

# Surgical thrombectomy in horses with aortoiliac thrombosis: 17 cases

A. B. M. RIJKENHUIZEN\*, D. SINCLAIR† and W. JAHN‡

\*Department of Equine Sciences, Utrecht University, Yalelaan 114, 3584CM Utrecht, The Netherlands; and \*Klinik für Pferde, University of Veterinary Medicine Wien, Veterinärplatz 1, Vienna, Austria; †Bell Equine Veterinary Clinic, Mereworth, Maidstone, Kent ME18 5GS, UK; and ‡Pferdeambulanz Bargteheide, Alte Landstr. 104 22941 Bargteheide, Germany.

**Keywords:** horse; aortoiliac thrombosis; thrombectomy

## Summary

**Reasons for performing study:** Aortoiliac thrombosis (AIT) is a progressive vascular disease characterised by an exercise-induced hindlimb lameness. After developing a surgical technique, a follow-up study was required.

**Objectives:** To assess the surgical results of a surgical thrombectomy in horses with AIT, a chronic arterial occlusive disease of the aorta and its caudal arteries.

**Methods:** Seventeen cases showed the typical signs of AIT and diagnosis was confirmed by Doppler-ultrasonography. Average age of the horses was 12 years. Seven stallions, 6 mares and 4 geldings were included.

**Results:** The thrombus was located in the left hindlimb (5 cases), the right hindlimb (9 cases) or in both hindlimbs (3 cases). Two cases were operated on both limbs with a few days between surgeries. Nine (53%) horses regained their athletic performance and 2 horses were able to work for at least 30 min without complaint, instead of the initial 5 min prior to surgery. During surgery one horse had to be subjected to euthanasia because the thrombus was too tightly attached to the arterial wall and could not be removed. Two horses were subjected to euthanasia post operatively due to severe myopathy and one due to a femoral fracture during recovery. Two reocclusions of the treated artery occurred 4 months after surgical intervention; one horse was reoperated and, due to the extent of the thrombus and quality of the arterial wall, the horse was subjected to euthanasia; the other horse was subjected to euthanasia without a second surgery. A severe complication was the appearance of AIT in the contralateral limb after surgery as result of occlusion caused by an embolus loosened by the procedure. Post anaesthetic myopathy was seen in 4 (24%) of the cases and could be so severe that euthanasia had to be considered.

**Conclusion and potential relevance:** Surgical intervention by means of a thrombectomy in horses with AIT should be considered; 65% of the horses regained athletic activity and 53% of the operated horses in this study performed at their previous level. Adequate padding, correct positioning, prevention of intraoperative hypotension and keeping surgery time as short as possible, are important parameters to prevent post operative myopathy.

## Introduction

The concept of surgical intervention in horses affected by aortoiliac thrombosis (AIT) was introduced by Brama *et al.* (1996). The chronic arterial occlusive disease of the aorta and its caudal arteries is characterised by a reproducible predictable exercise induced hindlimb lameness that disappears with a resting period of 5–10 min. Horses that are forced to train 'through the pain' show a more severe lameness and may require significantly more time for the clinical signs to resolve. The worse the signs, the longer recovery takes. Affected horses could be without signs or show only vague performance complaints; however, the clinical signs can also be very severe and acute colic-like after training. The severity of clinical signs is related to the degree of vascular occlusion, the presence of collateral circulation and the speed of onset of the occlusion. The signs are caused by ischaemia in the hindlimb tissues as a result of insufficient perfusion due to vascular occlusion (Rijkenhuizen 2006).

Diagnosis is based on history, clinical presentation, transrectal palpation, ultrasonography, thermography and scintigraphy (Boswell *et al.* 1999; Rijkenhuizen 2006). The absence of a pulse in the extremity, a collapsed vein and a colder limb on palpation are probably the most common physical findings; and are typically apparent only after exercise. Rectal ultrasonography is used to recognise the thrombus in the aorta, internal and external iliac artery. With the use of Doppler ultrasonography the extent of the thrombus as well as the degree of the arterial occlusion (remaining functional blood flow) in the femoral artery in the inguinal region can be estimated (Brama *et al.* 1996). Conservative treatment, with exercise programmes and pharmacological thrombolytic therapy has so far been unsatisfactory. Promising results can be obtained by restoring blood supply to the ischaemic regions through vascular surgery (Brama *et al.* 1996; Hilton *et al.* 2008).

