and pressure as well as impaired function due to pain do not indicate a fracture definitively because these signs also occur with other diseases. However, these signs can often be used to localise single or multiple fracture sites.

When a fracture runs through the mandibular foramen, there may be increased sensitivity due to involvement of the mandibular and/or mental nerves. Often impaired jaw function manifests as limited and painful opening of the mouth or reluctance or inability to close or open the mouth.

b) **Imaging modalities**

Radiographs must be taken in at least two views to assess dislocations and diagnose multiple fractures. Depending on the clinical findings, dental radiographs or special radiographic views may be required. In certain cases, more involved imaging techniques such as computed tomography (CT) or magnetic resonance imaging (MRI) are necessary. Computed tomography using coronary (and axial) views is particularly useful and superior to conventional radiography in the diagnosis of fractures of the condyloid process with luxation.

**Treatment of fractures**

As previously mentioned, the goal of fracture repair is correct anatomical and functional restoration of the mandible so that both the functional and aesthetic results are excellent. This entails exact repositioning of the bone fragments, which usually involves manual reduction, as well as stabilisation (fixation) of the fracture. The latter can be accomplished indirectly using splints or directly by osteosynthesis. A combination of both methods is frequently used. The method of repair depends on the location and type of fracture, concurrent injuries and the...
general condition of the patient. In addition, the condition of the teeth and the age of the patient will dictate the type of treatment, which must be tailored to the individual patient.

Not all fractures need to be repaired. These include all incomplete fractures, for example fissures and greenstick fractures. As well, non-dislocated, closed fractures not involving the teeth (fractures of the ramus of the mandible, coronoid process, condylloid process and edentulous mandible) may heal spontaneously. During the healing period, the patient is limited to fluid or pureed food and activity must be restricted until the fracture has healed. Other treatment methods must be used if movement of the bone fragments is detected. In patients with fractures other than those previously described or with open fractures within the dental arcade, treatment should be carried out as quickly as possible.

After conservative or surgical treatment, radiographs must be taken to evaluate the position of the fragments; incorrect positioning must be rectified or revised.

a) Conservative treatment

Conservative treatment usually involves the use of splints and wire, which are secured by the teeth. Perimandibular circumferential wiring allows fixation of splints that cannot be secured adequately by the teeth. For certain cases (e.g. for luxated teeth), wire and orthodontic brackets with adhesive techniques can be used for stabilisation of fractures and, in exceptional cases, for mandibulomaxillary stabilisation.

b) Surgical treatment

The disadvantages of conservative treatment (e.g. mandibulomaxillary stabilisation) are eliminated when surgical correction is carried out. Particularly in patients with dislocated fractures, repositioning and stabilisation of the fragments is more easily and reliably achieved with surgical treatment. Generally, osteosynthesis is carried out under general anaesthesia with tracheal intubation via a tracheotomy.

There are various methods of osteosynthesis. For fractures in which the bone ends are perfectly aligned, wire (wire suture with a diameter of 0.2 mm to a maximum of 0.4 mm), with Kirschner wire with a diameter of 0.8 mm to 1.6 mm) may be used but because of inadequate stability, a splint and mandibulomaxillary stabilisation are also required. Wire allows healing without tissue reaction and is usually not removed after bone consolidation. However, studies have shown that this method is inferior to the use of miniplates for osteosynthesis.

Osteosynthesis plates are recommended particularly in patients with atrophy of the jaw bones, in which mandibulomaxillary fixation is not commonly required. An example is osteosynthesis using compression plates and an extraoral approach, in which the screws are placed in the buccal as well as the lingual cortex. During the operation, care must be taken to avoid critical structures such as the roots of teeth and the mandibular nerve, which runs through the mandibular canal. Thus, it is preferable to place the osteosynthesis plates on the basal margin of the mandible. However, with stress (e.g., mastication), unfavourable strain relations occur at that site; near the dental arcade there are predominantly tractional forces, which are not neutralised by the plate at the basal margin. As well, gapping between the bone fragments on the lingual side may occur. To compensate for these tractional forces, additional techniques must be used within the dental arcade. A splint can be used or, with fractures outside the dental arcade, wire or a second plate must be applied. Today, finer compression plates are available (2.4 mm Limited Contact-DCP, 2.0 mm Mandibular-Mini-DCP plates).

Miniplates with monocortical fixation, developed by Champy, represent a completely different approach: Each fragment must be stabilised with at least two screws. Substantially smaller screws can be placed directly in the area under the most tension; for example on the body of the mandible basal to the mandibular alveolar processes, without causing damage to tooth roots and nerves. The correct position of the miniplates, which today are usually made of titanium, follows an ideal line corresponding to the external oblique line (linea obliqua externa)
in the area of the angle of the jaw. To overcome torsional forces in the area of the front teeth, two plates, one placed over the other, must be applied mesial to the premolars. Miniplates can almost always be placed on the mandible using an intraoral approach. But even when an extraoral approach is used, the anatomy of the region must be carefully considered. For example with collum fractures an extraoral approach is complicated by the close proximity of the facial nerve.

New treatments in traumatology include the development of, or improvement of existing, bioabsorbable osteosynthetic materials, which, however, have not yet been developed to the point of routine use. They are usually made of poly-L-lactid (PLA), polyglycolide (PGA) and polydioxanone (PDS). With this technique, metal implants do not have to be removed after bone consolidation, and the patient is spared a second operation.

At our clinic, the treatment of 47 canine patients with skull trauma consisted first of fluid therapy for the treatment of shock. Five dogs required an operation because of depressed fractures. Twenty-seven of the 47 dogs had a normal mental status and 12 died or were euthanised. No follow-up was available for eight dogs. Of 88 jaw fractures, interfragmentary wires were used in 37, external fixation in 16, osteosynthesis plates in 11, other fixation methods in 10, and 14 dogs were treated conservatively.

Of 472 jaw fractures in cats, 135 (26.8%) were at the mandibular symphysis, 130 (27.5%) in the palatine suture, 97 (20.6%) in the body and ramus of the mandible, 49 (10.4%) in the temporomandibular joint and 27 (5.7%) in the maxilla, zygomatic bone or zygomatic arch. As well, there were 34 jaw luxations. Treatment was initiated in 251 cats.

c) Treatment of individual types of fractures

► Fracture of the alveolar process
With this type, the cranial aspect of the tooth-bearing part is fractured while the basal part of the mandible remains intact. The recommended treatment is cerclage wire for six to eight weeks. However, extensive fractures should be repaired with miniplates. In every patient, regular physical and radiographic re-examinations should be carried out to identify the need for additional treatment.

► Fractures within the dental arcade
Stable types of osteosynthesis are the treatment of choice in the adult jaw. Fine miniplates are ideal because they can almost always be applied intraorally and in difficult places while guaranteeing adequate stability. With the exception of collum fractures, almost all mandibular fractures can be repaired using miniplates.

► Fractures outside of the dental arcade
With bilateral fractures of the jaw angles, stable repair is a priority. It is important to remember that with conservative treatment of unilateral fractures, only one fragment remains static, while the other smaller fragment may become dislocated by muscular (muscles of mastication) forces. Longitudinal fractures of the ramus of the mandible can be treated conservatively, in contrast to transverse fractures, in which surgical repair is preferred.

► Fractures of parts of the jaw with few or no teeth
In these patients, concurrent mandibular atrophy increases the complication rate (pseudoarthroses). Reduced contact surface of the bone fragments, poor vascularisation and sclerosis almost always dictate the use of osteosynthesis. In these cases, rigid compression plates are preferred over miniplates.

► Fracture of the condyloid process
In both young and old patients with this type of fracture, conservative treatment is preferred, although functionally and anatomically, the result is only satisfactory. In patients with a dislocation, surgical correction is now being done more often to provide correct anatomical repositioning of the bones. Care must be exercised with an extraoral approach because the facial nerve (nervus facialis), parotid gland (glandula parotis) and the
external ear canal are situated in close proximity. The disadvantage of an intraoral approach is the poor anatomic view.

► Multiple fractures
In areas with an adequate number of teeth, multiple fractures can be managed conservatively. However, in many cases, it is better to use a combination of repair methods.

► Comminuted fractures and fractures with a bone defect
These fractures may be challenging considering the soft tissue damage alone. Provided there is enough bony substance, repositioning and stabilisation of the numerous tiny fragments should be carried out. Bridging plates, used as a biological osteosynthesis, or bone transplants (autogenous spongiosa or ribs) are also indicated for the reconstruction of the mandible. Conservative treatment is used as an adjunct. In addition, a combination of various methods of osteosynthesis may be useful.

► Infected fractures
Mandibulomaxillary stabilisation using splints on the upper and lower jaws and external fixation have been the method of choice for a long time. Reliable stabilisation using plates together with drainage and antibiotic therapy appears to be adequate to treat or cure infection.

► Incorrect alignment after healing
Particularly in severe combined trauma, exact repositioning of the fragments is difficult and sometimes impossible. As well, resorptive processes may result in asymmetry. In these patients, correction of the alignment must be discussed. One must consider whether osteotomy of the affected bone or targeted tooth extraction would facilitate occlusion.

d) Concurrent medical treatment

• Prophylaxis of infection
Wounds that communicate with the oro- or nasopharyngeal area will always undergo primary or secondary infection with various microorganisms. In particular, perforation of soft tissues and fractures within the dental arcade (desmodontal splits) are at high risk of infection. Wound infection depends on the general condition of the patient, the characteristics of the wound (location, size and type), the presence of a foreign body and the number and virulence of the microorganisms.

