Tutorial Article

Ultrasound-aided tendon and ligament surgery in the horse

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Introduction

Image-guided surgery refers to any surgical procedure involving the intraoperative use of a representation of patient anatomy obtained via imaging techniques or computerised methods. These representations are used for real-time visualisation of targeted tissues and structures, as well as physical alteration with surgical tools and instruments. In recent decades, there has been a continuing shift toward less invasive interventional and surgical protocols and an associated increase in demand for imaging and computerised guidance/navigation technologies (Chandler et al. 1982; Gronningsaeter et al. 1996; Lindseth et al. 2002; Chen et al. 2005). There is also an increasing availability of sophisticated imaging tools specifically designed for intraoperative use, with the advent of more user-friendly surgical navigation technologies.

Ultrasound imaging is a relatively low-cost, nonionising, readily available, noninvasive imaging technique that makes use of ultrasound to image the patient's body (Lutz and Mendt 1984). Ultrasound is also a valuable tool for guiding a variety of surgical interventions. The technique enables the surgeon to guide the surgical instrument accurately to the desired anatomical structure with a minimum of trauma to the surrounding structures (soft tissues, cartilage and bone).

Ultrasound-aided surgery was first reported in human surgery (Chandler et al. 1982; Staren 2004; Kavia and Rottenberg 2005) and then adapted in veterinary medicine, first for procedures such as liver and kidney biopsies and location of abscesses (Modransky 1986; Sellon et al. 2000). There is also an increasing availability of sophisticated imaging tools specifically designed for intraoperative use, with the advent of more user-friendly surgical navigation technologies.

Requirements for ultrasound-aided surgery

A good understanding of the basics of ultrasonography and of 2-dimensional imaging is necessary for ultrasound-aided surgery. Appreciation of the visualisation of instrument movement on ultrasonogram is mandatory, and training can be performed for example on cadaver limbs to acquire the necessary skills and sensations.

The equipment needed for ultrasound-aided tendon and ligament surgery includes a 7.5 MHz or a focused 5 MHz real-time sector or linear ultrasound probe, sterile, water-soluble nonirritant lubricant, sterile surgical sleeve to protect the ultrasound probe and cable and maintain sterility at the surgical site, sterile surgical gloves, sterile leg bandage material, appropriate surgical instruments, blades and needles. In addition, higher frequency probes from 8–15 MHz can also be used and may refine the surgeon's movements in small structures.

Applications of ultrasound-aided tendon and ligament surgery in the horse

Tendon and ligament surgery is certainly the equine orthopaedic surgical field where ultrasonography was most used to perform minimally invasive surgical procedures (Allen 1992; Henninger et al. 1992; White 1995, 1998; Dabareiner et al. 2000, Tnibar 2001, 2006; McGhee et al. 2005; Hewes and White 2006). There are several applications of tendon- and ligament-aided surgery in the horse: tendon splitting (digital flexor tendons), ligament splitting (medial patellar, suspensory palmar/plantar annular and inferior check ligament), intratendinous/ligamentous therapeutic injection, tendon sheath/bursa injection or aspiration, desmotomy (inferior check ligament, palmar/plantar annular ligament), tenotomy (deep digital flexor tendon) and enthesopathic surgery.
Ultrasound-aided tendon splitting

Tendon splitting for the treatment of tendon and ligament injuries in the horse was first reported by Asheim (1964, 1967).

Ultrasound-guided tendon splitting has been used in horses in recent decades (Allen 1992; Henninger et al. 1992; White 1998; Dabareiner et al. 2000; Tnibar 2006). A major indication of ultrasound-aided tendon splitting is acute digital flexor tendonitis with core lesions whether they are located within or outside the tendon sheath (Henninger et al. 1992). White (1998) reported the benefit of tendon splitting in horses with chronically painful and enlarged tendons, even months after the initial injury.

The rationale of tendon splitting is to create a communication between the tendon core and peritendinous tissues that ‘decompresses’ the core lesion, allowing evacuation of accumulated inflammatory fluid and promotes vascular ingrowth within the lesion (Henninger et al. 1992). It is hoped that this decompression would prevent the development of excessive scar tissue as the tendon heals. Percutaneous tendon splitting involves multiple stab incisions into the swollen portion of the tendon to decompress the core lesion.

