Tutorial Article

Full body support sling in horses. Part 2: indications

A. ISHIHARA*, J. E. MADIGAN†, J. D. HUBERT‡ AND R. S. MCCONNICO‡

The Ohio State University, College of Veterinary Medicine, 601 Vernon L. Tharp Street, Columbus, Ohio 43210; †University of California Davis, School of Veterinary Medicine, Davis, California 95616; and ‡Louisiana State University, School of Veterinary Medicine, Baton Rouge, Louisiana 70803, USA.

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Introduction

The first report of using a full body support sling for fracture healing was several centuries ago (Pauli *et al.* 1994; Schatzmann 1998) and is used for various therapeutic purposes. The equine sling has substantially assisted helicopter rescues and anaesthetic protocols when assistance in induction or recovery are required. As equipment and quality of sedation have developed, the equine sling has become a more useful and practical method in a variety of clinical situations (Schatzmann 1998).

Practical indications

Rescue

One of the most difficult circumstances in equine rescue is the horse that becomes stranded in a relatively inaccessible location, such as those that fall into a large hole or cavity, become trapped in snow or stranded in a flood (Madigan and Moore 1995; Cox 1998). Helicopter-assisted rescue has been previously attempted in a number of horses without incident (Bowman 1995; Madigan and Moore 1995; Madigan and Morgan 1995). These rescue manoeuvres can be safe and successful if the location is accessible, the horse sufficiently sedated and is carried out by experienced personnel (Madigan and Moore 1995; Cox 1998).

The U.C. Davis-Anderson sling[1] (**Fig 1**) was designed with this in mind and is considered to be the most appropriate full body support sling to use in equine airlift rescue (Madigan 1993; Madigan and Moore 1995). The frame system of the U.C. Davis-Anderson sling secures neck movement to make the horse more comfortable under deep sedation, and the leg supports minimise pressure over the abdomen allowing the horse to breathe with greater ease during suspension (Bowman 1995; Madigan and Moore 1995; Strickland 2001). A cargo net may be used for helicopter rescue; however, a horse placed in the net may encounter problems on landing and there is the added danger of falling from the net.

Fig 1: Horse rescue from a flood using a U.C. Davis-Anderson sling.

Chemical restraint is important for a helicopter rescue to minimise further injury to the patient (Madigan and Morgan 1995). Administration of detomidine (0.005–0.02 mg/kg bwt bwt) followed by butorphanol (0.01–0.02 mg/kg bwt) are recommended, which can be reversed by yohimbine (0.12 mg/kg bwt) after transport. Sedation in mules is generally more difficult and may require acetylpromazine premedication

*Author to whom correspondence should be addressed.

(0.03–0.06 mg/kg bwt). The appropriate doses are determined by bodyweight, temperament and circumstances, because cardiovascular changes induced by an over-dose of sedative may produce hypotension, abnormal gut motility and alteration in tissue perfusion (Madigan and Morgan 1995).

The protocol of helicopter rescue has been previously described (Madigan 1995; Madigan and Morgan 1995):

- Following jugular catheter placement and administration of appropriate sedation, the sling is applied and the helicopter called.
- After blindfold and nose twitch application, the sling is attached to the helicopter.
- The twitch is removed and the horse lifted just above the ground.
- The sling is re-evaluated to ensure all attachments fit correctly and securely.
- The horse is then transported to the receiving site and is blindfolded during flight.
- The horse should be landed slowly on an area with good footing and limited dust and debris, and the sling and blindfold are then removed.
- Supportive therapies and drug reversal may need to be administered depending on the systemic conditions of the horse.
- Protective equipment such as hard hat, goggles and ear plugs should be worn for those under the helicopter and all safety aspects taken into consideration.

Anaesthesia induction

During induction of equine general anaesthesia, various approaches have been performed for smoothing the transition to unconsciousness, such as freestanding (providing no support and allowing the horse to sink quietly to the soft ground), support from handlers or a swinging door (to stabilise the animal as it sinks to the ground) and a tilt table (the animal is maintained against a firm surface and mechanically moved into lateral recumbency as unconsciousness ensues) (Bednarski 1991; Taylor and Clarke 1999). Induction with a sling requires special equipment but is a less complicated technique than induction with a tilt table (Taylor and Clarke 1999).

Anaesthesia induction with full body support sling has been effectively utilised in cases with severe musculoskeletal injuries (Krpan 1985; Taylor and Clarke 1999; Sullivan *et al.* 2002). It may also be more practical for larger size patients, such as draft horses or pregnant mares, who do not fit in a swinging door protocol. Zoo animal species that are even heavier than horses have been effectively anaesthetised without significant problems using the U.C. Davis-Anderson sling (Fowler *et al.* 2000). Sling induction may also be worthwhile in cases that have sustained an incomplete fracture. It would be helpful to prevent a sudden fall, which may exacerbate the fracture, as well as for transporting the patient from the induction area to the surgery room (Nixon 1996). To maximise anaesthesia induction using a full body support sling, the horse should be introduced to the sling beforehand in order to familiarise it to the sling (Steffanus 1998; Taylor and Clarke 1999).

