The incidence of post anaesthetic myopathy (PAM) in horses after general anaesthesia for MRI in comparison to the incidence of PAM in horses anaesthetised for other reasons

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Summary

In a retrospective study the anaesthetic records of 1270 horses were evaluated to determine the incidence of post anaesthetic myopathy (PAM). These horses were grouped into four categories: surgery in dorsal recumbency *(n=493)*, surgery in lateral recumbency *(n=546)*, MRI *(n=150)* and CT *(n=74)*. The aim of the study was to determine whether the incidence of PAM is higher in the MRI group, and to evaluate the possible risk factors. It was found that the incidence of PAM in the MRI group is significantly higher compared to the surgery in lateral recumbency group. The body weight was not significantly different between the horses with and without PAM, but anaesthetic duration was significantly longer in horses that developed PAM compared to horses that did not develop PAM within the groups. There was a significant difference in the incidence of PAM when comparing emergency surgery patients to elective surgery patients. PAM has a higher incidence in the emergency surgery group.The overall incidence of PAM in this study was 1.35% with a mortality of 0.16%.

Introduction

Post anaesthetic myopathy (PAM) is a form of muscle necrosis in horses, which can occur after the horse has been anaesthetised. Myopathies can occur in single groups of muscle or in a generalized form. PAM has been described in the brachial triceps muscle of the forelimb, the extensor carpi radialis muscle, the hind limb adductors, the thorax, back and rump muscles. [2,8, 9]
The myopathy is caused directly by ischaemia and indirectly by post-ischaemic reperfusion injury. The ischaemia can be the result of many different factors. Firstly, by low perfusion of the muscles secondary to hypotension, secondly by increased intracompartmental muscle pressure (ICMP) and thirdly, by hypoxemia.[8, 10, 17, 19, 20, 21]
Hypotension in anaesthetised horses is caused by the negative inotropic and vasodilatory effects of inhaled anaesthetics, to which horses are particularly susceptible. In the late eighties and begin nineties the relationship between hypotension during anaesthesia, the duration of anaesthesia, and PAM was documented. If the mean arterial blood pressure drops to 60 mm Hg or less the risk of developing PAM increases. Since the nineties, monitoring of blood pressure and treatment of hypotension has reduced the incidence of PAM. [9, 10, 19, 25]
The positioning of the anaesthetised horse is of great importance. If the limbs are not placed correctly, the venous draining may be impaired, causing an increase in the intracompartmental muscle pressure (ICMP). Furthermore, a soft material should be used to place the horse on, preferably an air or water mattress. [17, 24, 26]
Hypoxemia can be caused by hypoventilation or reduction of inspired oxygen, which is unlikely in an anaesthetised horse, and by ventilation-perfusion mismatch or shunting. The lower lung in an anaesthetised horse becomes atelectatic within 20 minutes. This causes a ventilation-perfusion mismatch which can cause hypoxemia. This can lead to a shortage of oxygen in peripheral tissue. [11, 21]

Symptoms

The symptoms become evident in recovery or soon after. The horse may be lame or even unable to stand. The affected muscles are generally the muscles which were dependent during surgery, but occasionally the uppermost muscles are affected. If the non-dependant limb is affected it can be due to improper placement of the limb, causing impairment of the venous draining, increasing the ICMP. A generalised form of myopathy may also occur. Muscles commonly affected are the masseter, triceps, and flank muscles when placed in lateral recumbency, and the gluteal muscles when placed in dorsal recumbency.[17]
The affected muscles are swollen and painful, and muscle fasciculations may be observed. The horse may be sweating and anxious due to the pain.
If the hind limbs are affected the horse may not be able to rise. If the triceps muscle is affected, the horse will drop its elbow in a way similar to a radial nerve paralysis. The difference is that in a neuropathy, the muscle is not swollen and painful. However, a neuropathy and a myopathy can occur simultaneously.[1, 21]