The equipment needed for such surgery is the same as previously described. Clipping or shaving and aseptically preparing the involved limb are imperative. The technique can be performed on a standing horse or under general anaesthesia for intractable horses and for lesions within a tendon sheath. When the procedure is performed standing, the horse is sedated and a high 4-point nerve block is completed with local anaesthetic.

A 7.5 MHz or a focused 5 MHz real-time sector or linear ultrasound probe is covered with sterile nonirritant lubricant and placed within a sterile surgical sleeve. The sterile lubricant is placed over the aseptically prepared palmar/plantar aspect of the limb (Fig 1). The superficial/deep digital flexor tendon is then visualised in the transverse plane. The splitting incisions using a No. 11 scalpel blade or a splitting knife should start at the most distal aspect of the tendinous lesion and proceeding proximally to avoid blood contamination of the following splitting incision.

The blade is inserted into the medial or lateral aspect of the tendon, perpendicular to the ultrasound probe. The blade is located and observed within the core lesion (Fig 2) and should split the lesion and avoid damaging normal tendon fibres. The blade is removed and subsequent splitting incisions are made to split the entire length of the core lesion. These incisions are not sutured and a sterile support bandage is placed on the limb and changed 24 h later. Support bandage is maintained for 2 weeks until healing of the splitting incisions. Usually nonsteroidal anti-inflammatory drugs are administered to help avoid complications such as excessive swelling, pain and lameness at the walk. Horses tolerate the procedure well without significant complication. Ultrasound-guided splitting is easy to perform, allows precise visualisation of the scalpel as it is directed into the core lesion and hence ensures that the entire core lesion is decompressed and minimises damage to surrounding normal tendon fibres.

Ultrasound-aided intratendinous/ligamentous therapeutic injection

Ultrasound-aided intratendinous/ligamentous therapy is becoming increasingly used in equine medicine (Dabareiner et al. 2000; Smith et al. 2003). Indications of ultrasound-aided intratendinous/ligamentous therapy are core lesions (tendonitis, desmitis) within any of the palmar (plantar) soft tissue structures of the distal limb. This procedure is used to inject stem cells, growth factors (i.e. insulin-like growth factor), bioresorbable scaffolds, or medication such as hyaluronic acid or corticosteroids within the tendinous/ligamentous lesion.

Ultrasound-guided tendon and ligament therapeutic injections enhance the accuracy of intralesional treatment by allowing precise deposition of medication within the core lesion thereby maximising the accuracy of the treatment and

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**Fig 1:** Ultrasound-aided splitting using a No. 11 scalpel blade in a horse with superficial digital flexor tendonitis. Ultrasound probe and cable are covered by a sterile surgical sheath.

**Fig 2:** Transverse ultrasonographic image of a superficial digital flexor tendonitis with the surgical blade visualised into the core lesion during tendon splitting.
minimising damage to normal surrounding tendon/ligament fibres.

The therapeutic injections can be performed on a standing horse or under general anaesthesia when the patient is intractable or when the lesion is within a tendon sheath. On a standing horse, it is highly recommended to achieve the therapeutic injection with the limb weightbearing as this minimises movement, tenses the tendon and makes easier concurrent placement of the needle and ultrasound transducer in line with the needle.

The same limb preparation and materials are required as for the tendon splitting procedure with appropriate needles. The injection is performed in a sterile fashion under standing sedation using ultrasonographic guidance (Fig 3).

The mesenchymal stem cells can be used for tendinous/ligamentous core lesions within 3 months after injury (Smith et al. 2003). These cells are injected in 2–5 sites depending on the nature of the core lesion and more advanced healing requires more injection sites (Smith et al. 2003). Extracellular matrix, a bioresorbable scaffold, has been injected as powder under ultrasound guidance in horses with tendon and ligament injuries (Mitchell 2006). Hyaluronic acid is injected intra- or peritendinously (Dabareiner et al. 2000) and corticosteroids are used in acute (less than 4–6 weeks duration) hindlimb proximal suspensory desmitis (Dyson 2006). Triamcinolone is the one of the most recommended corticosteroids for intratendinous/ligamentous therapeutic injection in the horse.

After the therapeutic injection, the limb is then bandaged to minimise loss of injected cells or medication from the tendon.