The prerequisite for the prevention of infection is rapid surgical repair of the wound with thorough cleaning and debridement. There is no medication that can replace natural body defence mechanisms or the principles of aseptic surgery (asepsis, antisepsis, atraumatic surgery). However, administration of antibiotics perioperatively is always recommended. Knowledge of the possible pathogenic bacteria is particularly important when choosing an antibiotic. With mixed flora, which is commonly encountered, broad-spectrum antibiotics such as penicillin, amoxicillin combined with clavulanic acid or a cephalosporin, are suitable. In patients with infected fractures, the choice of antibiotic must be based on the results of culture and sensitivity.

• Analgesia
For the treatment and prophylaxis of pain, various analgesics can be used. The analgesics can be divided into two groups: predominantly peripherally-acting analgesics and centrally-acting analgesics. The former inhibit the synthesis of pain-inducing inflammatory substances such as prostaglandins. They also provide antiinflammatory, antpyretic and spasmodlytic effects partially through a central site of action. There are various classes of substances including derivatives of salicylic acid (acetylsalicylic acid), organic acids (non-steroidal antiinflammatory drugs) and derivatives of pyrazolone.

The centrally-acting analgesics with their morphine-like effects inhibit neural pain responses via opiate receptors on pain neurons located in the brain and spinal cord. Classes of substances in this category of analgesics include opiates (alkaloids of opium) and opioids. Opiates such as morphine, codeine, papaverine and
thebaine occur naturally, whereas opioids are partially or completely synthetic substances with morphine-like effects.

**Intraoperative complications and those occurring later**

In our clinic, 25 of 78 dogs had different types of complications; the maxilla was affected in only one case. Complications arose with external fixation (8 of 16), osteosynthesis plates (3 of 11), interfragmentary wires (10 of 37) and conservative treatment (2 of 14). The most common complications were loosening of the implant (n=15), pseudoarthrosis (n=4) and bone sequesters (n=3). Malocclusion occurred in two of the cases. Complications occurred mainly in the region of the incisors and canines (40%), molars (33%), premolars (22%) and symphysis (25%). In 11 dogs, the mandible was repaired using an osteosynthesis plate. In our in-clinic patients as well as in nine experimental dogs, we investigated whether the screws in the plate injured the roots of the teeth or the mandibular nerve (nervus mandibularis). In the in-clinic patients, 5 of 18 screws damaged tooth roots in dogs that weighed up to 10 kg. However, in dogs that weighed between 11 and 20 kg, only 4 of 18 screws damaged tooth roots and in dogs weighing more than 21 kg, only 2 of 40 screws caused damage. Nevertheless, almost 70% of the screws penetrated the mandibular canal. Clinical signs were not evident in any of the five affected dogs; all reacted to a pain stimulus and none of the teeth were devitalised.

Of 251 treated cats, 92 (38%) underwent a follow-up examination at 1.5 to 80 months (average= 24 months) postoperatively. The results of clinical and radiographic examinations were deemed good in 79% of the cats, satisfactory (clinically normal but radiographic lesions present) in 16% and unsatisfactory (clinical symptoms and radiographic lesions) in 5.3%.

Natural oral hygiene can be difficult or impossible, particularly in patients with intraoral splints. This favours paradontopathies. Even with careful fitting, a narrow gap occurs between the splint and the surface of the teeth. Food material and bacteria collect in this area and demineralisation and loss of enamel may result. To prevent caries, intensive application of fluoride is imperative. Disinfecting mouthwash or sprays that contain chlorhexidine also help.

Permanent dental damage such as necrosis of the pulp with inflamed apical processes occurs commonly after fracture or luxation of a tooth, fracture of the alveolar process or after trauma caused by screws. General disturbances in wound healing within the oral cavity occur mainly after operations. Suture dehiscence and loosening of screws and plates can result in free or loose osteosynthesis material.

Infection of the fracture line in the form of a fracture line abscess can result from instability of the bone fragments and accumulation of bacteria-laden saliva and debris within the fracture line. This is seen frequently in unstable fractures within the dental arcade. Treatment involves incision, drainage and antibiotic therapy with stabilisation of the fragments. Spread of the infection into the bone marrow may result in extensive fracture line osteomyelitis, which necessitates a bone transplant.

Pseudoarthrosis is another severe complication. This may occur after an infected fracture line has healed or after inadequate repositioning and stabilisation of bone fragments.

In patients with a fracture of the condyloid process, dislocated bone fragments may heal in the wrong position; through remodelling, an incongruent joint head may develop, which can result in a limited range of motion for the mandible and sideways motion when opening the mouth.

Bony communication between the condyloid process, zygomatic arch and base of the skull after fracture of the condyloid process is considered the most severe complication and requires surgical intervention or resection of the joint. This type of ankylosis is often seen in cats.
ANESTHESIA AND SURGERY OF CAMELS

Falah K. Al-Ani, BVM&S, PhD.
Professor of Veterinary Medicine, P.O. Box 620026 Irbid 21162, Jordan alani 99@hotmail.com

General
The majority of surgical procedures in camels can be done safely and painlessly with some form of physical restraint and regional or general anesthesia (Al-Ani, 2004). Anesthetics are used for a variety of reasons: to minimize or eliminate pain, relax muscles, and facilitate animal restraint during surgery or diagnostic procedures. Following anesthesia administration, camels are prone to regurgitation and aspiration pneumonia, especially if abdominal pressure is exerted such as occurs during lateral recumbency (Said, 1964). Therefore, food should be withheld for at least 24 to 36 hours, and water should be withheld for 12 hours prior surgery.

Camel Anesthesia

Analgesic agent
An analgesic agent is a substance which temporarily abolishes awareness of pain. These commonly used in camels include:

- **Phenylbutazone** is sometimes recommended for camels as oral paste or as an intravenous preparation for long-term analgesia and to control inflammation associated with arthritis, sodalities, and laminitis. The recommended dose is 2-4 mg/kg once daily. The elimination half life of phenylbutazone is 13 hours while that of oxyphenbutazone is 24 hours. In certain countries, it is forbidden to be used for racing camels, and should not be given for at least 7 days prior to racing.

- **Flunixin meglumine** (Banamine) is a potent carboxylic acid NSAID. It has been used as analgesic and antipyretic to treat musculoskeletal pain, abdominal pain, acute mastitis and lameness. The recommended dose ranges between 1.1mg/kg three times daily, and 2.2mg/kg of body weight, administered twice daily. The recommended drug withdrawal time for flunixin melanine for meat is 10 days, and that for milk is 72 hours.

- **Aspirin** is administered at a dose of 100 mg/kg of body weight orally, twice daily. It is recommended that aspirin-treated animals be given a withdrawal time of 24 hours for both meat and milk.

Sedative agents
Sedative is a narcotic agent, which is used to calm a nervous, vicious or excited animal, while tranquilization is a state of behavioural change in which the patient is relaxed but unconcerned of his surroundings (Al-Ani, 2004). Drugs used to induce tranquilization and/or sedation in camels include acepromazine, the alpha 2-agonists, xylazine, detomidine, medetomidine, and romifidine; pentobarbital, chloral hydrate, and diazepam.

- **Xylazine** (Rompun) can be given for camels as a sedative in a dose of 0.1-0.2 mg/kg by intravenous or intramuscular route (Custer et al., 1977). A standard dose of 0.25 mg/kg is recommended for llama. Alpacas appear to be less sensitive to xylazine than llamas. Bradycardia and salivation are lessened in camels by giving IM atropine (0.1 mg/kg) ten minutes prior to injection of xylazine. For immobilization, a dose of 0.5 mg/kg may be given, though not without risk, especially in the use of xylazine in camels with cardio-respiratory complication. Onset of sedation usually occurs within 10 minutes and can vary in duration from 45 minutes to 5 hours. In Asiatic camels xylazine sedation can be antagonized with doxapram administration (0.05 to 0.13 mg/kg IV).
Detomidine HCL is a sedative-analgesic which is more potent than xylazine, with greater specificity at central alpha 2-adrenoceptors. It may be administered intravenously or intramuscularly in a dose of 0.02-0.04 mg/kg. Detomidine is an effective preanesthetic and can be used in combination with ketamine to induce short periods of anesthesia.

Medetomidine HCL is the most potent alpha 2-adrenoceptor-selective agonist. It can be given by intramuscular or intravenous route to enhance sedation and analgesia. A dose of 40-80 microgram/kg is recommended. Combinations of medetomidine and ketamine have short periods of anesthesia and immobilization.

Etorphine HCL has been used in the immobilization and capture of exotic species. Etorphine in a dose of 0.25-0.5 mg/45 kg by intravenous route is recommended for immobilization. A maximum of 4 mg is suggested for the adult camel weighing 400-500 kg; for juvenile animals, a total intramuscularly dose of 0.5-2 mg is suggested. A mixture of etorphine and acepromazine (2.45 mg/ml and 10 mg/ml, respectively) is commercially available under the name of Immobilon. It has been used in various zoo animals.
Figure 2: Immobilization of a camel by etorphine and acepromazine combination.

- **Acepromazine** maleate (Atravet) is a phenothiazine derivative. It is used as sedative, tranquilizing action, or as a preanesthetic agent. A dose of 0.05 to 0.15 mg/kg can be given intramuscularly or intravenously. Acepromazine reduces excitability so that the animal can be easily handled.

- **Diazepam** (Valium) is used for its principal action upon CNS, such as its hypnotic, sedative, anxiolytic, anticonvulsant, and skeletal muscle-relaxant effects. A dose of 0.1-0.5 mg/kg intramuscularly or intravenously is recommended.

- **Carfentanil citrate** (Wildnil) is a phenylperadine derivative. It is currently labeled only for the immobilization of cervidae but it has been used in camelids. The normal dose used for capture is
0.005-0.02 mg/kg injected intramuscularly.