General anaesthaesia

Under general anaesthesia, an adult horse is usually positioned in either lateral or dorsal recumbency. Complications to consider with these positions are 1) risk of nerve paralysis, 2) ischaemic muscle disorder, and 3) lung compression by the weight of abdominal viscera via the dome-shaped diaphragm. Due to the inconvenient patient manipulation and difficult positioning of surgery sites, sternal recumbency has been used for horses only in rare anaesthetic situations (Brugmans and Deegan 2001; Cornelisse *et al.* 2001).

In an attempt to avoid respiratory complications, maintenance of anaesthesia with the adult horse in an upright position has been investigated. Studies have revealed that sternal recumbency could prevent hypoxaemia and ventilation/perfusion mismatching (Gleed and Dobson 1988; Steffey *et al.* 1990; Brosnan *et al.* 2002). In fact, significantly higher mean partial oxygen pressure was obtained in horses maintained in a sternal (upright) position compared to horses maintained in recumbency (Steffey *et al.* 1990; Brosnan *et al.* 2002). Achieving higher mean partial pressure of oxygen theoretically shortens recovery time and minimises the risk of post anaesthetic muscle disorders. It has also been observed that sternal as opposed to dorsal or lateral (Brosnan *et al.* 2002) recumbency may lead to significantly higher cerebral perfusion pressures, which in turn could minimise the risk of cerebral ischaemia.

Other studies report that horses may be anaesthetised in the standing position using a full body support sling (Schatzmann *et al.* 1991; Schatzmann 1998). One report of general anaesthesia using a sling showed the horse had significantly higher mean partial oxygen pressure and a quicker recovery with fewer attempts to stand compared to those recovering in lateral recumbency (Schatzmann *et al.* 1991). It has also been speculated that sternal recumbency could cause post anaesthetic lameness due to the limbs being tucked under the body (Gleed and Dobson 1988); therefore, general anaesthesia with a sling may address this problem because there is minimum pressure on the hanging limbs. Despite the advantages, however, positioning a limb for musculoskeletal surgery may be difficult and limit the use of this method for performing certain procedures.

Controlled recovery

The recovery phase is the most critical period in equine general anaesthesia, and several techniques have been developed to maximise the potential for a smooth recovery. It is often necessary to include physical hands-on support (assisted manual recovery) or head and tail rope assistance (Bednarski 1991; Hubbell 1999; Taylor and Clarke 1999). However, recovery with even greater control is necessary for post operative orthopaedic cases. Myelogram or pelvic radiography

Fig 2: Anaesthesia recovery with the Liftex large animal sling (Photo courtesy of John Hubbell, The Ohio State University).

usually requires general anaesthesia; therefore, controlled recovery is also important in cases with severe ataxia or incomplete pelvic fracture, as a complete fracture or displacement may occur during ecovery from anaesthesia (Rutkowski and Richardson 1999).

For these purposes, pool recovery has been performed in combination with the Liftex large animal sling[2] (Richter *et al.* 2001; Tidwell *et al.* 2002; Sullivan *et al.* 2002). A hydro-pool system with elevator floor can minimise stress and weightbearing forces and may prevent disruption of surgically repaired fractures (Tidwell *et al.* 2002). Eighty-three percent (50/60) of cases in this report were recovered without complications. Recovery from anaesthesia with a pool-raft system is useful to avoid incisional immersion or excessive hydrostatic pressure and has been performed in horses with severe musculoskeletal injuries (Sullivan *et al.* 2002). Although the buoyancy of the water supports the majority of the weight, sling suspension is required to transport the horse to the surgery room, pool and recovery stall. In addition, the authors mention the potential disadvantages of these techniques including its cost, number of experienced personnel, and complications such as skin abrasions, incisional infections and pulmonary oedema (Tidwell *et al.* 2002; Sullivan *et al.* 2002).

Full body support sling has also been used for controlled recovery in clinical situations (Bednarski 1991; Schatzmann *et al.* 1995; Hubbell 1999; Rodgerson *et al.* 2001) (**Figs 2, 3**), and may be preferred as 1) a simpler and less costly technique than pool recovery system, 2) it may provide greater hoisting power compared to head and tail rope assistance, and 3) the horse can be introduced to the sling system prior to anaesthesia and estimated smooth recovery before the surgery (Taylor and Clarke 1999).