**Tendon sheath/bursa injection or aspiration**

Ultrasonographic guidance has highly improved tendon sheath (bursa) injection or aspiration in man (Sofka et al. 2001). In the horse, ultrasonography is readily used for guidance into tendon sheath/bursae especially deep tendinous bursae, e.g. bicipital bursa (Tudor et al. 1998; Tinbar 2006) (Fig 4).

**Ultrasound-aided ligament splitting**

In the horse, ultrasonography has been used as a guide for medial patellar, suspensory, palmar/plantar annular and inferior check ligament splitting.

**Medial patellar ligament splitting (MPLS)**

Medial patellar ligament splitting is a recently described surgical procedure for the treatment of upward fixation of the patella (UFP) (Tinbar 2001). This surgical technique is indicated in horses and ponies with UFP unresponsive to conservative treatments, including cases with severe or mild forms of the condition, as well as cases with subtle delayed release of the patella. The surgical procedure was first reported with horses under general anaesthesia (Tinbar 2001) and, recently, Reiners et al. (2005) reported the procedure on the standing horse, which should encourage more equine practitioners to perform this surgery.

The rationale for MPLS is to induce a localised desmitis, without transecting the ligament, which subsequently leads to a localised thickening of this ligament (Tinbar 2002, 2003). This will disable the proximal part of this ligament to hook easily over the notch of the medial femoral trochlea, thus preventing UFP. This surgical procedure abolished UFP even in cases with conformation abnormalities (straight hindlimb). The clinical effects of this surgical technique were attributed to the increase in size of the proximal third of the medial patellar ligament resulting from the induced surgical desmitis.

Under general anaesthesia, horses are placed in dorsal recumbency. Both hindlimbs are suspended under complete extension to hook and subsequently tense the medial patellar ligament over the medial femoral trochlea. The surgery site is shaved and surgical skin preparation is performed. Horses undergo an ultrasound-guided percutaneous splitting of the proximal third of the medial patellar ligament using a surgical knife with a No. 15 blade. The ultrasonographic transducer is placed transversely over the proximal part of the medial
patellar ligament and the blade is introduced longitudinally into the ligament in a craniocaudal direction (Fig 5). The blade is fully visualised as it enters the ligament, progresses into it and throughout the splitting procedure (Fig 6). The blade enters the medial patellar ligament, but should not proceed through the femoropatellar synovial pouch, which lies immediately under the ligament, nor through the articular cartilage of the medial femoral trochlea. The blade is then fanned 45° proximally, then distally, laterally and medially. Fanning the blade medially and laterally will sever fibres, and these incisions are approximately 3–5 mm in length. The procedure is repeated at approximately 5 mm increments until the entire length of the proximal third of the medial patellar ligament, as determined by intraoperative ultrasonography, has been split. Splitting is not performed on the parapatellar fibrocartilage. The largest skin incisions are sutured and a sterile bandage is applied over the surgery site. Perioperative antibiotics are used for 5 days, but no anti-inflammatory drug is administered.

Long-term follow-up showed that this surgical procedure is highly successful in the treatment of UFP with a success rate of 95.5% and no short- or long-term complications were observed (Tnibar 2005). Performing this surgery on the standing horse has also resulted in highly successful outcome (92%) and no complications were reported (Reiners et al. 2005).

**Suspensory ligament (SL)**

Suspensory desmitis also benefits from the effects of ultrasound-aided splitting. Ultrasound-aided SL splitting has been used for mid-body and suspensory branch core lesions (White 1998; Dabareiner et al. 2000; Dyson 2006; Tnibar 2006). Recently, White (2003) has described ultrasound-guided percutaneous ligament splitting for the management of chronic hindlimb proximal suspensory desmitis, with encouraging results. Bathe (2004) reserved this procedure for chronic or nonresponsive cases of mid-body and suspensory branch injuries, especially where there has been the persistence of a hypoechoic core lesion and for restrictive fibrosis of the suspensory branches.