- **Butorphanol tartrate** (Torbugesic, Stadol) is a morphine derivative (opioid agonist-antagonist) that has narcotic antagonist activity equivalent to that of allopine. It can be used to provide sedation and analgesia in camelids. The recommended intramuscular or intravenous dose for the camel is 0.02-0.1 mg/kg and for llamas and alpacas is 0.1 to 0.2 mg/kg IM. Combinations of xylazine and butorphanol in a dose of 0.2 mg/kg IV of each drug have been used in camelids to provide neuroleptanalgesia. Duration of action is approximately one hour (Lumbs and Johns, 1996).

- **Reserpine** (Rakelin) is a long lasting calming and tranquilizing agent used commonly to assist with handling and transportation of camels by aircraft or by sea. It may also make a non-trained camel easier to ride. A dose of 1 to 2 mg per adult camel every 4-8 days is recommended.

**Local anesthesia**

Local anesthesia is a loss of sensation in a limited body area.

1. **Local infiltration anesthesia**

   It is the direct injection of a surgical site with analgesic agent. Lidocaine KCL (xylocaine and lignocaine) 2% solution is the most common one used for this purpose. The anesthetic should be inject under the skin and then deeply in the underneath muscles along the line of incision.

2. **Regional anesthesia**

   Desensitization by blocking the major nerve to a given region is called regional anesthesia. It can be given by different routes.

   - **Peripheral nerve block** is the injection of local anesthetic into the immediate vicinity of individual peripheral nerves or a nerve plexus.
   - **Paravertebral anesthesia** by inducing paravertebral block of the last thoracic and first and second spinal lumbar nerves.
   - **Extradural anesthesia** (epidural block) injection of local anesthetic solution into the extradural space of the spinal canal at the level of lumbosacral region, sacrococcygeal space, or first or second intercoccygeal space by slanting 5-cmneedle forward about 45° from vertical. A dose of 6-12 ml of 2% lidocaine produces analgesia of the anus, udder, vagina, scrotum, and hind limbs. Injection should be made in a standing or sternum recumbency position. It should be performed under clean conditions with aseptic solutions and sterilized instruments.

**General anesthetics**

General anesthesia is complete unconsciousness. To do major surgery, general anesthesia may be needed. Before administering the general anesthesia, pre-anesthetic medications may be given (Geddes et al. 1974). The primary aims of pre-anesthetic medication are to calm the animal, facilitate handling, and relieve pro-operative pain. Food and water should be withheld from the animal before general anesthesia at least 12-24 hours. This will decrease the occurrence of bloating and regurgitation of rumen contents. The most common tranquilizers or sedatives used for this purpose are acepromazine, diazepam, midazolam or isoprene (Manefield and Tinson, 1996). Xylazine, deoxidize or medetomidine as alfa2-adrenergic agonist may be also used.

**Intubation**

Endotracheal intubation is routinely used with general anesthesia. It is used for administration of the anesthetic vapor, to protect the airway from possible regurgitated ruminal contents and to administer oxygen in the event of respiratory depression. Camelids are prone to increased vagal discharge during intubation or painful stimuli during surgery. Atropine (0.02 mg/kg IV or 0.04 mg/kg IM) is recommended to prevent bradyarrhythmia and will also decrease salivary secretions (Lumb and Jones, 1996). Glycopyrrolate (0.005 to 0.01 mg/kg IM or 0.002 to 0.005 mg/kg IV) may be substituted for atropine (Gahlot and Chouhan, 1992, Gahlot, 2000). The endotracheal tube should be placed in the oral pharynx and inserted into the larynx during inspiration. A laryngoscopy with a 250- to 350-mm laryngoscope is recommended. Another means of intubation is by inserting one hand deeply into the laryngeal area through which the tube can be inserted (Kumar, 1994).
Figure 3: Intubation of the trachea by passing the tube and one hand of the operator into the pharynx and the epiglottis.

Nasotracheal intubation is also possible in camelids, although camelids are prone to epistaxis and use of a lubricant that contains phenylephrine is recommended. The endotracheal tube is advanced through the external narse into the ventral meatus with slow gentle pressure. After the endotracheal tube has been advanced into the nasopharynx, the camel head and neck should be extended and the tube manipulated into the larynx (Al-Ani, 2004).

General anesthetics are usually given by inhalation or injection.  
1. **Inhalation anesthesia** has been used on camels for major surgical procedures. Xylazine (0.2 mg/kg) should be administered intravenously 15 minutes prior to induction of anesthesia. Kitamin (2 mg/kg with saline solution IV) or tileamine hydrochloride/zolazepam hydrochloride (1 mg/kg IV) can use as an induction agent; the camel is then intubated and anesthesia is maintained with isoflurane in the oxygen, using intermittent positive-pressure ventilation. Other commonly used agents are methoxyflurane and halothane. Nitrous oxide may be administered as 25 to 40% of the total gas flow, with 1 to 2% halothane or with 1 to 1.5% methoxyflurane. Fluothane concentrations required are 4 % for induction and 2% for maintenance.
Figure 4: Connection of the general anesthesia to the intube. The endotracheal tube is secured with tape or gauze to the Y piece of the re-breathing circuit and to the dental wedge that is left in-place during anesthesia.

2. Injection anesthesia can be accomplished with one of the following:

- **Ketamine HCL** (Ketalar) is a unique general anesthetic. Xylazine in a dose of 0.2 mg/kg should generally be injected 10 minutes before the injection of ketamine. The recommended dose of ketamine in inducing anesthesia for camelids is 2.2 mg/kg. Muscle relaxation is usually adequate for tracheal intubation. Depth of anesthesia varies with the amount given and the camelids temperament, but is usually sufficient for minor surgery.

- **Tiletamine-Zolazepam**: Telazol is a proprietary combination of equal parts of tiletamne and zolazepam. A dose of 4.0 mg/kg IM provides up to 2 hours of restraint in camelids. Telazol in a dose of 2 mg/kg IV provides 15 to 20 minutes of restraint and 25 to 35 minutes of recumbency.

- **Barbiturates**: intravenous injection of pentobarbital (15 mg/kg IV) or thiopentone sodium (10 mg/kg IV) has been used as a satisfactory method of inducing general anesthesia in camels and llamas. Glyceryl guaiacolate (10 % solution of GGE) and thiopentone sodium (5 g) in one liter intravenously is also an efficient anesthetic mixture for camels. A mixture of guaifenesin (110 mg/kg) and thiopental (4.4 mg/kg) can be given intravenously for the administration of anesthesia in camels. For maintenance of general anesthesia, 5% guaifenesin in 5% dextrose plus thiopental (2 mg/ml) are given “to effect”. Inhalant anesthetics such as halothane or isoflurane can be used to maintain longer periods of anesthesia.

- **Chloral hydrate** in solution can be injected intravenously. The combination of chloral hydrate and magnesium sulfate has proved useful in anesthetizing the Arabian camel (Singh et al. 1962). An intravenous dose of 12 g/100 kg of the mixture (i.e. 6 gm each of choral hydrate and magnesium sulfate are administered for each 100 kg body weight). Premedication with intramuscular chlorpromazine (1 mg/kg) decreases the dose of chloral hydrate or pentabarbital.
sodium necessary to induce anesthesia while prolonging its duration. Satisfactory intravenous anesthesia has been achieved in adult camels with a combination of chlorpromazine (0.5 mg/kg), pentobarbital (2.0 g total dose), and 2.5 g/50 kg of body weight of chloral hydrate. Anesthesia can be prolonged with supplemental doses of pentobarbital (Lumb and Jones', 1996).

Supportive measurements and therapy

During general anesthesia and following the surgery, special care of the patient must be undertaken. Supportive therapy includes patient positioning, fluid administration, mechanical ventilation, cardiovascular support, and good monitoring techniques.

Camelids have prominent eyes, and special attention should be given to the dependent eye to avoid injury. When the animal awakes from anesthesia, the animal will try to raise up. Since his coordination is weak, the animal may fall down and fracture his bones.

Fluid administration during anesthesia is important to correct preexisting dehydration and provide body fluid volume. Monitoring heart beat, pulse pressure, color of mucous membranes, capillary refill time, respiratory movement, and blood gases during surgery is important. Electrocardiography is used for the detection of cardiac rate and rhythm disturbances. Monitoring of blood gases, especially arterial blood gas every 15 to 30 minutes during surgery is important.

Recovery from general anesthesia will take some time. This will depend upon the type of anesthetic and duration of the surgery. Extubation should not occur until the laryngeal reflex has returned. Also, precautions should be taken to prevent the camelid from aspirating the endotracheal tube. If the camel begins regurgitating, the buccal cavity and pharynx should be lavaged to prevent aspiration of the material (Lumb and Jones, 1996).

Postoperative complication

Aspiration pneumonia can occur following regurgitation of rumen contents and subsequent inhalation of the material. Eye injury and fracture of bones may accidentally occur. Thrombophelebitis sometimes occurs following perivascular injection of irritating compounds. Postoperative myopathy and neuropathy can occur when a heavy camel lies down in an improper position for too long.

Surgical Techniques

The good surgical technique is based on knowledge of anatomy, physiology and pathology. The surgeon should try to use aseptic procedure as far as possible to achieve high rate of success (Kumar, 1994). The surgical site should be prepared by clipping and shaving a larger area beyond the proposed line of incision. The clipped or shaved area should be scrubbed with soap and then with an antiseptic. The surgeon should wear sterilized surgical gloves and all surgical team should wear gown and is ready for surgical operation (Al-Ani, 2004).