In a study using a full-harness and sling system, 95% (40/42) of horses recovered successfully from general anaesthesia without significant complications (Schatzmann *et al.* 1995). Suitable anaesthesia recovery with mechanical sling/shell recovery system was also demonstrated in 83% (69/83) of horses following inhalation anaesthesia (Liechti *et al.* 2003). Use of the U.C. Davis-Anderson sling with head support device can easily maintain the horse in a sternal position preventing the development of nerve paralysis, ischaemic muscle disorders, and atelectasis of the down side of the lung.

Therapeutic indications

Physical therapy

In small animal clinics, slings are commonly used for paralysed patients (Reininger 1969; Bojrab and Brown 1978; Vaughan and Kirkland 1983). Indications for use of a full body support sling include those with central nerve disorders, peripheral neuropathies, and those requiring post operative rehabilitation following vertebral surgery. Physical therapy using the sling can encourage recovering muscle functions, improve hygienic conditions, and may help to reduce mental depression (Vaughan and Kirkland 1983). Similar physical therapy with a sling has also been successfully performed in large animal species (Hoogmoed *et al.* 1998; Wadhwa and Prasad 2002).

In equine practice, smaller slings can be used in foals (**Fig 4**) or miniature breeds (Costa *et al.* 2000). A good example for use of a full body sling in a foal would be the need to improve muscle atrophy in a premature foal or in the case of severe limb deformities. Physical therapy using a sling may effectively improve tendon contractions by avoiding further injury or unnecessary fatigue during exercise, whereas foals with severe flexural deformities are occasionally unable to stand without assistance. Prior to this therapy, however, patients should be carefully examined for potential conditions such as cuboid bone hypoplasia or rupture of the common digital extensor tendon in which cases aggressive exercise may be contraindicated (Kidd and Barr 2002). Although a custom-made sling could be applicable and inexpensive, Liftex corporation and CDA Products provide commercially available slings in different sizes for small and large animals.

Immobilisation

Stall rest is often the treatment of choice for horses with fractures located in proximal anatomical locations such as scapula and pelvis, or cases of incomplete long bone fracture. Immobilisation can facilitate the conservative treatment of musculoskeletal injuries and fracture repair with internal fixation, and may also decrease the risk of cast complication or suture breakdown in a high tension area. During the transportation of suspected fracture patients, the horse should be strictly confined in a trailer to prevent further injury or displacement (Bramlage 1983). Sling immobilisation is applicable inside transportation vehicles (Schatzmann 1998) and may assist fracture patients by maintaining balance.

Horses have been immobilised by a head-tie confinement to an overhead wire (**Fig 5**), which may prevent worsening of incomplete fractures (Stashak 1987; Richardson 1990; Derungs *et al.* 2001). However, it has been observed that the horses are still able to circle or may simply collapse (Richardson 1990). Complications, such as depression, anorexia, lower

Fig 3: Anaesthesia recovery with the U.C. Davis-Anderson sling. Note the ropes connected the overhead frame with corners of the recovery stall to prevent an excessive circling and maintain the patient in the centre of the stall (Photo courtesy of Veterinary Teaching Hospital, University of Wisconsin-Madison.)

Fig 4: Physical therapy with a custom-made sling for a foal with severe carpus flexural deformity.

limb oedema and pulmonary disease, induced by poor tracheal mucociliary clearance, have also been observed with the head-tie restraint method. A significant accumulation of lower respiratory tract secretions, bacteria and inflammatory cells were evident in horses confined with their heads elevated for 24 h (Raidal *et al.* 1996).

A small number of fatal injuries associated with head-tie confinements has been reported. In a retrospective study of equine tibial fractures, 2 of 3 cases with incomplete fractures worsened to complete fractures during conservative treatment consisting of stall rest (Haynes *et al.* 1980). Actual causes of these fractures were not clear, but self-trauma or struggling in limited stall space was suspected. Another study reported that one out of 12 cases of radial fissure fractures and 3 out of 9 cases of tibial fissure fractures similarly became complete catastrophic fractures, even though one of the horses was under head-tie confinement at the time of the accident (Derungs *et al.* 2001).

Equine full body support sling has been used during stall confinement (**Fig 6**) with reasonable outcomes reported (Jones 1975; McCann and Hunt 1992; Derungs *et al.* 2001). In contrast to head-tie confinement, the sling provides greater restraint, natural standing position, and normal head carriage. Disadvantages of sling confinement include the requirement for intensive care and it may be stressful for the patient if used for long periods of time. However, unlike the head-tie restraint technique, horses can learn to handle the sling to maximise its use (Steffanus 1998). Many horses will rest and even sleep in the sling. Depending on the horse's temperament or ability to 'use' the sling, the horse may be more comfortable than under head-tie confinement.

Fig 5: Immobilisation by head-tie confinement with overhead wire for a conservative treatment in a horse with incomplete radial fracture.

Fig 6: Immobilisation with the Liftex large animal sling for a case of radial fracture which stabilised by internal fixation and Robert-Jones bandage with extended lateral splint.