This procedure is similar to tendon splitting and is often performed on standing horse for mid-body and suspensory branch (Fig 7) injuries. However, for proximal suspensory desmitis, the procedure is recommended for the horse under general anaesthesia to ensure accurate blade placement and to avoid palmar/plantar vessels and nerves (White 1998). Though not visualised, the linear placement of the incisions (desmoplasty) creates a fasciotomy as part of this procedure (White 2003). Hewes and White (2006) reported that 85% of horses with proximal suspensory desmitis that did not respond to stall rest were able to return to full work after desmoplasty with fasciotomy. Suspensory ligament lesions at the attachment of the sesamoid bone are also best done under general anaesthesia (White 2003).

When injury involves bone attachment of the SL, ultrasound guidance allows splitting with puncture along the bone attachment (White 2003). In cases in which fibres are avulsed off the sesamoid bone, the surgeon splits the suspensory branch down to the bone by guiding the blade in the core lesion to the SL attachment (White 1998).

![Fig 5: Ultrasound-aided percutaneous splitting of the proximal third of the medial patellar ligament on a standing horse.](image1)

![Fig 6: Sagittal ultrasonographic image of the medial patellar ligament with the surgical blade visualised into the ligament during ligament splitting.](image2)

![Fig 7: Ultrasound-aided splitting of the lateral branch of the suspensory ligament using a No. 15 surgical blade.](image3)
Palmar/plantar annular ligament (PAL)

PAL splitting and fasciotomy, also called PAL desmoplasty, is indicated for horses with primary desmitis of the PAL that do not respond to conservative treatment and do not have any evidence of constriction of the digital flexor tendons (McGhee et al. 2005). These horses have ultrasonographic thickening of the PAL, with or without abnormal fibre pattern. In a study, 20 of the 25 horses with primary desmits of the PAL had hypoechoic lesions within the thickened PAL (McGhee et al. 2005).

PAL desmoplasty is performed under ultrasound guidance and a scalpel is used to transcutaneously split the hypoechoic lesions within the thickened ligament (McGhee et al. 2005). The ligament is carefully incised but not transected.

Incisions can be made perpendicular to the fibres of the PAL and approximately 50% of the thickness of the ligament is transected or the incisions are made parallel to the ligament fibres and abaxial to the lesion. The lesion is entered without transecting any part of the ligament and without penetrating the digital sheath or superficial digital flexor tendon (McGhee et al. 2005). Skin incisions are not sutured and a sterile bandage is applied over the limb.

McGhee et al. (2005) reported that PAL desmoplasty appears subjectively to result in less tendon sheath deformity than PAL desmotomy.

Inferior check ligament (ICL)

Acute core lesions of the ICL are rarely an indication for splitting, since most of these lesions heal without surgery. Splitting the affected ligament under ultrasound guidance is reserved for lesions that are refractory to rest and intralesional injection, where the desmitis is still apparent after 2 months of rest and conservative therapy (White 1998; Dabareiner et al. 2000).

As with the SL, splitting of the ICL desmitis can be performed on standing horse, unless the defect is in the proximal part of the ligament, which will require general anaesthesia to avoid cutting the large palmar vessels (White 1998).

Ultrasound-aided desmotomy

In the horse, desmotomy of the inferior check ligament and of the palmar/plantar annular ligament have been performed under ultrasound control.

Inferior check ligament

There are several indications for ICL desmotomy: 1) acquired distal interphalangeal joint flexural deformity (Type I, if not responsive to conservative treatment and Type II [severe form]); 2) acquired metacarpo/metatarso-phalangeal joint flexural deformity; 3) inferior check ligament desmitis (if unresponsive to conservative treatment) and 4) chronic rotation from laminitis (McIlwraith and Fessler 1978).

Limb preparation is similar as for completing tendon splitting and stringent asepsis is mandatory. The surgical site is located at the proximal-third juncture between the carpus and fetlock, where there is an adequate separation of the inferior check ligament from the deep digital flexor tendon.

In foals and in intractable horses, surgery is performed under general anaesthesia, in dorsal or lateral recumbency, depending on the surgeon’s preference. However, in most horses, this surgery is completed on standing horse with local anaesthesia using high 4-point nerve block (White 1995).

Under ultrasound guidance, the lateral approach is the best one on the standing horse. The advantages of the lateral approach are avoidance of the major vasculature, which is medial at this level, and the more lateral position of the ICL. The author finds that the major advantage of the medial approach is cosmetic. A 1–1.5 cm incision is made on the lateral surface of the metacarpal region at the level where the ICL separates from the deep digital flexor tendon.