Head and neck Surgery

Different surgical techniques may be needed for the head. These include:

Mandibular fracture

Mandibular fractures are common and are invariably compound in nature (Bahtia et al. 1978). Mostly the horizontal fused rami of the mandible get fracture because the other male breeding camel easily grasps the part during a fight (Lavania, 1998). Different surgical techniques include wiring between teeth, bone plating, transfixation of bone pin with plaster of Paris bandaging has been used for the repair of mandibular fracture. Diverse reparative techniques have been used and reported. Interdental wiring technique for mandibular fracture repair is practiced (Gahlot et al. 1984). The interdental wiring between incisors and premolar teeth using a 1mm thick copper wire can be performed. Submandibular abscess formation is a common complication feature in most of the compound mandibular fractures.

Recently, Plaster of Paris bandage and a wooden plate such as a splint have been practiced with good results as a technique for repair of mandibular fracture (Lavania et al. 1999). Camels are restrained in sternal recumbency and sedated by xylazine 0.2 mg/kg body weight and butorphanol 0.02 mg/kg. The fractured segment of the mandible is kept in normal alignment with the help of a 6” wide cotton bandage. Plywood of 4 to 5 mm thickness is used as a splint for giving support to the fractured part of the
mandible. The length of the wooden plate is measured from the body of the mandible to the rami to an extent that the fracture site of the bone remains almost in the middle. A Plaster of Paris bandage is applied with 2 to 3 rounds, at first circling over the bridge of the nose and the posterior part of the wooden plate kept under the mandible. It is then passed along one side of lateral border of the wooden plate to anterior border and then turning to its other lateral border. It is then passed obliquely, posterior to the labial commissure, along the cheek to the bridge of the nose then to the other side of the cheek, continuing obliquely to the lateral border of the wooden plate and all around it as before (Lavania et al. 1999). The wound inside the oral cavity is cleaned and sutured. Systemic antibiotic is recommended for 5 to 7 days. The plaster of Paris will be removed after 6 weeks.
Figure 5: Camel with fracture mandible. A: before surgery, B: taking x-ray, and C: after surgery.
**Enucleation of the eye**

Exirpation of the eyeball is recommended where there is complete damage of the eyeball which is not responding to treatment. Corneal neoplasm, foreign bodies, and abscess are the most common causes of eye damage.

Preanesthetic sedation is recommended. Anesthesia for enucleation is best accomplished by regional anesthesia or general anesthesia. Regional anesthesia can be given by insertion of the operator finger in the lateral canthus between the eyeball and the lateral canthus. Position the infusion needle between the outside of the finger and the inside of the canthus. Direct the needle caudally and medially through the conjunctiva until the needle point is just retrobulbar. Infuse 10 to 15 ml of 2% lidocaine then remove the needle after the infusion. The same thing should be done on the medial canthus between the eyeball and the third eyelid. A local anesthesia of the eyelids is usually accomplished by local infiltration of the eyelid with 2% lidocaine.

Grasp the upper and lower lids with two towel clamps. Make elliptical skin incisions continuing through the subcutaneous tissue down to the orbital muscles. By using curved scissors, continue dissecting the orbital muscles until the eyeball and conjunctival sac loosen from the muscular attachment. Grasp the eyeball within the conjunctival sac and apply traction while continuing transection with the scissors. Periconjunctival incisions should help ensure a sterile enucleation. Suture in an interrupted horizontal mattress pattern can be done by using double strands of No. 3-O chromic catgut suture. It is recommended to insert a sterile, soluble antibiotic bolus into the orbit before complete suturing. Systemic antibiotic is also recommended.

**Tracheotomy**

In camels with extensive damage of the nose, nasal sinuses and trachea, in which breathing is very difficult and the animal starts to suffer from asphyxia, tracheotomy is required.

The camel is sedated in sternal recumbency and the head is securely controlled. Following shaving and disinfecting of the surgical site, which is usually the middle and lower third of the neck region, a local anesthesia is given where the incision is to be made. A 10 cm long incision on the skin and underneath muscles is made. Elliptical portions of the tracheal rings proximal and distal to an incision in the interanular ligament will be removed. Blunt separation is made of the muscle to the tracheal rings. A 4
cm incision is made through the internular ligament. Through this incision, a permanent field tube (tracheotomy tube) or any self-retaining endotracheal tube can be inserted.

The tracheal tube should be checked daily for mucus which may plug it and can be left in position as far as there is a need.

Figure 6: Rupture of the dulaa that removed surgically.

**Soft Palatectomy**

The soft palate of the camel is long. In the male camel the dulla is a well-developed structure, especially during breeding season. Removal of the dulla is sometimes recommended for racing camels since it causes exercise-induced dyspnea during racing. Also, injuries of the dulla occur predominantly in the male during the breeding season. Thus soft palatectomy is recommended for racing camels.

Following the control of front and hind limbs by ropes in sternal recumbency, the mouth is held open using a Varnells or Swale mouth gag. The dulla is then pulled to full extent through the mouth with trying to ligate visible blood vessels. The dulla is then cut from its base and cut surface is closed using an inverted suture pattern.

**Nose-peg**

Piercing of the nostrils and fixing a ring or a nose-peg is commonly practiced in riding and
draught camels. Different techniques have been recommended for insertion of a nose-peg. The most common and simple procedure for piercing the nostrils is described below (Rathore, 1986). After getting the camel into a position of sternal recumbency, a local anesthetic is given to the surgical site. Following the insertion of one or two fingers of the operator under the upper flap inside the nostril, the other hand of the operator will start to pass an iron needle with a thick cotton cord about 2.5 cm from the posterior fissure of the nostril in the cartilage below the edge of the nasal bone. When the tip of the needle pierces the inner mucous membrane of the nose and touches the left-hand fingers of the operator, the operator slowly rotates the needle to make the hole a little wider, then pushes the needle downward and outward, and with the help of the left-hand fingers pulls it out of the nostril. The cotton cord will be fixed in the hole for 7 to 10 days till the wound heals.

A wooden peg of 5 to 7 cm long, with the shape of a collar stud but with one pointed end, is usually used. The pointed end of the pig is inserted into the hole from inside the nostril and slowly pushed outward with the left-hand fingers and by using the right hand of the operator the point of the peg will be pulled out and secured in place. Another nose-peg will be fixed in the other nostril by the same procedure.

When the camel becomes accustomed to the pegs, the wound heals completely and the camel does not feel any pain on touching the pegs, reins are attached to the pegs and the camel will learn to walk according to the order of the man who holds his reins (Rathore, 1986).

The advantage of using a nose-peg is to make leading the camel easier and safer especially for male camels during rutting season. Camels used as packing animals or for draught purposes are more secure to be lead in addition to the halter or the neck robes by a nose-peg.

**Abdominal Surgery**

The most common reason for abdominal surgery is to perform diagnostic labrotomy, cesarean section, diagnosis of intestinal obstruction, removal of foreign bodies from the forestomach, and surgical repair of hernia.

**Laparotomy**

Laparotomy may be performed with the animal sedation and local anesthesia. Left or right side paralumbar fossa approach is preferable and depends upon the aim and the need of the laparotomy. The operator has access to the forestomach, liver, spleen, kidneys, intestine, and uterus (Anderson et al. 1996). Ventral midline laparotomy under general anesthesia is useful for access to the third forestomach compartment, liver, small and large intestine, bladder and uterus.

**Rumenotomy**

Rumenotomy has been described in camels (Ramadan et al. 1986, Gahlot and Chouhan 1992). It is conventionally done similar to the bovines using a Weingarth rumenotomy set. Also, a clamp fixation technique has been applied in camels (Dehghani 1999). The left flank area is shaved and prepared for an aseptic operation. Following a local or paravertebral administration of anesthetic, a 15-20 cm long incision is made in the skin, muscles and the peritoneum. The rumen is gently pulled out of the incision and firmly anchored to the skin dorsally, ventrally, cranially and caudally by towel clamps. The rumen is then opened and its edges are fixed cranially and caudally to the skin incision. The hand of the operator is ready to examine the rumen contents. The same suture techniques described for bovine rumenotomy can be applied to suture the rumen, peritoneum, muscles and the skin. Systemic antibiotic is recommended for 3-5 days post-surgery (Dehghani, 1999).
Cannulation of forestomach
First compartment cannulation in Arabian camels has been undertaken. The cannula can be fixed in place for several years (Manefield et al. 1997).

Intestinal surgery
With intestinal obstruction, surgical intervention is required to treat digesta impaction of the proximal loop of the spiral colon, enterolith obstruction of the spiral colon, extramural obstruction of the descending colon caused by an umbilical abscess, and post-operative obstructive adhesions with small intestinal strangulation.

Enteroliths may be removed via enterotomy. Strangulation and intussusception may be treated by resection and end-to-end anastomosis.

Rectal prolapse
Rectal prolapse is a condition in which part or all layers of the rectum are extruded through the anal sphincter. Surgical treatment of the condition is sometimes recommended especially when there is complete prolapse and the outer surface of the mucous membrane of the rectum becomes hyperemic and even necrotic.

Following epidural anesthesia, the prolapse part of the rectum is cleaned and replaced manually. Purse string sutures may be placed around the anus leaving a small opening which should be observed daily. When the exposed part of the rectum is severely edematous and necrotic, amputation of the part is recommended.