Fig 7: Suspension therapy using the U.C. Davis-Anderson sling for a recumbent horse.

Fig 8: Suspension therapy using the Liftex large animal sling for a horse with equine herpes virus 1 infection. (Photo courtesy of Stephen Reed, The Ohio State University.)

An advantage of immobilisation using the full body support sling is minimising the risk of complications associated with external fixation devices. Common complications associated with fibreglass cast application are decubital sores and mid-diaphyseal fracture of long bones (Murray and DeBowes 1996). Rupture of *peroneous tertius* muscle or coxofemoral luxation can also occur as a result of struggling in a full, hindlimb cast (Trotter *et al.* 1986; Murray and DeBowes 1996), because the horse cannot flex the stifle without flexion of the tarsus due to the presence of the reciprocal apparatus. The external skeletal fixation tools with transfixation pins or walking cast techniques have been used in clinical cases with severe distal limb injuries and successful outcomes reported (Nunamaker *et al.* 1986; Nemeth and Back 1991; Nunamaker and Richardson 1991). Nevertheless, some horses treated with

Fig 9: Weightbearing reduction with the U.C. Davis-Anderson sling and flotation tank filled with soft plastic balls. The physical support by the balls can reduce the effective bodyweight onto the injured limb without complications associated with continuous water immersion.

these techniques developed catastrophic bone failures and the authors indicate a large torsional force occurred when the animal turned was a primary factor (Nunamaker *et al.* 1986). Immobilisation in a sling can prevent tight-turning in the stall or struggling when standing-up and alternatively minimise the risk of such fatal complications.

When stabilisation of long-bone fractures is attempted, compression plates are often placed on the tension side of the bone surface. However, research of multidirectional strain analysis revealed that, at walk with full-limb cast placement, the cast will change the tension side on the tibia and radius possibly resulting in distraction of the fracture fragment, loss of stability, and implant failure (Schneider *et al.* 1982). Therefore, sling confinement to prevent the horse from moving in a stall may be justifiable for the management of those fracture cases treated with a combination of internal fixation and cast.

Fig 10: Weightbearing reduction with the U.C. Davis-Anderson sling for a case with right hind support-limb laminitis induced by septic arthritis of left hock. Note the overhead device is inclined due to the partial suspension on both hindlimbs.

Suspension

Using the full body support sling is often appropriate for recumbent patients with severe infectious diseases or neurological disorders (Komarek 1986; Green 1993; Coumbe 1998; Goehring and Sloet van Oldruitenborgh-Oosterbaan 2001; Maanen *et al.* 2001; Saville *et al.* 2003) (**Figs 7, 8**). A major goal in using a sling for suspension is to assist the recumbent horse to stand as prolonged recumbency is contraindicated.

The development of decubital ulceration is a common complication with prolonged recumbency. Managements of pressure sores include the use of liberal amounts of bedding, padding the pressure points, keeping the patient and bedding dry (McConnico *et al.* 1991), and using a sling can minimise the risk of decubital ulcers (Green 1993). Gastrointestinal disorders such as large colon impaction, gastric dilatation and volvulus or colonic displacement may also occur (McConnico *et al.* 1991). Slinging may help to maintain the normal position of the large colon or movement of ingesta under natural gravity, and possibly decrease the risk of impaction or colon displacement. Compartment syndrome has been reported as a post anaesthetic complication and similar chronic pressure damage of muscle can occur by prolonged recumbency. Research into post anaesthetic myopathy demonstrated that pressures high enough to cause muscle damage can occur in as few as 2 h of recumbency (Lindsay *et al.* 1980; White and Suarez 1986). It is therefore imperative to incorporate regular-interval rolling, maintain the horse in sternal recumbency, or use a full body support sling to avoid this complication. Horses with some infectious diseases inducing cervical muscle weakness or myonecrosis may develop massive gravitational head oedema (Whitlock and Buckley 1997; Peek and Semrad 2002). Use of the U.C. Davis-Anderson sling with head support device will be useful to prevent abnormal low head carriage and gradually help regain strength of neck muscles.

Suspension therapy for the recumbent patient is ideally performed at least several times a day where the horse remains standing with the opportunity to relax in the sling. Some horses may aggressively pivot themselves during suspension so that marked skin aberration or tangle of fluid lines may be a concern. Therefore, patients may need to be restrained with the multiple lead-chains on the halter or ropes connecting from corners of the stall to the overhead frame of the U.C. Davis-Anderson sling. A recumbent horse, incapable of standing on its own, should not be forced to stand in a full body support sling due to the risk of asphyxiation (McConnico *et al.* 1991; Semrad and Peek 2002). For this reason, the horse should be allowed to lie down in a recumbent position for periodic intervals, which depends upon fatigue and an attitude change, and the recumbent side alternated. Intensive care for slinging horses includes monitoring respiratory distress, sustaining adequate bedding material, providing reachable feed and water bucket, maintaining hygienic conditions, and urine catheterisation if the horse is dysuric.