Following the technique described by White (1995), a first curved mosquito forceps is introduced under ultrasound guidance through the incision then between the palmar aspect of the ICL and the dorsal aspect of the deep digital flexor tendon (DDFT) and is used to separate the fascia between these structures (Fig 8). A second curved mosquito forceps is introduced in the same way between the dorsal aspect of the ICL and the palmar aspect of the suspensory ligament. The forceps that is located palmarly to the ICL will be turned to help retract the ICL then both forceps are used to isolate the ICL and to pull it toward the skin incision. An assistant is useful to hold the first forceps slightly palmarly to allow cutting the ICL. The author prefers using Metzenbaum scissors to transect the ligament between both forceps. Ultrasonography is then used to check that all the ICL was

Fig 8: Transverse ultrasonographic image at the level of the inferior check ligament showing the haemostatic forceps (arrow) visualised between the inferior check ligament and the deep digital flexor tendon.
transected, knowing that air into the surgical wound may make this imaging difficult. Only the skin incision is sutured and a sterile bandage is applied over the limb until the skin sutures are removed. The cosmetic results are much better than in the open incisional procedure. A corrective shoeing is often used to improve the final result and to ensure success in some cases (White 1998). White (1995) reported that ultrasound aided ICL desmotomy offers the following advantages in comparison with incisional technique: 1) limits incision size, 2) decreases incision morbidity and 3) decreases post operative scarring.

**Palmar/plantar annular ligament (PAL)**

The PAL can undergo ultrasound-guided desmotomy. This minimally invasive surgery is indicated in horses with annular ligament syndrome (constriction of the digital flexor tendons, primary desmitis of the palmar/plantar ligament) that are unresponsive to conservative treatment and that do not have digital flexor tendons adhesions (McGhee et al. 2005) (Fig 9).

Surgery may be performed on the standing horse but general anaesthesia is preferable (Tnibar 2006). A 1 cm paramedial skin incision is performed over the proximal edge of the PAL and the ligament can be incised under ultrasound guidance using Metzenbaum scissors (Fig 10). If performed correctly, this technique prevents opening of the tendon sheath. Hawkins and Churchill (1998) described an extrasynovial PAL desmotomy through a 2 cm skin incision directly on the palmar-plantar midline. Because the desmotomy is performed over the midline in this approach, ultrasound guidance is possible but helps less than for the first approach.

Ultrasound-aided PAL desmotomy may offer a less invasive method for the surgical treatment of PAL syndrome that may offer patients an expedited recovery.

**Ultrasound-aided tenotomy**

Tenotomy of the deep digital flexor tendon (DDFT) is usually indicated as a salvage procedure (breeding, pasture soundness) for horses with chronic refractory laminitis and may benefit horses with acute laminitis, characterised by progressive, severe distal phalangeal rotation or sinking, or horses with recurrent sepsis and osteomyelitis of the distal phalanx (Goetz 1989; Hunt et al. 1991).

Furthermore, a DDF tenotomy can be used in cases of Stage II of distal interphalangeal joint flexural deformities that do not respond to an ICL desmotomy or are considered to be very severe (Fackelman et al. 1983).

This surgery can be performed in either the standing or recumbent horse. Ultrasound guidance is very helpful in

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**Fig 9**: Transverse ultrasonographic image of a primary plantar annular ligament (PAL) desmitis (arrow), which is an indication of PAL desmotomy. SDF = superficial digital flexor tendon; DDF = deep digital flexor tendon.

**Fig 10**: Transverse ultrasonographic image showing ultrasound-aided plantar annular ligament (PAL) desmotomy using Metzenbaum scissors (arrow) through a small stab incision. SDF = superficial digital flexor tendon; DDF = deep digital flexor tendon; SB = sesamoid bone.

**Fig 11**: Ultrasound-aided tenotomy of the deep digital flexor tendon at mid metacarpus.
performing such surgery. Surgical preparation is similar to tendon splitting. The surgical technique can be performed either at the level of the mid-metacarpus/metatarsus or at the pastern, although a DDF tenotomy performed at the pastern level may produce a more cosmetic result. DDF tenotomy should be performed at the level of the mid-metacarpus/metatarsus initially and subsequently in the region of the pastern, if a repeat tenotomy is required. In the mid-metacarpal region, there is less risk of surgical infection as the tenotomy is accomplished outside the tendon sheaths.