The aim of this study is to describe a series of clinical cases on which thrombectomy was performed. The hypothesis was that the surgical technique alleviated clinical signs.

## Materials and methods

### *Surgical procedure*

Surgery was performed under general anaesthesia and in lateral recumbency as described by Brama *et al.* (1996) and Rijkenhuizen

\*Author to whom correspondence should be addressed. Present address: Singel 10, 3961CE Wijk bij Duurstede, The Netherlands.

[Paper received for publication 12.11.08; Accepted 07.01.09]

(2006). Anticoagulation was obtained intraoperatively just before arteriotomy by the administration of 100 iu heparin/kg bwt i.v. This was followed post operatively by the administration of 50 iu heparin<sup>1</sup>/kg bwt subcut. once and carbasalatum calcium (Ascal)<sup>2</sup> 5 mg/kg bwt or acetylsalicylate (5 mg/kg bwt) orally once daily for at least 3 months. In one case used intra- (50 iu/kg bwt i.v.) and post operatively (50 iu/kg bwt subcut.). Antibiotics were administered prior to surgery and continued to 3 days post operatively. The choice of antibiotic drugs depended on the clinic where surgery was performed.

Handwalking was advised starting the day after surgery for 14 days, after which light exercise began.

#### Case details of diagnosis

From 1993–2008 17 Warmblood horses (mean age 11.5 years; range 5–20 years) underwent surgery for AIT: 6 horses were used for dressage, 7 for showjumping, one for eventing and 3 for recreational purposes (Table 1). Prior to surgical intervention all cases had received clinical examination before and after exercise, as well as transrectal examination and ultrasonography and, in 10 cases, transcutaneous Doppler ultrasonography. According to the history the duration of the complaints varied from one week to 18 months. In all cases, clinical signs showed a progressive character. As far as known horses were not previously treated, other than with administration of phenylbutazone and/or anticoagulant (acetylsalicylate, heparin or isoxuprine) and box rest combined with handwalking, which did not result in improvement of the condition. Diagnosis was based on history, clinical examination, and ultrasonography. During surgery an estimation was made of the length of the thrombus, the attachment of the thrombus to the arterial wall and the consistency of the thrombus (fragile or fibrous).

#### Complications and follow-up

During surgery a major complication was defined as the occurrence of severe bleeding. Minor complications included intraoperative bleeding, which delayed surgical time. Technical success was defined as ante- and retrograde blood flow being

obtained intraoperatively. Post operative complications were divided into seroma formation, wound healing in second intention and post operative myopathy. Clinical success was defined as performance as before onset or better. Clinical improvement was defined as being able to perform for at least 30 min without clinical signs. The follow-up information was obtained by telephone call with the owner, between 6 months and 12 years after surgery.

## Results

#### Preoperative

The right hindlimb was involved in 9 cases and the left in 5 (Table 1). In 3 cases thrombosis occurred in both limbs, the right hindlimb causing the most severe clinical signs. Clinical signs varied from an obvious progressively worsening lameness after 10 min of exercise to severe colic-like symptoms. Clinical signs subsided within 10–20 min rest. In 3 horses the sweating was so severe that i.v. infusion (Ringer's USP solution) was necessary and the recovery took at least 2 h. In those cases muscle enzymes were increased and surgery postponed for 3–7 days. Twelve horses were without lameness before exercise, 2 slightly lame and 2 severely lame (*grade 3–4/5*). In 10 cases Doppler ultrasonography was performed at the level of the femoral artery and, in these cases, an occluded artery was observed in which no blood flow could be detected. In all cases the thrombus was located in the aorta, starting about 7–10 cm cranially to the iliac bifurcation and running into the iliac arteries towards the femoral artery, with the thrombus occluding the lumen of the aorta by 40–70%.