Weightbearing reduction

Horses with severe lameness of one limb are generally willing to stay standing instead of recumbent (Peloso *et al.* 1996). It has been reported that horses' standing with one limb raised can shift approximately 60% of whole bodyweight onto the contralateral limb rather than equally allocate it among three remaining legs (Miyaki *et al.* 1979). Those patients can subsequently acquire laminitis or deformity in the contralateral limb and muscle atrophy or joint stiffness in the injured limb. Therefore, weightbearing reduction using full body support sling has been attempted to prevent the development of contralateral limb complication.

Excessive bodyweight is considered a risk factor of laminitis. One retrospective study of 12 horses with sinking laminitis revealed that the horses who did not survive had larger mean bodyweight than the survived horses (Baxter 1986). Another case report of 33 horses with duodenitis or proximal jejunitis revealed that horses weighing over 550 kg were more than twice as likely to develop laminitis than horses less than 550 kg (Cohen *et al.* 1994). It is therefore expected that reducing the weightbearing forces by using a full body support sling is theoretically beneficial to increase survival rate and minimise the risk of development of support laminitis.

There are multiple theories of triggering factors for the aetiology of laminitis (Sprouse *et al.* 1987; Pollitt 1999; Weiss *et al.* 2000; Rodgerson *et al.* 2001); however, it has been theorised that foot ischaemia induced by excessive weightbearing may be the predisposing factor of support laminitis. The perfusion deficits of laminar vasculature were evident by one *post mortem* plastic perfusion study of laminitic feet (Hood *et al.* 1994). Digital venography of equine feet also proved that laminar perfusion is substantially reduced while the foot is fully loaded (Redden 2001). Slinging severely lame horses to prevent persistent weightbearing on the contralateral limb would be useful to maintain sufficient blood perfusion to the foot.

Weightbearing reduction has been attempted by using the Liftex large animal sling and flotation tank technique (Smith 1981). Although it has been shown that approximately 75% of effective bodyweight can be reduced by buoyancy (McClintock *et al.* 1987), a number of complications including alopecia, osteopenia, and respiratory disorders have been observed (Smith 1981; Hutchins *et al.* 1987). Air-filled plastic balls have also been effectively utilised for physical therapy and rehabilitation in human medicine. Weightbearing reduction by slinging a horse into a tank filled with balls, as opposed to water, may be applicable to avoid a risk of complications associated with continuous immersion (**Fig 9**).

Although slinging cattle for extended periods has been previously performed (Shoor *et al.* 1979; Gayle *et al.* 2001), prolonged suspension with a sling has not previously been recommended in horses due to the risk of pressure sores and asphyxiation (McConnico *et al.* 1991; Bowman 1995; Schatzmann 1998). However, the improved design of full body support slings such as the U.C. Davis-Anderson sling have addressed the problems identified with earlier versions. The

U.C. Davis-Anderson sling has a system whereby the overhead frame can adjust to lift only the front or hindlimbs (**Fig 10**) and can make the horse more comfortable with less pressure over the abdomen (Steffanus 1998; Strickland 2001).

Conclusion

Although the equine full body support sling is fundamentally a supporting tool, it can be very useful when used in appropriate clinical situations. The Liftex large animal sling has been applied for various practical and therapeutic purposes, and a great number of successful outcomes reported. The advantages of the U.C. Davis-Anderson sling have been described, but it is not commonly used at present. Therefore, a prospective study would be necessary to truly evaluate its usefulness and effectiveness for the future.

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Manufacturers' addresses

[1]Care for Disabled Animals (CDA) Products, Potter Valley, California, USA.
[2]Liftex Corp., Warminster, Pennsylvania, USA.

References

Baxter, G.M. (1986) Equine laminitis caused by distal displacement of the distal phalanx: 12 cases (1976-1985) *J. Am. vet. med. Ass.* **189**, 326-329.

Bednarski, R.M. (1991) Anesthetic Equipment. In: *Equine Anesthesia Monitoring and Emergency Therapy.* Eds: W.W. Muir and J.A.E. Hubbell, Mosby, St. Louis. pp 325-351.

Bojrab, M.J. and Brown, R.E. (1978) A sling for recumbent dogs. *Modern vet. Prac.* **59**, 374.

Bowman, K.F. (1995) Slinging horses. *J. equine vet. Sci.* **15**, 152-154.

Bramlage, L.R. (1983) Current concepts of emergency first aid treatment and transportation of equine fracture patients. *Comp. cont. Educ. pract. Vet.* **8**, S564-S573.

Brosnan, R.J., Steffey, E.P., LeCouteur, R.A., Imai, A., Farver, T.B. and Kortz, G.D. (2002) Effects of body position on intracranial and cerebral perfusion pressures in isoflurene-anesthetized horses. *J. appl. Physiol.* **92**, 2542-2546.