Hernia
Umbilical hernias are occasionally diagnosed. It may be present at birth or acquired due to infection of the cord. The operation can be done under sedation and local infiltration of anesthesia. An elliptical skin incision is made over the swelling and the skin is reflected. Dissection is carried out to the hernial ring. Herniorrhaphy with appositional closure of the abdominal wall by interrupted mattress sutures is recommended. The skin is then sutured as usual.
Castration

Camels are castrated for various reasons. One is to increase the animal tractability. Camels used for transport are better castrated, rendering them large but docile pack animals. Castration of pack camels reduces the tendency to fight and make them much easier to handle, especially during rutting. Poorly bred or inferior animals should be castrated to avoid transmission of unwanted characteristics. Testicular disease and cryptorchidism are indications for castration.

In llamas and alpacas, castration may be chosen to allow commingling of pets or fiber producing males and females, to restrict the available genetic pool, to lessen aggressive behavior, and to create gelding males to be sold as pets or show animals.

The descent of the testicles in camels is complete at birth and thus castration can be done at any age. However, it is recommended to castrate camels when mature body size and weight have been achieved at age of 4-6 years. Early castration that occurs before maturity results in stunted growth and loss of potential weight-carrying ability due to less under-developed bones and muscles.

Different techniques have been developed to castrate camels. The most primitive and traditional one commonly used by Bedouin is by applying two sticks to macerate the cord. Young camels can be castrated by Burdizzo, but the open method is more usual.

The camel should preferably fast for 1-2 days before surgery, and pre-operative tetanus toxoid and procaine penicillin G should be administered to the animal. Castration may be performed after sedation and local anesthesia or after induction of general anesthesia. Xylazine in a dose of 0.1-0.2 mg/kg intravenously can be given. The camel is placed in sternal recumbency and the tail is tied to one side. After proper clipping and disinfection, the scrotum is infiltrated with 10 ml of 2% lidocaine hydrochloride solution along the lines of the proposed incision. Also, the deeper structures may also be anesthetized by injecting the anesthetic in the spermatic cords. The scrotum is thoroughly cleaned with surgical soap and antiseptic. The skin, dartos, and scrotal facia are cut. In closed method, the testis and spermatic cord contained within the parietal layer of the tunica vaginalis are bluntly dissected from the surrounding tissues. The emasculator is placed around the tunica vaginalis and cord and then crushes the contained structures. The emasculator should be left 1-2 minutes after each cord is severed.

In open technique, the tunica vaginalis is freed from surrounding tissues by making an incision through the tunica vaginalis to the cranial pole of the testis. The emasculator is then applied to the cord. To avoid hemorrhage, a non-absorbable suture should be placed around the spermatic cord above the emasculator. The second testis should be removed by the same procedure.
Aftercare needs tetanus antitoxin and antibiotic therapy. Avoid contamination with the flour and control fly infestation till complete healing of the wound. The most common complications reported are hernia, infection and schirrous cord. **Schirrous cord** means a chronic hyperplastic inflammation of the spermatic cord. Infection of the spermatic cord following surgery has been reported. An infected wound may granulate and become prominent with exuberant granulation tissue. It protrudes above normal skin as reddish-brown hemorrhagic tissue oozing a serosanguineous fluid. Tetanus may complicate the case. Surgical interference is recommended by separation of the cord from adjusting tissue by blunt dissection. Following legation all granulated tissues should be cut-off close to the healthy tissue as much as possible. Local and systemic antibiotics are recommended.

**Other Surgical Techniques**

Figure 10: Caesarian section technique.
References


MODIFIED SURGICAL APPROACH FOR CORRECTION OF THE LEFT ABOMASAL DISPLACEMENT

Borut Zemljic Dr.Vet.Med. MrSci PhD

Veterinary Polyclinic Ormoz, Ljutomerska 25, SI 2270 ORMOZ, Slovenia, borut.zemljic@veterina-ormoz.si

Thirty-two dairy cows Holstein-Frisian breed, with left abomasal displacement (LDA), from 17 different farms were surgically treated by using modified surgical approach and right paramedian abomasopexy. Abomasal wall (serosis, l.muscularis and part of submucosis) was sutured together with abdominal wall (peritoneum, internal rectus sheet, rectus muscle, external rectus sheet and fascias) in a simple continuous pattern, subcutaneous tissues was sutured separately. Skin was closed with interrupted "U" pattern.

25 cows were treated during first 24 hours, 5 cows during 48 hours and two cows four days after manifestation of clinical signs. In average LDA was diagnosed on a day 14-post partum (min. 2nd day – max. 33rd day). Animals were surgically treated inside 12 hours after diagnosis was made.

In 31 cases (96.8 %) surgical procedure succeeded. One animal (3.2 %) was culled on the same day, because of abomasal ulcerations and perforation diagnosed during surgery. Seven animals (21.9 %) were culled in a year because of reproduction or production problems.

25 cows (78.1 %) restored normal milk production, got pregnant and started next lactation.

This modified method is quick and efficient; animals were placed in dorsal recumbence for 20 –25 minutes. Only one type of suture material (Polysorb® Double No. 2) was used to fix abomasum and to close abdominal wall. For skin closure non-absorbable No.4 material was used. The efficiency of the method is better then classical ones and comparable to similar studies.

INTRODUCTION

In the working region with about 5500 dairy cows, an incidence of LDA in last five years dramatically increases. By our data an incidence in average is 0.8 % and varies among herds, comparable to some authors (1, 2, 3, 9, 13).

Different surgical techniques are used in Slovenia for correction of displaced abomasum, mostly right paralumbar fossa omentopexy.

Since early sixties of the 20th century right paramedian abomasopexy (RPA) has been accepted as a surgical treatment of choice for LDA correction. Different authors refers recovery rates from 83.5 % to 94.0 % (8, 10, 14) which are slightly higher than in right paralumbar fossa omentopexy (86 % to 92%) (2, 6, 18).

Following some authors (4, 5, 11, 14) different modification of RPA has been described according to abomasal fixation to the ventral abomasal wall and wound closing. We developed an efficient modification of the method, which is quicker and cheaper to handle.

MATERIAL AND METHODS

Using modified right paramedian abomasopexy surgically treated 32 dairy cows Holstein-Frisian breed, with left abomasal displacement, from 17 different farms.
Table 1. Distribution of treated cows related to the onset of clinical signs

<table>
<thead>
<tr>
<th>No. of cows</th>
<th>Surgery performed after manifestation of clinical signs (hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>24</td>
</tr>
<tr>
<td>5</td>
<td>48</td>
</tr>
<tr>
<td>2</td>
<td>96</td>
</tr>
</tbody>
</table>

In average LDA was diagnosed on a day 14-post partum (min. 2nd day – max. 33rd day). Animals were surgically treated inside 12 hours after diagnosis was made.

Cows where sedated with xylazin (Rompun®) 0,042 –0,052 mg/b.w. and placed in dorsal recumbence by using rope. Surgical area was shaved and disinfected. 30 ml of 2% lidocaine (Lurocaine®) was infiltrated into abdominal wall tissues in an incision area. Incision of 10 –15 cm length was made 10 cm caudal from sternum and 10 cm right-lateral from linea alba. Following spontaneously gas decompression, added in some cases with per abdomen compression, the abomasum was placed in to correct anatomical position. A 6 cm of portion of the abomasal greater curvature was incorporated into closure of the ventral abdominal wall.

Abomasal wall (serosis, l.muscularis and part of submucosis) was sutured together with abdominal wall (peritoneum, internal rectus sheet, rectus muscle, external rectus sheet and fascias) in a simple continuous pattern. Special care was taken not to penetrate into abomasal lumen. Subcutaneous tissues were sutured separately with a simple continuous pattern also. Only one type of absorbable suture material (Polysorb® Double No. 2) was used to fix abomasum and to close abdominal wall.

Skin was closed with 3-4 interrupted “U” pattern using non-absorbable No.4 material.

Cows were after surgical procedure turn back in the normal recumbence and were placed in dorsal recumbence for the procedure only for 20 –25 minutes.
Animals were treated with sulphonamides (Borgal® 3ml/kg b.w., i.v.) once on a day 0 and clinically examined on day 1 and 2 and 14 follow-up surgeries.

RESULTS

In 31 cases (96.8 %) surgical procedure succeeded. One animal (3.2 %) was culled on the same day, because of abomasal ulcerations and perforation diagnosed during surgery.

| Table 2. Clinical findings on a day 1, 2, 14 follow-up surgeries |
|----------------------|------------------|------------------|------------------|
| Clinical findings    | No. cows on a day 1 | day 2       | day 14      |
| NT/HT*               | 21/10            | 26/5          | 31/0          |
| NR/PR**              | 22/ 9            | 25/6          | 30/1          |
| Wound condition      |                  |               |               |
| Swelling/Serosity exudation | 31/20 | 31/9 | 7/1 |

* Normal body temperature/ High b.T ≥ 39.2°C  ** Normal ruminations 7-12 per 5 min/ Poor ruminations < 6 per 5 min.

18 (58%) animals started to consume food 8-12 hours after treatment, 13 (42%) after 12-24 hours.

None of those cows was culled in 6-month follow-up surgery.

Seven animals (21.9 %) were culled in a year because of reproduction or production problems.

25 cows (78.1%) restored normal milk production, got pregnant in average109 days post partum (min. 72 – max. 135) and started next lactation.

DISCUSSION

The purpose of this study was to develop quick, cheap but also highly efficient modification of RPA, which could be used in everyday practice. It is generally accepted that paramedian approach to the displaced abomasum is easy and requires less manipulation to return the organ to the normal position (15). Decompression is rarely necessary.

There is little information about time needed for RPA procedure. Some authors mentioned one hour (4), which is quite a long time, considering cow is in no-physiological position. We managed to finish a procedure in 20-25 min. because the incision is smaller, only 10-15 cm, comparing to some authors (11, 14), abdominal wall is closed with only three sutured layers. Suture material we use is strong and reliable and so far it did not cause any complications. Short time needed for surgical procedure (20-25 min) and low cost for suture material make this modification cheaper than classical ones.