#### Intraoperative

Surgery was technically successful in 16 cases. In *Case 14* the thrombus was fibrous and tightly adhered to the arterial wall. Despite multiple attempts, it could not be debulked due to its consistency without the risk of rupturing the arterial wall, and the horse was subjected to euthanasia.

In 15 cases, the femoral artery was totally (Fig 1) and in 2 cases partially occluded, with blood flow present, although poor,

**TABLE 1: Cases operated on: sex, age, signs besides progressive lameness during exercise, duration of signs, intraoperative attachment of the thrombus to the arterial (-: loose; +/- slightly attached; + tightly attached), post operative complications and result († euthanasia)**

Case no.	Sex	Age (years)	Affected limb	Clinical signs besides progressive lameness during exercise	Duration of signs	Thrombus attached to arterial wall	Post operative complications	Outcome
1	Mare	14	R		4 weeks	+/-	Myopathy	Improved
2	Mare	12	R	Colic like + lame	1 week	+/-	Myopathy	Improved
3	Stallion	12	R/L		≥4 months	+/-	Myopathy	† in recovery
4	Mare	18	R/L		≥4 months	+/-	Myopathy	† in recovery
5	Stallion	8	R		3 months	-		Full recovery
6	Gelding	10	L		4 weeks	-		Full recovery
7	Mare	10	R	Colic like	≥4 months	+/-		Full recovery
8	Mare	13	L	Colic like	1.5 years	-		Full recovery
9	Gelding	8	L		4 weeks	-		Full recovery
10	Gelding	10	R		7 months	+		Full recovery
11	Stallion	10	R		3 weeks	-		Initially improved, reocclusion†
12	Stallion	11	L		≥4 months	+		Full recovery
13	Stallion	15	R/L	Colic like	2 weeks	+/-		Full recovery
14	Stallion	6	L	Colic like	1 year	Unremovable		†
15	Stallion	5	R	Colic like	3 weeks	+		Full recovery
16	Mare	20	R	Lame	6 weeks	+/-		Initially improved, reocclusion
17	Gelding	12	R		≥4 months	+/-	Femur fracture	† in recovery



Fig 1: Surgical view showing the incised femoral artery. The artery is surrounded by penrose drains proximal and distal to the arteriotomy to prevent excessive blood loss during surgery. In the transverse arteriotomy the thrombus is shown occluding the entire lumen.

when the femoral artery was incised. In 11 cases, the thrombus was tightly attached to the arterial wall and debulked in small fragments (Fig 2). These thrombi had a segmental appearance composed of small segments. In 6 cases, a large part of the thrombus was removed in one piece (length 12–20 cm), followed by the removal of smaller fragments. Two of those large thrombi consisted of several crescent shaped 5 mm thrombi, organised in several layers. When the thrombus could almost be removed *in toto*, the thrombus was tightly attached to the arterial wall only at a small area, more proximally in the artery. Most of the thrombi were dark red, in some, the thrombus had a brownish-yellow fibrin appearance.

After removal of the thrombi, in all but 3 cases, a rough arterial wall could be palpated when retrieving the catheter. The length of the rough wall was short (1–2 cm) if the thrombus could be removed *in toto* and longer in those cases where the thrombus was removed in small segments (varying from almost the entire length to 4–5 cm).

Removal of the thrombi distally was in general more difficult due to the smaller diameter and bifurcation. In 3 cases, distal to the incisional site no thrombosis was detected. During surgery, in 2 cases, venous bleeding occurred in the area proximomedial to the transverse incision, which delayed surgical time.

When the thrombus was removed blood flow was restored. At that moment and before closure of the artery a functional suction drain was necessary. Suction was used to maintain visibility before closure of the artery. In 2 cases, obstruction of the suction drain occurred increasing surgical time.