Brugmans, F. and Deegan, E. (2001) Laparoscopic surgical technique for repair of rectal and colonic tears in horses: an experimental study. *Vet. Surg.* **30**, 409-416.

Cohen, N.D., Parson, E.M., Seahorn, T.L. and Carter, G.K. (1994) Prevalence and factors associated with development of laminitis in horses with duodenitis/proximal jejunitis: 33 cases (1985-1991) *J. Am. vet. med. Ass.* **204**, 250-254.

Cornelisse, C.J., Rosenstein, D.S., Derksen, F.J., Holcombe, and S.J. (2001) Computed tomographic study of the effect of a tongue-tie on hyoid apparatus position and nasopharyngeal dimensions in anesthetized horses. *Am. J. vet. Res.* **62**, 1865-1869.

Costa, L.R.R., McClure, J.J., Snider, T.G. and Stewart, T.B. (2000) Verminous meningoencephalomyelitis by *Angiostrongylus* (= *Parastrongylus*) *cantonensis* in an American miniature horse. *Equine vet. Educ.* **12**, 2-6.

Coumbe, K. (1998) Anaesthetic complications and emergencies - Part 2. *Equine vet. Educ.* **10**, 161-168.

Cox, J.H. (1998) Rescue techniques. In: *Current Techniques in Equine Surgery and Lameness*, 2nd edn., Eds: N.A. White and J.N. Moore, W.B. Saunders Co., Philadelphia. pp 60-65.

Derungs, S., Fuerst, A., Haas, C., Geissbuhler, U. and Auer, J.A. (2001) Fissure fractures of the radius and tibia in 23 horses: a retrospective study. *Equine vet. Educ.* **13**, 313-318.

Fowler, M.E., Steffey, E.P., Galuppo, L. and Pascoe, J.R. (2000) Facilitation of Asian elephant (*Elephas maximus*) standing immobilization and anesthesia with a sling. *Journal of Zoo and Wildlife Medicine* **31**, 118-123.

Gayle, J.M., Burrell, G.A., Anderson, K.L., Redding, W.R. and Blikslager, A.T. (2001) Deep digital flexor tenotomy for treatment of severe laminitis in a cow. *J. Am. vet. med. Ass.* **219**, 644-646.

Gleed, R.D. and Dobson, A. (1988) Improvement in arterial oxygen tension with change in posture in anaesthetized horses. *Res. vet. Sci.* **44**, 255-259.

Goehring, L.S. and Sloet van Oldruitenborgh-Oosterbaan, M.M. (2001) The mystery of equine herpes myeloencephalopathy. *Equine vet. Educ.* **13**, 36-42.

Green, S.L. (1993) Equine tetanus: a review of the clinical features and current perspectives on treatment and prophylaxis. *Proc. Am. Ass. equine Practnrs.* **38**, 299-306.

Haynes, P.F., Watters, J.W., McClure, J.R. and French, D. (1980) Incomplete tibial fractures in three horses. *J. Am. vet. med. Ass.* **177**, 1143-1145.

Hood, D.M., Grosenbaugh, D.A. and Slater, M.R. (1994) Vascular perfusion in horses with chronic laminitis. *Equine vet. J.* **26**, 191-196.

Hoogmoed, L.V., Snyder, J.R. and Vasseur, P. (1998) Surgical repair of patellar luxation in llamas: 7 cases (1980-1996) *J. Am. vet. med. Ass.* **212**, 860-865.

Hubbell, J.A.E. (1999) Recovery from anaesthesia in horses. *Equine vet. Educ.* **11**, 160-167.

Hutchins, D.R., McClintock, S.A. and Brownlow, M.A. (1987) Use of flotation tank for the treatment of seven cases of skeletal injury in horses. *Equine vet. J.* **19**, 73-77.

Jones, D.G.C. (1975) The repair of equine fractures 1843-1975. *Vet. Rec.* **97**, 193-197.

Kidd, J.A. and Barr, A.R.S. (2002) Flexural deformities in foals. *Equine vet. Educ.* **14**, 311-321.

Komarek, J. (1986) Tetanus in horses: prevalence and results of treatment in the past 25 years. *Veterinarstvi* **36**, 543-544.

Krpan, M.K., Grant, B.D., Crawley, G.R., Ratzlaff, M.H., Eckstein, D.T. and Held, G.K. (1985) Amputation of the equine limb: a report of three cases. *Proc. Am. Ass. equine Practnrs.* **31**, 429-444.

Liechti, J., Pauli, H., Jaggin, N. and Schatzman, U. (2003) Investigation into the assisted standing up procedure in horses during recovery phase after inhalation anesthesia. *Pferdeheikunde.* **19**, 271-276.