Diagnosis

Based on clinical history and the symptoms described above, a post anaesthetic myopathy can be suspected. The diagnosis can be confirmed by measuring the serum muscles enzymes. A myopathy always causes elevated creatine kinase (CK) levels, so if this enzyme is low it rules out a myopathy. It should be kept in mind that general anaesthesia can raise the concentrations of CK and aspartate aminotransferase (AST). Immediately after anaesthesia the perfusion of the affected muscles may not be optimal, and an increase in activity in CK and AST might not be found. If the blood sample is taken an hour after the horse has recovered from the anaesthesia the concentration of CK can exceed 10 000 IU/L in the case of a myopathy (normal CK levels <100 IU/L). [21]
Ultrasound evaluation of the affected muscles may show a diffuse increased echogenicity and loss of striated pattern compared to non-weight-bearing unaffected muscles. Focal areas of increased echogenicity may also exist in myopathy patients. The entire muscle should be scanned to avoid missing these lesions. The prognostic value of the severity of the ultrasound evaluation is uncertain. Based on a few cases, the pathology seen on ultrasound seems to correlate with the severity of the myopathy.[23]

Treatment

Treatment should reduce pain, swelling and anxiety. Analgesia can be given in the form of NSAID's, opioids and α2-agonists. In severe cases dimethyl sulfoxide can be used as a topical analgesic, as well as corticosteroids and dantrolene sodium to relax the muscle. Dantrolene is normally used in malignant hyperthermia. It alters the intracellular calcium dynamics, decreasing muscle spasms.[21] To calm the horse a dose of acepromazine can be given. This will also help improve peripheral perfusion, but should not be given to hypovolemic horses due to the hypotension caused by vasodilation. Furthermore, the horse should receive Ringer's lactate

solution, or other balanced electrolyte solution to maintain cardiovascular function and to prevent kidney dysfunction due to myoglobinurea.[21]
It has been suggested that free radical scavengers could be used to prevent any reperfusion damage, but there is no evidence to the effect.
Lastly, the horse may benefit from physiotherapy, massage or ultraviolet light. [1, 11, 21]
If the horse is not bearing weight on the affected limb, there is a chance of developing support limb laminitis. Prevention should be directed at reducing inflammation (NSAIDs), improving lamellar blood flow (acepromazine), and preventing platelet aggregation (heparin, aspirin). To reduce the weight on the limb a supportive bandage can be applied and the horse should be placed on a soft bedding to ensure the frog and sole bear weight too. The horse should be encouraged to lie down. Slinging the horse is a good way to reduce the weight on the supporting limb, but it requires close monitoring and not all horses tolerate a sling.[3]

Prevention

There is an increased risk of myopathies if hypotension is present for more than 15 minutes, or if the duration of anaesthesia exceeds 3 hours. [1] The prevention of PAM should be directed at keeping the anaesthetic time as short as possible, reducing the ICMP and increasing the blood flow to the muscles.
Anaesthetic duration can be reduced by an efficient work environment. The ICMP can be reduced by correct placement of the horse and its limbs, and using a soft surface to place the horse on. An air mattress or waterbed is preferable to a foam mattress. In lateral recumbency the dependant front limb should be pulled forward and the upper limb should also be supported. Ideally both limbs should be parallel or slightly raised from the table, with enough space between them to allow venous draining of the limb. In dorsal recumbency care should be taken to position the horse as straight as possible. The hind limbs can be supported by a hoist, but should not be extended as this may result in hind limb lameness due to femoral nerve damage.[11]
The difference between the mean arterial blood pressure (MAP) and ICMP is called the perfusion pressure. This should be >30 mmHg for sufficient microcirculation in the muscle. MAP is easily measured by placing an arterial catheter. ICMP can be measured by placing a wick catheter or a slit catheter in the muscle. The pressure in the triceps muscle of the lower limb has been measured at 30-60 mmHg and the ICMP of the upper limb has been measured at 4-16 mmHg, meaning MAP would need to be 90 mmHg to provide adequate microcirculation in the dependant muscles. [17, 28]
Arterial blood pressure can be elevated by increasing peripheral resistance and increasing cardiac output (CO). Peripheral resistance can be increased by administering vasoconstrictors. However, this will not help increase the blood flow to the muscles. Increasing CO can be accomplished by administering i.v. fluids and by administering positive inotropes which will increase myocardial contractions. Usually dobutamine is used to effect.[11] Dobutamine has been shown to improve blood flow in the muscle by increasing CO and MAP.[16]
Vasoconstrictors will increase MAP, but will not increase peripheral perfusion, and are therefore not the best choice.[20] If possible, the use of halothane or isoflurane should be