Considering clinical finding data in Table 2, cows recovered well with no complications observed. 96.8% recovery rate after the procedure is promising and higher then in similar studies (8,10,14).

Evaluation of restored milk production is difficult because many factors influence it (negative energy balance, metabolic disorders, mastitis etc.), however there seems to be a small, but economically significant, long-term improvement in milk production associated with permanent abomasal fixation (4,5).

Survival rate of 78, 1% in one-year follow-up surgery seems to be a good result comparing to some studies (4,5)
Disadvantages of the modification could be the same as in classical RPA: mesenteric torsion and abomasal volvulus after rolling (7, 12, 16), abomasal fistula (17), and injuries associated with dorsal recumbence, regurgitation and aspiration (15). A good postoperative care should be taken because of the wound position (clean floor, strew). The RPA is not a method of choice if there is a possibility of adhesion of greater curvature to the left abdominal wall.

However, we are aware that 32 cases are maybe insufficient to make firm conclusions, but we think this method follows its purpose.
References

17. Sams A.E., Fubini SL.: Primary repair of abomasal fistulae resulting from right paramedian abomasopexy in eight adult dairy cattle; Veterinary Surgery, 22,3, p.190-193, 1993
Though the origin of Veterinary Medicine dates back to prehistoric times, the modern world’s first veterinary school was opened on January 1, 1762 at Lyon, France by Bourgelat (1712-1779) who had shifted from the practice of law to equine husbandry. The second veterinary school was also established in France by the same person in 1764 at Paris. Another prominent French veterinarian, Saint-Bel (1753-1793), who was forced to flee to England during French revolution, established the London veterinary college in 1791. Most European countries established their national veterinary schools in the next 20 years. During the first half of 19th century many other countries such as U.S.A., Canada, Australia, Turkey etc. also established their veterinary schools. The first veterinary college in the Indian subcontinent was started in Lahore in 1880, then in Bombay (now Mumbai) in 1886, Calcutta (now Kolkata) in 1892, and Madras (now Chennai) in 1903. The establishment of veterinary colleges in Iran, Iraq and most of the middle-east countries started in 20th century along with those in Africa – Egypt (1901), South Africa (1920), Sudan (1938) and Kenya (1949) – and the proliferation continued during the whole of that century. By the end of 20th century India alone had 33 colleges, closely followed by U.S.A. which had 27 colleges. The number of veterinary colleges in the developing countries has markedly increased in the last two decades and the trend is still continuing.

Animal health authorities estimate that within one hundred years of establishment of national veterinary services and schools in Europe several major diseases like Rinderpest, Contagious Pleurapneumonia, Anthrax, Sheep Pox had been eradicated or brought under control, saving millions of lives, averting thousands of millions of dollars in losses, preventing immeasurable human suffering and illness, and providing impetus to Asian and African countries to establish their own veterinary services and schools. However, establishment of new veterinary colleges had earlier been opposed in these countries because of real or unreal fears that we may be producing too many veterinarians particularly because tractors and autos were fast replacing the horse. Similar opposition is now being made for the opening of new veterinary colleges in the developing countries, where animal husbandry is now developing at a much faster rate than before. Similar to what followed the industrial revolution in Europe, the increased demand for livestock products in developing countries is leading to tremendous advances in livestock production, food animal medicine, and processing and marketing of animal products. This, and a tremendous increase in animal experimentation and research, has also increased the demand for veterinary graduates in these countries. This justification for establishment of new veterinary colleges is undeniable. However, under the garb of these justified reasons, a trend is setting in certain places where colleges are being opened without proper planning and provision of short-term and long-term funds necessary to achieve and maintain minimum standards of veterinary education.

It is necessary to realize that a veterinary college is quite expensive to establish. A veterinary teaching hospital, which forms an integral component of teaching, research and extension activities of a veterinary college, is not only expensive to establish but is also expensive to run. Similarly, the establishment and continuous updating of a library is very expensive. So are the other infra-structures like farms, hostels, guest house, canteens, play grounds, and other academic requirements such as a museum.

In their initial over enthusiasm to achieve their political or commercial objectives, the sponsors of some of these new veterinary colleges often fail to make proper planning or take a serious note of all aspects of the essential requirements and their costs (including their possible escalation) and thereby become responsible not only for creating jobless veterinarians but also for lowering the standards of education which in turn may lead to the production of unemployable veterinarians.

Since the new colleges have to coexist with the previously running well established colleges in the same country, it is necessary that all the colleges in a particular country should have uniform curricula,
syllabi, admission procedures, training facilities and teaching standards for easy inter-institutional transfers of students and for easy employability of the graduates in all regions of the country irrespective of their place of graduation. This uniformity of teaching programmes and establishment and maintenance of minimum standards of veterinary education is also essential for inter-country exchange of students and/or graduates for higher education and/or employment. The multifaceted roles that the veterinarians have to play in the present world can be played successfully only if the veterinary colleges in the developing countries make themselves standardized and competitive.

Following suggestions are made to achieve and maintain minimum standards and uniformity in veterinary education in developing countries:-

1. Each country should set up a powerful central statutory autonomous veterinary body (e.g. a Veterinary Council) to govern veterinary education in all veterinary colleges of the country, whether run by governmental or semi governmental bodies or by private individuals or agencies, trusts etc. The President and members of Veterinary Council should be chosen from the most eminent and experienced veterinary academicians of the country not below the rank of a full professor. This body should be free from governmental influence or control and be strictly professional.

2. The Veterinary Council should prescribe the minimum duration of a veterinary degree course and the minimum qualifications essential for admission of a student to the course. (NOTE: In most of the developing countries including India a Veterinary degree course is spread over a duration of 5 years or more, including compulsory internship of at least 6 months duration undertaken after completion of course work. The minimum qualification for admission is a successful completion of 12 years of schooling (10 years for High school and 2 years of Physics, Biology and Chemistry along with other subjects). In the countries where the minimum admission requirement is a High school certificate (after 10 years of schooling), the instruction of Physics, Chemistry and Biology is added to the Veterinary curriculum and the duration of the latter is appropriately increased).

3. The Council should establish uniform procedures of selection for admission of students to the Veterinary Colleges on the basis of merit over and above the minimum qualifications prescribed by it. If administratively feasible, a uniform collective pre-admission test be given to all candidates seeking admission to all colleges of the country every year and admission to colleges of their preference be given on the basis of comparative merit based on the performance at this test. Other admission criteria, based on individual requirements of the concerned countries can also be devised by the Veterinary Councils without unnecessary deviation from the ultimate goal of international uniformity.

4. The Veterinary Council should formulate a standard curriculum and syllabus for the basic veterinary degree, by taking into account the requirements of all regions of the country without forgetting the international developments in Veterinary Medicine and make it obligatory for all the existing veterinary colleges to follow it. Apart from specifying the minimum duration of lectures and practicals for each unit of all types of courses of different subjects, the minimum duration of the semester/academic year should also be specified in terms of actual working days (e.g. 210 days in an academic year, excluding the time spent in examinations). A standardized system of imparting theoretical and practical instruction by the teachers, including procedure for examinations and methods of evaluation of the students, and the exact system of running an internship programme, should also be specified in the curriculum.

5. The Council should fix the minimum number of departments in a college, and the strength of teaching staff, technical supporting staff and non technical staff for each department for up to a fixed number of students (say sixty). Similarly, the minimum building space (number and size of each of the laboratories etc) and the minimum equipment for each department should be specified. The council regulations should make the provision of an appropriate teaching hospital, an instructional / experimental animal house and a library essential and specify the minimum space, staff and equipment for these units. (Note: The Veterinary Council of India –VCI- stipulates 17 departments in a college, and also that a teaching hospital should have an average minimum of 35 outdoor cases daily and 10 indoor cases to get recognition).

6. All the existing colleges should apply to seek approval of the Veterinary Council by submitting details of their infra-structure by a specified date following the introduction of the Council guidelines. The council should send teams of inspectors to verify these details and recommend approval of those
colleges which conform to the minimum requirements laid down in the guidelines. The remaining colleges should be provided one of the following options:

(a) Be given a date bound extension of the time limit to make the necessary improvements so as to remove the deficiencies and reapply for approval.

(b) Be allowed to merge with other unapproved college(s) and apply for fresh approval.

(c) Be asked to close down the college and transfer the students, staff and equipment to the approved colleges.

7. No new veterinary college should be allowed to be opened without the approval of the Veterinary Council. The Council should, while according permission for opening a new veterinary college, take into account a set of its pre-decided conditions such as the requirements of veterinarians vis-à-vis the number of graduates already being produced, the justifiability of its location in the country, assessment of funds guaranteed for short-term and long-term needs of the proposed college, and an irrevocable undertaking to follow the Veterinary Council guidelines in all its academic activities. Following establishment of a new college, the same procedure be followed for its approval in due course of time.

8. The graduate of the approved college should be registered and awarded a registration number and license for practice of Veterinary Medicine as Doctors. Approval of the colleges once approved should be reviewed by the council every 10 years or earlier if they intend to increase their seats beyond the number for which the initial approval was granted, and also when post graduation programmes are introduced.

9. In order to encourage and facilitate mutual exchange of scholars and ideas and for reciprocal utilization of each others’ educational and research facilities amongst the developing countries, it is suggested that a Federation of Veterinary Councils be formed for bringing about the uniformity in their standards for achieving the ultimate goal of an international standardization.

This list of suggestions given here is not exhaustive; but is only a representative of some essential areas of Veterinary education.