Lindsay, W.A., McDonell, W. and Bignell, W. (1980) Equine postanesthetic forelimb lameness: intracompartmental muscle changes and biochemical patterns. *Am. J. vet. Res.* **41**, 1919-1924.

Maanen, C. van. and Sloet van Oldruitenborgh-Oosterbaan, M.M., Damen, E.A. and Derksen, A.G.P. (2001) Neurological disease associated with EHV-1 infection in a riding school: clinical and virological characteristics. *Equine vet. J.* **33**, 191-196.

Madigan, J.E. (1993) Evaluation of a new sling support device for horses. *J. equine. vet. Sci.* **13**, 260-261.

Madigan, J.E. and Moore, B. (1995) Helicopter rescue of horses. *J.*

equine vet. Sci. **15**, 155-157.

Madigan, J.E. and Morgan, R. (1995) Rescue of the individual horse. *Am. J. vet. Res.* **39**, 141- 144.

McCann, M.E. and Hunt, R.J. (1992) Conservative management of femoral diaphyseal fractures in four foals. *Cornell vet.* **83**, 125-132.

McClintock, S.A., Hutchins, D.R. and Brownlow, M.A. (1987) Determination of weight reduction in horses in flotation tanks. *Equine vet. J.* **19**, 70-71.

McConnico, R.S., Clem, M.F. and DeBowes, R.M. (1991) Supportive medical care of recumbent horses. *Comp. cont. Educ. pract. Vet.* **13**, 1287-1295.

Miyaki, H., Ohnishi, T., Yamamoto, T. and Yoshida, S. (1979) Distribution of the body weight to each foot and movement of the center gravity of the body in standing horses. *Journal of Veterinary Techniques in Japan Racing Association* **4**, 75-82.

Murray, R.C. and DeBowes, R.M. (1996) Casting techniques. In: *Equine Fracture Repair*, Ed: A.J. Nixon, W.B. Saunders Co., Philadelphia. pp 104-113.

Nemeth, F. and Back, W. (1991) The use of the walking cast to repair fractures in horses and ponies. *Equine vet. J.* **23**, 32-36.

Nixon, A.J. (1996) Perioperative considerations. In: *Equine Fracture Repair*, Ed: A.J. Nixon, W.B. Saunders Co., Philadelphia. pp 43-51.

Nunamaker, D.M., Richardson, D.W., Butterweck, D.M., Provost, M.T. and Sigafoos, R.D. (1986) A new external skeletal fixation device that allows immediate full weightbearing: Application in horses. *Vet. Surg.* **15**, 345-355.

Nunamaker, D.M. and Richardson, D.W. (1991) External skeletal fixation in the horse. *Proc. Am. Ass. equine Practnrs.* **37**, 549-555.

Pauli, H., Schatzmann, U. and Schaffer. J. (1994) Historical review of ways of slinging horses. *Pferdeheikunde* **10**, 325-333.

Peek, S.F. and Semrad, S.D. (2002) Clostridial myonecrosis in horses. *Equine vet. Educ.* **14**, 163-168.

Peloso, J.G., Cohen, N.D., Walker, M.A., Watkins, J.P., Gayle, J.M. and Moyer, W. (1996) Case-control study of risk factors for the development of laminitis in the contralateral limb in Equidae with unilateral lameness. *J. Am. vet. med. Ass.* **209**, 1746-1749.

Pollitt, C.C. (1999) Equine laminitis: a revised pathophysiology. *Proc. Am. Ass. equine Practnrs.* **45**, 188-192.

Raidal, S.L., Love, D.N. and Bailey, G. (1996) Effects of posture and accumulated airway secretions on tracheal mucociliary transport in the horse. *Aust. vet. J.* **73**, 45-49.

Redden, R.F. (2001) A technique for performing digital venography in the standing horse. *Equine vet. Educ.* **13**, 128-134.

Reininger, E.J. (1969) A body sling to keep dogs in the standing position. *J. exp. Anal. Behav.* **12**, 462.

Richardson, D.W. (1990) Fractures of tibia. In: *Current Practice of Equine Surgery*, Eds: N.A. White and J.N. Moore, J.B. Lippincott, Philadelphia, pp 660-665.

Richter, M.C., Bayly, W.M., Keegan, R.D., Schneider, R.K., Weil, A.B. and Ragle, C.A. (2001) Cardiopulmonary function in horses during anesthetic recovery in a hydropool. *Am. J. vet. Res.* **62**, 1903-1910.

Rodgerson, D.H., Belknap, J.K., Moore, J.N. and Fontaine, G.L. (2001) Investigation of mRNA expression of tumor necrosis factor-alpha, interleukin-1beta, and cyclooxygenase-2 in cultured equine digital artery smooth muscle cells after exposure to endotoxin. *Am. J. vet. Res.* **62**, 1957-1963.