Three horses had a bilateral problem. One horse was operated on both sites in one surgical session, developed post operatively a severe myopathy and was subjected to euthanasia. In the other 2 cases it was decided to postpone surgery of the contralateral limb for 7–10 days. In one of these horses the femoral artery was transected totally and the artery had to be sutured circumferentially. Unfortunately, this horse developed a severe myopathy and had to be subjected to euthanasia. The other horse was operated 10 days after the first surgery and recovered uneventfully. The thrombus in the controlateral limb had a length of 20 cm, unattached to the arterial wall, and could be removed easily.



Fig 2: View of a thrombus that had a segmental aspect, being composed of small segments.

#### Post operative

Post operative recovery was uneventful in 12 horses. One horse broke its femur during recovery and had to be subjected to euthanasia. In 3 cases a severe myopathy occurred, 2 were subjected to euthanasia and the other was treated with saline infusion, with i.v. corticosteroid and NSAID therapy and recovered within 2 days.

Case 2 developed a mild post anaesthetic myopathy (creatinine phosphokinase 837 iu/l, aspartate transaminase 779 iu/l), and handwalking started the day after the operation. On the second day, the horse was trotted over a short distance, on the night of the second day the horse again showed acute colic-like signs of pawing, straining, sweating, lying down and rolling. Upon examination the horse had a cold left hindlimb and was reluctant to bear weight on this limb. Filling of the left medial saphenous vein was absent and no femoral or digital pulse was palpable. The right hindlimb was warm, had a clearly visible medial saphenous vein, a palpable digital pulse and was bearing full weight. It was concluded that the horse now had AIT in the left hindlimb. With Doppler ultrasound, extensive thrombosis of the left femoral artery was found over the entire visible length. Because of the wound it was not possible to evaluate the right femoral artery with Doppler ultrasound. A second operation on the left hindlimb was postponed until 4 days later because of the mild myopathy.

During surgery a very good blood flow from the proximal side was present at the site of the incision in the left femoral artery and no thrombi were found proximal to the incision. Back flow was absent and a large layered thrombus of approximately 20 cm was removed from the artery distal to the incision site by means of the catheter. Back flow was restored and the wound closed. The next day the horse was handwalked. No lameness or signs of discomfort were seen. Both hindlimbs were warm, a digital pulse was palpable and the medial saphenous veins were both filled. On the sixth day, after the second operation, the horse was trotted over a short distance and no lameness was observed. The other 12 horses were handwalked the day after surgery.

#### Follow-up

Wound healing was by primary intention in 14 horses. Oedema distal and around the access site with haematoma or seroma formation was observed in 5 horses and, in one horse, the seroma (diameter of approximately 10–15 cm) was drained 7 days post operatively. This horse received antibiotic drugs and NSAIDs for 10 days. The drain wound healed by secondary intention within a week. One of these horses had some oedematous swelling and minor purulent discharge from the wound one week post operatively.

Post operatively all horses could be handwalked. Nine horses (53%) returned to their previous performance, the competition

horses being successful at the same level or higher. Two (12%) horses improved and were able to be trained for more than 30 min without clinical signs. Four (23%) horses were subjected to euthanasia, one because of a technically unsuccessful surgery, one due to a femur fracture and 2 because of severe post operative myopathy. Reocclusion of the treated artery occurred after 4 months in 2 cases following surgical intervention. One horse was reoperated and, due to the extent of the thrombus and the quality of the arterial wall it was decided to subject the horse to euthanasia. The other horse was subjected to euthanasia without a second surgery.

Of the horses that were lame before exercise both had a thrombus well attached to the arterial wall. One horse returned to previous performance activity and developed a reocclusion and the other one improved.

Of the 6 horses that showed colic like symptoms prior to surgery, 4 returned to athletic activity and the remainder were technically unsuccessful.

## Discussion

Since the first 2 recanalizations of a totally occluded femoral and iliac artery (Brama *et al.* 1986) 17 horses have been operated on. The surgical intervention was technically successful in 16 cases. In only one case (*Case 14*) was it impossible to loosen the thrombus which was tightly attached to the arterial wall at the site of the incision to proximal and distal. No association could be made between the duration and severity of clinical signs and the degree of the adhesion of the thrombus to the arterial wall or the length of the palpable roughness of the arterial wall; *Case 14* had clinical signs for about one year.