In order to provide a base upon which the veterinary faculty of the concerned countries can set their own standards and build their own minimums without losing the ultimate purpose of uniformity, this paper suggests a sample set of minimum requirements in respect of courses, space, staff etc. for a 5-year bachelor’s degree course in Veterinary Medicine. Appendix-1, 2 and 3 list the courses of study, their theory and practical weightage and their semester-wise and department-wise distribution. The detailed course outlines and requirements of space, staff and equipment only for Surgery, Radiology and the Teaching Hospital are given in Appendix 4 to 8. (Details for other subjects can also be made available later.) Appendix-9 lists some general suggestions/comments for academic and administrative staff of the departments and the office of the Dean. These appendices would be made available at the symposium.

* Former Professor of Veterinary Surgery, Ahwaz (Iran), Tripoli (Libya), Maiduguri (Nigeria), Baghdad (Iraq), and Ludhiana (India).
A STUDY ON PROPOFOL ANAESTHESIA IN DOGS

Sayyad Aun Muhammad; Abdul Asim Farooq; M. Saleem Akhtar1; C.S Hayat2

1: Department of Clinical Sciences, Gomal College of Veterinary Sciences, Gomal University, D.I.Khan-Pakistan
2: Department of Bio- Sciences and Pathobiology, Gomal College of Veterinary Sciences, Gomal University, D.I.Khan-Pakistan

Present study was conducted on 12 adult clinically healthy dogs, which were divided into two groups A and B, with 6 animals in each group. In group A propofol @ 6mg/kg B.wt. and in group B Propofol @ 10 mg/kg B.wt intravenously were administered. The depth of anaesthesia was gauged by observing various body reflexes. The effects of above treatments on rectal temperature, respiration and pulse rates were also recorded. The mean duration of anaesthesia (in minutes) in animals of group A and B was 4.67±0.75 and 10.94± 1.20 respectively.

INTRODUCTION

Propofol (2,6-di-isopropylphenol) is an alkyl phenol derivative and a non-barbiturate, non-steroidal hypnotic and intravenous anaesthetic agent. It has short duration of action in small experimental animals (Glen, 1980), horses (Nolan and Hall, 1985), dogs (Watkins et al., 1987) sheep (Waterman, 1988) and cats (Bearly et al., 1988).

The present study was conducted to evaluate Propofol for anaesthesia in dogs.

MATERIALS AND METHODS

Experimental animals

A total of 12 adult, stray dogs of either sex were selected. These animals were divided into two numerically equal groups A and B. All the animals were thoroughly examined to ascertain their health status, and only clinically healthy animals without any physical abnormality were included in the trial.

Preparation of animals

Food and water were withheld 24 and 12 hours respectively prior to the induction of anaesthesia to avoid regurgitation and respiratory embarrassment. Dogs were cast in lateral recumbency, with head slightly lower than the hindquarters. They were allowed to relax for some time to overcome excitement created during casting. The base line respiration, pulse rate and temperature were recorded.

Anaesthetics administration

The animals of group A were administered propofol @ 6mg/kg B.wt. and group B, propofol @ 10 mg/kg B.wt.

The total calculated dose of the anaesthetic solution was administered slowly through cephalic vein. With the start of intravenous injection, the time was noted, and this was used as reference to describe the changes in various parameters.

Criteria of anaesthetic evaluation

The effects of experimental anaesthetic agents on various body reflexes were recorded at 2 minutes interval while respiration, temperature and pulse rate were recorded at 10 minutes interval.

In this study the following parameters were recorded:

1. Body reflexes, which include corneal reflex, pupil reflex, mandibular tone, muscular tone, pharyngeal reflex, tongue pinch reflex, tail flaccidity and anal pinch reflex.
2. Induction time.
3. Duration of anaesthetic stage.
4. Recovery period and nature of recovery.
5. State of respiration, temperature and pulse rate before, during and after induction of anaesthesia.
6. Rate and nature of salivation.
Untoward effect, if any during the various phases of the trial.

RESULTS AND DISCUSSION

In group A propofol was used as an anaesthetic agent @ 6mg/kg body weight intravenously. No side effect was observed. Induction of anaesthesia was rapid and smooth, which is similar to the finding of Genevois et al. (1988) and Flecknell et al. (1990). Changes in the heart rate were insignificant, which is similar to finding of Bufalari (1995). Respiration rate decreased after administration of anaesthesia, which is similar to finding of Portella et al. (1996). Changes in the body temperature were insignificant. This finding is similar is to the finding of Kelawala and Parsania (1992). Recovery from the anaesthesia was smooth and swift which is similar to finding of Short (1987). Recovery from the anaesthesia was faster than thiopentone, which similar to finding of Healy and Cohen (1995).

In group B, propofol was injected @ 10mg/kg B.wt intravenously. Induction was rapid and smooth. All body reflexes disappeared during surgical stage of anaesthesia. Respiration rate decreased rapidly after anaesthetic administration. Apnea of 50 seconds and two minutes was recorded in dog-number 1 and dog-number 2 respectively. This is in agreement with the finding of Healy and Cohen (1995). No nausea and vomiting were recorded during propofol anaesthesia, which is similar to finding of Ronald and Miller (1981). These results show that propofol can be safely used for the induction of anaesthesia in canine in short surgical procedures which need significantly quick recovery and an earlier return of psychomotor function.

TABLES:

Table I. Duration of Surgical Anaesthesia and Nature of Recovery.

<table>
<thead>
<tr>
<th>Groups</th>
<th>No. of animals</th>
<th>Anaesthetic Regimens</th>
<th>Duration of surgical anesthesia</th>
<th>Nature of recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>6</td>
<td>Propofol @ 6mg/kg b. wt. I/V</td>
<td>4.67±0.75</td>
<td>Smooth (n=5) Paddling (n=1)</td>
</tr>
<tr>
<td>B</td>
<td>6</td>
<td>Propofol @ 10mg/kg b. wt. I/V</td>
<td>10.94±1.20</td>
<td>Smooth (n=4) Shivering (n=2)</td>
</tr>
</tbody>
</table>

Table II. Effects of Anaesthetic Administration on Respiration Rate (Mean values ±SEM)

<table>
<thead>
<tr>
<th>Groups</th>
<th>Anaesthetic Regimens</th>
<th>0 minutes</th>
<th>10 minutes</th>
<th>20 minutes</th>
<th>30 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Propofol @ 6mg/kg b. wt. I/V</td>
<td>21.33±2.12</td>
<td>17.00±1.91</td>
<td>19.67±1.50</td>
<td>20.33±1.31</td>
</tr>
<tr>
<td>B</td>
<td>Propofol @ 10mg/kg b. wt. I/V</td>
<td>21.67±1.09</td>
<td>24.17±2.61</td>
<td>21.33±2.17</td>
<td>20.33±0.61</td>
</tr>
</tbody>
</table>

Table III. Effects of Anaesthetics Administration on Body Temperature (Mean values ±SEM)

<table>
<thead>
<tr>
<th>Groups</th>
<th>Anaesthetic Regimens</th>
<th>0 minutes</th>
<th>10 minutes</th>
<th>20 minutes</th>
<th>30 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Propofol @ 6mg/kg b. wt. I/V</td>
<td>101.73±0.17</td>
<td>101.10±0.15</td>
<td>101.10±0.22</td>
<td>101.13±0.11</td>
</tr>
<tr>
<td>B</td>
<td>Propofol @ 10mg/kg b. wt. I/V</td>
<td>100.97±0.27</td>
<td>100.60±0.24</td>
<td>100.43±0.42</td>
<td>100.17±0.36</td>
</tr>
</tbody>
</table>
### Table IV. Effects of Anaesthetics Administration on Pulse Rate (Mean values +SEM)

<table>
<thead>
<tr>
<th>Groups</th>
<th>Anaesthetic Regimens</th>
<th>0 minutes</th>
<th>10 minutes</th>
<th>20 minutes</th>
<th>30 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Propofol @ 6mg/kg b. wt. I/V</td>
<td>85± 4.55</td>
<td>84± 4.95</td>
<td>89.33± 4.70</td>
<td>88.67± 3.78</td>
</tr>
<tr>
<td>B</td>
<td>Propofol @ 10mg/kg b. wt. I/V</td>
<td>98.67± 9.06</td>
<td>100± 7.08</td>
<td>100± 5.43</td>
<td></td>
</tr>
</tbody>
</table>
References


COMPARISON OF PROPOFOL AND KETAMINE HCL ANAESTHESIA WITH PREMEDICATION OF NALBUPHINE HCL IN DOGS.

Sayyad Aun Muhammad; Abdul Asim Farooq; Muhammad Saleem Akhtar1, and C.S Hayat2

1- Department of Clinical Sciences, Gomal College of Veterinary Sciences, Gomal University, D.I.Khan-Pakistan
2- Department of Bio- Sciences and Pathobiology, Gomal College of Veterinary Sciences, Gomal University, D.I.Khan-Pakistan

Present study was conducted on 12 adult clinically healthy dogs, which were divided randomly into two groups A and B with 6 animals in each. In group A, animal were premedicated with nalbuphine HCl @ 1mg/kg B.wt, followed 20 minutes later, Propofol was administered @ 4mg/kg B.wt. intravenously and in group B, nalbuphine HCl @ 1mg/kg B.wt. was given intravenously as premedicant and 20 minutes later Ketamine HCl @10mg/kg B.wt. was administered intravenously. The depth of anaesthesia was gauged by observing various body reflexes. The effects of above treatments on rectal temperature, respiration and pulse rates were also recorded. The mean duration of anaesthesia (in minutes) in animals of group A and B was 10.17± 1.49 and 16.17± 2.89 respectively. The longest duration of anaesthesia was recorded in dogs with nalbuphine HCl 1mg/kg. B.wt. along with ketamine HCl @ 10mg/kg. B.wt (group B). However the quality of induction and recovery was superior in-group A in which nalbuphine HCl was given @ 1mg/kg B.wt. as premedicant with propofol @4mg/kg B.wt.