Rodgerson, D.H., Wilson, D.A. and Kramer, J. (2001) Fracture repair of the distal portion of the radius by use of a condylar screw implant in an adult horse. *J. Am. vet. med. Ass.* **218**, 1966-1969.

Rutkowski, J.A. and Richardson, D.W. (1999) A retrospective study of 100 pelvic fractures in horses. *Equine vet. J.* **21**, 256-259.

Saville, W.J.A., Sofaly, C.D. and Toribio, R.E. (2003) West nile virus encephalitis in horses. *Comp. cont. Educ. pract. Vet.* **25**, 220-236.

Schatzmann, U., Hotz, D., Stauffer, J.L. and Hess, N. (1991) General anesthesia in the horse in upright position. *Proceedings of the 4th International Congress of Veterinary Anaesthesia.* pp 291-299.

Schatzmann, U., Pauli, H., Ianni, O. and Ramseyer, B. (1995) Historical aspects of equine suspension (slinging) and a description of a new system for controlled recovery from general anesthesia. *Proc. Am. Ass. equine Practnrs.* **41**, 62-64.

Schatzmann, U. (1998) Suspension (slinging) of horses: history, technique and indications. *Equine vet. Educ.* **10**, 219-223.

Schneider, R.K., Milne, D.W., Gabel, A.A., Groom, J.J. and Bramlage, L.R. (1982) Multidirectional *in vivo* strain analysis of the equine radius and tibia during dynamic loading with and without a cast. *Am. J. vet. Res.* **43**, 1541-1550.

Semrad, S. and Peek, S. (2002) Equine botulism. *Comp. cont. Educ. pract. Vet.* **24**, 169-172.

Shoor, P.M., Stotts, J.S., Witzel, T.H., Zweifach, S., Vanderlip, J.E. and Bernstein, E.F. (1979) A system for restraint and anesthesia in calves. *Lab. Anim. Sci.* **29**, 389-394.

Smith, W.N. (1981) Use of a flotation tank to sling horses and cattle undergoing surgery to the limbs. *Aust. vet. J.* **57**, 441-443.

Sprouse, R.F., Garner, H.E. and Green, E.M. (1987) Plasma endotoxin levels in horses subjected to carbohydrate induced laminitis. *Equine vet. J.* **19**, 25-28.

Stashak, T.S. (1987) Method of therapy. In: *Adams Lameness in Horses*, Ed: T.S. Stashak, Media, Lippincott Williams & Wilkins. pp 840-877.

Steffanus, D. (1998) A life-saving support for the injured horse. *Equine Athlete* **11**, 34-36.

Steffey, E.P., Woliner, M.J. and Dunlop, C. (1990) Effects of five hours of constant 1.2 MAC halothane in sternally recumbent, spontaneously breathing horses. *Equine vet. J.* **22**, 433-436.

Strickland, C. (2001) Getting a lift. *The Horse* **18**, 49-56.

Sullivan, E.K., Klein, L.V., Richardson, D.W., Ross, M.W., Orsini, J.A. and Nunamaker, D.M. (2002) Use of a pool-raft system for recovery of horses from general anesthesia: 393 horses (1984-2000). *J. Am. vet. med. Ass.* **221**, 1014-1018.

Taylor, P.M. and Clarke, K.W. (1999) Anaesthetic problems. In: *Handbook of Equine Anaesthesia*, Eds: P.M. Taylor and K.W. Clarke, W.B. Saunders Co., Philadelphia. pp 95-143.

Tidwell, S.A., Schneider, R.K., Ragle, C.A., Weil, A.B. and Richter, M.C. (2002) Use of a hydro-pool system to recover horses after general anesthesia: 60 cases. *Vet. Surg.* **31**, 455-461.

Trotter, G.W., Auer, J.A., Arden, W. and Parks, A. (1986) Coxofemoral luxation in two foals wearing hindlimb casts. *J. Am. vet. med. Ass.* **189**, 560-561.

Vaughan, R.W. and Kirkland, K.D. (1983) Construction of a cart and sling for rehabilitation of immobile dogs. *Vet. Med. Sm. Anim. Clin.* **78**,191-194.

Wadhwa, D.R. and Prasad, B. (2002) Clinico-therapeutic observations of downer cow syndrome. *Indian vet. J.* **79**, 484-486.

Weiss, D.J., Evanson, O.A., Green, B.T. and Brown, D.R. (2000) *In vitro* evaluation of intraluminal factors that may alter intestinal permeability in ponies with carbohydrate-induced laminitis. *Am. J. vet. Res.* **61**, 858-861.

White, N.A. and Suarez, M. (1986) Change in triceps muscle intracompartmental pressure with repositioning and padding of the lowermost thoracic limb of the horse. *Am. J. vet. Res.* **47**, 2257-2260.

Whitlock, R.H. and Buckley, C. (1997) Botulism. *Vet. Clin. N. Am.: Equine Pract.* **13**, 107-128.