Removal of the thrombus at the distal site was more difficult, as described by Brama *et al.* (1986).

Intraoperative complications occurred in 3 cases varying from venous bleeding (2 horses) to transection of the arterial wall (one horse). Venous bleeding occurred while preparing the most proximal site of the thrombosed artery, the area most difficult to reach because it is deep between the muscle and more medial of the artery.

Total transection of the artery is a possible complication, especially when the thrombus adheres to the arterial wall at the site of the incision and the quality of the arterial wall has changed with an inflammatory reaction. During catheterisation it is important to be careful with the transverse incisional site, especially when blood flow after removal of a part of the thrombus is regained. At the moment of release of the ligature to introduce the catheter or to retract the catheter, vision of the incisional site is reduced. The ligature is tightened as the catheter is introduced or retracted and care must be taken not to tighten the artery too suddenly or under too much tension, causing an extension of the incision.

When good blood flow is achieved, a suction drain is essential to maintain visibility. With the release of a high volume of blood the suction drain can become obstructed, increasing the duration of surgery. Regular flushing of the suction drain with heparin solution during surgery might prevent this problem.

The intraoperative complications could be solved without affecting clinical outcome.

Post operative complications varied with severe myopathy, acute thromboembolism on the controlateral limb, wound healing problems to reocclusion. Post anaesthetic myopathy was seen in 4 cases (24%) and was so severe that euthanasia had to be

considered. This condition is assumed to be primarily caused by local hypoxaemia of various muscle groups, especially the muscle of the diseased limb, which happens to be the limb where the horse is positioned during surgery. Horses with AIT have pre-existing hypoxaemia before surgery and are therefore at high risk of this complication. Adequate padding, correct positioning, prevention of intraoperative hypotension and keeping surgery duration as short as possible, are extremely important parameters to consider (Brama *et al.* 1996). Surgery should be postponed when the muscle enzymes are highly increased as is seen after induced colic like signs.

If a horse is suffering from peripheral arterial occlusion in both limbs it is advisable to operate first on the most severe lame limb and, 7–10 days later, the controlateral limb, to reduce the risk of a myopathy as occurred in one of the cases in this series. *Cases 3* and *4* had to be subjected to euthanasia due to severe myopathy; *Case 3* was operated on both legs in one surgical session. After this it was decided to abandon surgery on both limbs in the same operation session and *Case 4* had only one limb operated on, but also suffered severe myopathy after surgery. *Cases 1* and *2* had myopathy and survived. *Case 2* had only a mild myopathy and had also thrombosis of both hindlimbs, whereas *Case 1* had severe myopathy and only thrombosis of one hindlimb. The thrombosis of the other hindlimb in *Case 2* was not observed in first instance. Although not statistically significant it seems that arterial occlusion on both hindlimbs increases the risk of a post operative myopathy.

Acute thrombo-embolism of the controlateral limb, induced by loosening of thrombi at the aorta, is a complication that must be taken into account (Brama *et al.* 1986). To be prepared for this complication a transrectal ultrasonography of both iliac arteries is advisable. Risk of wound healing problems, such as haematoma formation (2 cases) and seroma formation (2 cases) complicated by purulent wound discharge, is relatively high. Administration of heparin intra- and post operatively increases the chance of haematoma and seroma formation. The necessity for post operative heparin therapy is unknown and is based on human experiences. It is indicated to prevent early clot and thrombus formation. In case of intraoperative diffuse bleeding it is possible to avoid or delay the administration of heparin or to use low molecular weight heparin, which reduces the risk of bleeding (Feige *et al.* 2003).