Under local anaesthesia and stringent asepsis, a 1–1.5 cm skin incision is needed directly over the lateral aspect of the DDFT, thereby limiting the suturing required for closure. The position of the incision should be distal to the distal edge of the ICL and is determined by the ultrasonographic examination. Using Metzenbaum scissors, the DDFT is easily transected under ultrasound guidance (Fig 11). Care should be taken while transecting the medial aspect of the tendon near the median artery. Ultrasonography is very useful to perform a safe tenotomy (Fig 12). Only the skin is sutured, and a sterile and compressive bandage is applied over the limb.

The procedure can be performed in the pastern region where stringent asepsis should be observed because the digital sheath will be opened. In this region, the surgery is preferably performed under general anaesthesia; however, it is possible to perform it on a standing horse (Fig 13). A small skin incision is performed over the lateral edge of the DDFT. Under ultrasound guidance, Metzenbaum scissors are introduced in the wound and perforate the digital sheath and transect the tendon (Fig 14). With a small incision in the tendon sheath, synovial sinus formation is less likely and, on the standing horse, the author sutures only subcutaneous tissue and skin.
and a sterile and compressive bandage is applied on the limb. Nonsteroidal anti-inflammatory drugs and antibiotics are administered to the patient. In severe cases of distal interphalangeal joint flexural deformities, in conjunction with surgery, corrective shoeing in necessary and hoof acrylic is recommended to protect the foot. If tenotomy of the DDFT results in marked elevation of the toe during weightbearing, especially when treating laminitis, application of a shoe with heel extension is necessary.

**Enthesopathic surgery**

Entheses are sites of tendon and ligament attachment to bone and enthesisopathy is a disease process occurring at these sites. Ultrasound guidance may be a valuable help to treat some enthesopathies in the horse (Tnibar 2006). The author has used ultrasound guidance to remove traumatic avulsion fracture of the patella at the proximal insertion of the lateral patellar ligament (Fig 15).

**Discussion**

In recent years, minimally invasive techniques have become the standard of care for multiple procedures in man. Coincident with the widespread use of ultrasonography in the human surgical field over the last several years, indication has grown to include numerous other diagnostic, interventional, and even therapeutic uses (Staren 2005). Ultrasonography is used in all areas of general surgery and many surgical subspecialties (Staren 2005).

In the horse, ultrasound-aided orthopaedic surgery allows several applications (Tnibar 2006): tendon and ligament surgery, joint surgery, enthesisopathic surgery, foreign body removal, intraoperative fistula tract location and other applications such as surgical wound follow-up.

Tendon and ligament surgery is the equine surgical orthopaedic field where ultrasonography can be mostly used to perform minimally invasive surgical procedures such as tendon and ligament splitting, desmotomy, tenotomy, enthesisopathic surgery, intratendinous/ligamentous therapeutic injection, tendon sheath/bursa injection or aspiration. However, little attention has been given to ultrasound-aided tendon and ligament surgeries in the horse (Allen 1992; Henninger et al. 1992; White 1995, 1998; Dabareiner et al. 2000; Tnibar 2001; McGhee et al. 2005; Tnibar 2006; Hewes and White 2006).

Ultrasound-aided surgery requires from the surgeon a good understanding of the basics of ultrasonography and of 2-dimensional imaging. By allowing surgeons to essentially see through the body to the site of interest in 3 dimensions, the new ultrasound scanners could make such ultrasound-aided surgery easier to perform and eventually more precise. In addition, new intraoperative transducers should be designed for equine surgery to handle the surgeon’s needs.

The surgeon with ultrasound skills brings a number of advantages to clinical practice, including the ability to view dynamic images that are far superior to the interpretation of static ultrasound images. Ultrasound-aided surgery offers the advantages of minimally invasive surgery, which include reduced incisional morbidity/surgical time/cost, better cosmetic appearance and surgery under local anaesthesia for older horses.

In the horse, ultrasound-aided tendon and ligament interventional procedures are safe, easy to perform, have several indications, can be performed on an outpatient basis and sometimes under field conditions and are less invasive than many others.

**References**