INTRODUCTION

The dog as an animal occupies a unique and privileged place in our lives as a friend, helper and protector and with no other animal has such a relationship ever existed. A considerable body of literature is available on the efficacies of various anaesthetics in different animals, but information on study of general anaesthesia in canine is scanty and incomplete. There is a risk in applying generalization in canines derived on the basis of other animals. Keeping its fidelity and faithfulness in view, canine rearing is on the increase. The professionals should enable themselves to cope with the aspiration of the owners of the dogs to treat their animals in quiet calm and painless regimen.

Anaesthetics are available for both parenteral as well as inhalation routes in canine surgery. Due to the meager facilities available for field veterinarians in Pakistan, intravenous anaesthetics are preferred because of their early and safe induction. It is a dire need of the hour that efforts should be made to find some other safe and suitable alternative anaesthetics. The proposed study had been designed to evaluate and compare the efficacy of propofol and ketamine HCl with premedication of nalbuphine HCl.

MATERIALS AND METHODS

A total of 12 adult, stray dogs of either sex were selected. These animals were divided into two numerically equal groups A and B. All animals were thoroughly examined to ascertain their health status, and only clinically healthy animals without any physical abnormality were included in the trial.

In group A, animal were premedicated with nalbuphine HCl @ 1mg/kg B.wt, followed 20 minutes later, Propofol was administered @ 4mg/kg B.wt. intravenously and in group B, nalbuphine HCl @ 1mg/kg B.wt. was given intravenously as premedicant and 20 minutes later Ketamine HCl @10mg/kg B.wt. was administered intravenously.

The total calculated dose of the respective anaesthetic solution was administered slowly through cephalic vein. With the start of intravenous injection, the time was noted, and this was used as reference to describe the changes in various parameters.

In this study, the following parameters were recorded:
1. Body reflexes, which include corneal reflex, pupil reflex, mandibular tone, muscular tone, pharyngeal reflex, tongue pinch reflex, tail flaccidity and anal pinch reflex.
2. Induction time.
3. Duration of anaesthetic stage.
4. Recovery period and nature of recovery.
5. State of respiration, temperature and pulse rate before, during and after induction of anaesthesia.
6. Rate and nature of salivation.
7. Untoward effect, if any during the various phases of the trial.

Classification of reflexes

The effect of anaesthetics on various reflexes i.e. swallowing reflex, mandibular tone, corneal reflex, toe pinch reflex, muscular tone. Tail reflex after the administration of anaesthetics was recorded as 3P, 2P, 1P and N in order of decreasing response. The P stands for positive and (N) for negative. Hence the 3P represents the normal reflex, 2P moderately sluggish (light anaesthesia). 1P sluggish (medium anaesthesia) while N as almost complete absence of reflexes, indicates perfect anaesthesia with complete relaxation of muscles i.e. surgical anaesthesia. The reappearance of reflexes after a period of absence was noted and vice versa i.e. 1P, 2P and 3P showing in order of increasing response (Athar et al. 1996).

RESULTS AND DISCUSSION

In group A, animal were premedicated with nalbuphine HCl @ 1mg/kg B.wt, followed 20 minutes later, Propofol was administered @ 4mg/kg B.wt. intravenously. The induction of anaesthesia was rapid and smooth, which is similar to the finding of Genevois et al. (1988) and Flecknell et al. (1990). Changes in heart rate after the administration of anaesthetic drug were insignificant, which is similar to the finding of Short and Buflari et al. (1999). Respiration rate decreased after the administration of anaesthetic agents, which is similar to the findings of Portella et al. (1996). Changes in body temperature were insignificant. This is similar to the findings of Kelwala and Parsania (1992). Recovery from anaesthesia was smooth and swift which is similar to the finding of Short (1999). No apnea was observed in any dog of group B, which is similar to the findings of Healy and Cohen (1995).

These results show that propofol can be safely used for the induction of anaesthesia in canine in short surgical procedures which need significantly quick recovery and an earlier return of psychomotor function. No nausea and vomiting were reported during propofol anaesthesia, which is quite similar to the findings of Ronald and Miller (1981).

In group B, nalbuphine HCl @ 1mg/kg B.wt. was given intravenously as premedicant and 20 minutes later Ketamine HCl @10mg/kg B.wt. was administered intravenously.

Induction was rapid and smooth in all animals. Corneal, canthal and anal sphincter reflexes were reduced to moderately sluggish (2P) after the administration of anaesthetic agent. Ketamine HCl was also used alone as an anaesthetic agent in the past by various workers (Short, 1999; Kumar et al., 1995; Muir and Hubbel, 1991). Body temperature in this group increased slightly during anaesthesia, which is in accordance with finding of Kelawala et al (1992). Heart rate increases in all animals during anaesthesia. These finding are in accordance with result of Short. (1999) Kelawala et al. (1992) Portella et al. (1996) Muir and Hubbel (1991). Respiration rate decreased after the induction of anaesthesia but increased during the recovery period. This in agreement with the finding of Kumar et al., (1995) Kelawala et al. (1992) Portella et al. (1996). These results showed that administration of ketamine with nalbuphine HCl prevents respiratory depression. Nalbuphine HCl also reduced the dose of ketamine HCl required for the induction of anaesthesia but its administration with ketamine HCl changed the nature and duration of recovery from anaesthesia. These results also indicated that ketamine HCl and nalbuphine HCl combination produced increase in heart rate, body temperature. Salivation of mild degree was also observed in one animal during anaesthesia.

CONCLUSIONS

While comparing the results of the three groups, ketamine HCl showed longest duration of anaesthesia but recovery was not smooth. On the other hand, propofol showed rapid coordinated induction and recovery.
### Appendix 1. Duration of surgical anaesthesia and Nature of recovery.

<table>
<thead>
<tr>
<th>Groups</th>
<th>No. of animals</th>
<th>Anaesthetic Regimens</th>
<th>Duration of surgical anesthesia</th>
<th>Nature of recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>6</td>
<td>Nalbuphine HCL 1mg/kg b. wt. I/M. Propofol 4mg/kg b. wt. I/V</td>
<td>10.67± 1.49</td>
<td>Smooth (n=5) Paddling (n=1)</td>
</tr>
<tr>
<td>B</td>
<td>6</td>
<td>Nalbuphine HCL 1mg/kg b. wt. I/V. Ketamine HCl. 10 mg/kg b. wt. I/V</td>
<td>16.17± 2.89</td>
<td>In coordination (N)=6</td>
</tr>
</tbody>
</table>

### Appendix ii. Effects of Anaesthetic Administration on Respiration Rate (Mean values +SEM)

<table>
<thead>
<tr>
<th>Groups</th>
<th>Anaesthetic Regimens</th>
<th>0 minutes</th>
<th>10 minutes</th>
<th>20 minutes</th>
<th>30 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Nalbuphine HCL 1mg/kg b. wt. I/M. Propofol 4mg/kg b. wt. I/V</td>
<td>19.67± 0.87</td>
<td>17± 1.13</td>
<td>18± 0.69</td>
<td>19± 1.46</td>
</tr>
<tr>
<td>B</td>
<td>Nalbuphine HCL 1mg/kg b. wt. I/V. Ketamine HCl. 10 mg/kg b. wt. I/V</td>
<td>25.6± 1.93</td>
<td>24± 1.78</td>
<td>26.4± 0.74</td>
<td>26.2± 0.91</td>
</tr>
</tbody>
</table>

### Appendix iii. Effects of Anaesthetics Administration on Body Temperature Mean values +SEM)

<table>
<thead>
<tr>
<th>Groups</th>
<th>Anaesthetic Regimens</th>
<th>0 minutes</th>
<th>10 minutes</th>
<th>20 minutes</th>
<th>30 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Nalbuphine HCL 1mg/kg b. wt. I/M. Propofol 4mg/kg b. wt. I/V</td>
<td>101.5± 0.44</td>
<td>101.7± 0.3</td>
<td>101.26± 0.45</td>
<td>101.6± .43</td>
</tr>
<tr>
<td>B</td>
<td>Nalbuphine HCL 1mg/kg b. wt. I/V. Ketamine HCl. 10 mg/kg b. wt. I/V</td>
<td>101.08± 0.19</td>
<td>101.16± 0.37</td>
<td>101.28± 0.24</td>
<td>101.32± 0.23</td>
</tr>
</tbody>
</table>

### Appendix iv. Effects of Anaesthetics Administration on Pulse Rate (Mean values +SEM)

<table>
<thead>
<tr>
<th>Groups</th>
<th>Anaesthetic Regimens</th>
<th>0 minutes</th>
<th>10 minutes</th>
<th>20 minutes</th>
<th>30 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Nalbuphine HCL 0.5mg/kg b. wt. I/M. Propofol 4mg/kg b. wt. I/V</td>
<td>95.67± 10.72</td>
<td>110± 7.12</td>
<td>103.33± 6.88</td>
<td>101.33± 7.93</td>
</tr>
<tr>
<td>B</td>
<td>Nalbuphine HCL 1mg/kg b. wt. I/V. Ketamine HCl. 10 mg/kg b. wt. I/V</td>
<td>114.8± 10.51</td>
<td>141.6± 15.59</td>
<td>132.4± 9.37</td>
<td>130± 9.4</td>
</tr>
</tbody>
</table>
References