Reocclusion occurred in *Cases 11* and *16*, 4 months after surgery. Although a good blood flow was obtained at the time of surgery and both horses initially trained again without clinical signs, then signs gradually recurred. *Case 11* was reoperated and due to the extent of the thrombus and the quality of the arterial wall it was decided to subject the case to euthanasia. Whereas at surgery the thrombus was tightly adhered to the arterial wall it was concluded that the reocclusion was not caused by a loosened thrombus, but by the reformation of the thrombus at the damaged arterial wall or at the remaining thrombus. Thrombus development can be associated with arterial contraction, and preferentially occurs at one end of a thrombus in a zone of recirculating flow and does not seem to occur in those areas where the shear forces are most elevated (Zhu *et al.* 2003). Reocclusion was not a major complication in the present series, although in all cases the thrombus in the aorta was not removed. To reduce the risk of reocclusion anticoagulant treatment was continued for at least 6 months. Unfortunately, it was not possible to screen the horses post operatively for the presence of thrombus. The incidence of clinical signs of reocclusion might be low due to the anticoagulant treatment and the fact that only 25% of an artery's flow capacity is

needed to maintain tissue function at rest (Dotter *et al.* 1983; Maxie and Physick-Sheard 1985).

Nine horses (53%) returned to their previous performance, the competition horses having successful competition at the same level or higher; 2 (12%) horses improved and were able to be trained for more than 30 min without clinical complaints. No association could be made between the duration or the severity of the clinical signs and the clinical outcome. The success of this procedure is in the authors' opinion, dependent on the length of the occlusion in which the thrombus is adhered to the arterial wall, as described in human literature (Colapinto *et al.* 1986; Balzer *et al.* 2006). It seems that intraoperatively if the thrombus is only loosely adhered to the arterial wall the prognosis is more favourable than if the thrombus adheres tightly. In 6 cases the end of the thrombus was less attached to the arterial wall and 5 of those returned to their previous level of performance. In the other 11 cases the thrombus was attached tightly and 4 regained their athletic career as before. However, the number of cases is too low to draw conclusions.

Whereas surgery was always performed by the same surgeon but in various clinics, no post operative Doppler ultrasonography was obtained of the cases involved. Therefore, it is not clear whether less positive results are due to restenosis or to insufficient blood supply to the muscles caused by occlusion of the branches of the femoral artery. During surgery only the external iliac and femoral artery are opened and not the arterial branches. These branches might still be embolised, causing muscle degeneration and fibrosis (Oyamada *et al.* 2007).

With the repeated use of the Fogarty catheter, which tears the thrombus out of the artery, damaging of the arterial wall occurs. Improvement of the technique might be obtained by the use of an excimer laser for debulking the thrombus, and stent implantation (Balzer *et al.* 2006), reducing the chance of restenosis. However, in human patients, a 3 mm laser canal is created and then the implant is inserted after balloon dilation (Balzer *et al.* 2006). Whether a 3 mm canal would be sufficient in horses is questionable, as is whether the stent will be strong enough to dilate the artery permanently.

In man, symptomatic improvement for intermittent claudication may be obtained with cilostazol, concurrently with Ascal resulting in an increasing walking distance (Dawson *et al.* 2000; Chapman and Goa 2003). Cilostazol is a phosphodiesterase *type 3* inhibitor that acts by increasing the intracellular concentration of cyclic adenosine monophosphate; in the process, the drug suppresses platelet aggregation and serves as a direct arterial vasodilator. The drug has been shown to improve exercise capacity for patients with intermittent claudication. Despite the potential for symptomatic improvement with cilostazol, it must be borne in mind that such treatment is likely to result in no more than modest improvement in the ability to walk distances, but might be an option to improve results (Dawson *et al.* 2000; Chapman and Goa 2003).

In all horses handwalking exercise was started as soon as possible. This was based on human studies in which an exercise-training programme, improves the walking distance by increasing the oxygen extraction in the legs (Nehler and Hiatt 1999; Girolami *et al.* 1999).

In conclusion the prognosis after surgical intervention is reasonable: 65% of the horses regained athletic activity and 53%

performed at their previous level. Post anaesthetic myopathy is a serious complication, but despite this limitation, cases with peripheral arterial occlusion should be considered candidates for surgical thrombectomy.

## Acknowledgements

The authors would like to thank Dr Hannes Edinger, Dr Bernard Boussauw, Dr Anton Hülsey and Dr Swanson for referring their cases.

## Manufacturers' addresses

<sup>1</sup>Leo Pharmaceutical Products, Breda, The Netherlands.

<sup>2</sup>Dagra Pharma, Diemen, The Netherlands.

<sup>3</sup>Pfizer bv, Capelle aan den IJssel, The Netherlands.

## References

- Balzer, J.O., Gastinger, V., Thalhammer, A., Ritter, R.G., Lindhoff-Last, E., Schmitz-Rixen, T. and Vogl, T.J. (2006) Percutaneous laser-assisted recanalization of long chronic iliac artery occlusions: Primary and mid-term results. *Eur. Radiol.* **16**, 2381-2390.
- Brama, P.A.J., Rijkenhuizen, A.B.M., Swieten van, H.A. and Warmerdam, E.P.L. (1996) Thrombosis of the aorta and the caudal arteries in the horse; additional diagnostics and a new surgical treatment. *Vet. Quart.* **18**, 85-89.
- Boswell, J.C., Marr, C.M., Cauvin, E.R. and Schramme, M.C. (1999) The use of scintigraphy in the diagnosis of aortic-iliac thrombosis in a horse. *Equine vet. J.* **31**, 537-541.
- Chapman, T.M. and Goa, K.L. (2003) Cilostazol: A review of its use in intermittent claudication. *Am. J. Cardiovascular Drugs* **3**, 117-138.
- Colapinto, R.F., Stronell, R.D. and Johnston, W.K. (1986) Transluminal angioplasty of complete iliac obstructions. *Am. J. Roentgenol.* **146**, 859-862.
- Dawson, D., Cutler, B.S., Hiatt, W.R., Hobson, R.W. II, Martin, J.D., Bortey, E.B., Forbes, W.P. and Strandness, D. Jr. (2000) A comparison of cilostazol and pentoxifylline for treating intermittent claudication. *Am. J. Med.* **109**, 523-530.
- Dotter, C.T., Grüntzig, A., Schoop, W. and Zeitler, E. (1983) *Percutaneous Transluminal Angioplasty*, Springer-Verlag, Berlin.
- Feige, K., Schwarzwald, C.C. and Bombeli, T.H. (2003) Comparison of unfractionated and low molecular weight heparin for prophylaxis of coagulopathies in 52 horses with colic: a randomised double-blind clinical trial. *Equine vet. J.* **35**, 506-513.
- Girolami, B., Bernardi, E., Prins, M.H., Ten Cate, J.W., Hettiarachchi, R., Prandoni, P., Girolami, A. and Büller, H.R. (1999) Treatment of intermittent claudication with physical training, smoking cessation, pentoxifylline, or nafronyl: a meta-analysis. *Arch. Int. Med.* **159**, 337-345.
- Hilton, H., Aleman, M., Textor, J., Nieto, J. and Pevec, W. (2008) Ultrasound-guided balloon thrombectomy for treatment of aorto-iliac-femoral thrombosis in a horse. *J. vet. intern. Med.* **22**, 679-683.
- Maxie, M.G. and Physick-Sheard, P.W. (1985) Aortic-iliac thrombosis in horses. *Vet. Pathol.* **22**, 238-249.
- Nehler, M.R. and Hiatt, W.R. (1999) Exercise therapy for claudication. *Ann. Vasc. Surg.* **13**, 109-114.
- Oyamada, T., Saigami, K., Park, C.H., Katayama, Y. and Oikawa, M.A. (2007) Pathology of aortic-iliac thrombosis in two horses. *J. equine Sci.* **18**, 59-65.
- Rijkenhuizen, A.B.M. (2006) Thrombectomy. Minimally invasive surgical techniques. In: *Equine Surgery*, 3rd edn., Eds: J.A. Auer and J.A. Stick, W.B. Saunders, St Louis. pp 167-168.
- Zhu, T., Zhao, H., Wu, J. and Hoylaerts, M.F. (2003) Three-dimensional reconstruction of thrombus formation during photochemically induced arterial and venous thrombosis. *Ann. Biomed. Eng.* **31**, 515-525.

**Author contributions** All authors contributed to all aspects of this study.