minimised, as they produce dose-dependent decrease in blood flow in skeletal muscles. [1, 2, 20, 21] Both anaesthetic agents have been demonstrated to decrease CO and MAP. However, the incidence of PAM is lower in hypotensive horses anaesthetised with isoflurane than with halothane. CO was higher in the horses anaesthetised with isoflurane, suggesting CO has a greater effect on muscle perfusion than MAP.[20]

Prognosis

Depending on the severity of the muscle damage, the temperament of the horse and the treatment, the horse can recover completely. In some cases euthanasia is required due to the extreme pain or inability to rise, or because the horse has developed laminitis of the contralateral limb. [21]

The purpose of this research project

Horses undergoing an MRI scan present us with certain difficulties. The padding and placement of the horse and its limbs is not always optimal, because the space available in the bore of the magnet is limited. This can lead to an increase in ICMP in the limb that is being imaged, but placement and padding of the other limbs is equally important.

Monitoring a patient in the MR environment is more challenging than monitoring a patient in an operating room; Monitoring devices containing ferromagnetic components are attracted by the magnetic field, and if essential must be fixed to the wall or floor. The electromagnetic field can affect the monitoring equipment, or vice versa, causing artefacts on the MR images. There is also a risk of burn injuries, when conductive materials are heated by electronic currents.[1,11]

There are MRI-compatible monitoring devices which are safe to use in the MR environment and do not interfere with imaging. This allows monitoring of blood pressure during MRI. If this equipment is not available, the patient cannot be monitored adequately and long periods of hypotension could go unnoticed.

Finally, the duration of anaesthesia cannot easily be shortened because the scanning time is fixed. However, an experienced team will be able to position the horse quickly and the average time of anaesthesia for MRI is shorter than most surgical procedures (graph 2).

Due to these difficulties, there was an unsubstantiated clinical impression that horses undergoing an MRI scan were more susceptible to developing PAM, than horses anaesthetised for other reasons, i.e. surgery. The aim of this research project is to determine whether the incidence of PAM is higher in horses anaesthetised for MRI in comparison to horses anaesthetised for surgery, and to determine which risk factors are involved. The incidence of PAM in horses anaesthetised for a CT scan was another point of interest, since these patients tend to have a much shorter anaesthetic time and are always anaesthetised intravenously. However, they do share the same difficulties as MRI patients in positioning of the body. Furthermore, we were interested in the incidence of PAM in elective surgery compared to emergency surgery. Colic, wounds and fractures were considered to be emergency surgery. All other procedures were considered to be elective surgery.

Hypothesis

The hypothesis is that the incidence of PAM is higher in horses anaesthetised for MRI compared to horses anaesthetised for surgery or CT.

Materials and Methods

In a retrospective study the records of all horses undergoing anaesthesia at the faculty of Veterinary Medicine in Utrecht, the Netherlands, between January 1st 2008 and December 31st 2010 were reviewed. The records of horses anaesthetised for MRI between January 1st 2005 and December 31st 2007 were also reviewed to obtain a larger dataset. Patients who died or were euthanised during anaesthesia, or whose anaesthetic records were not complete, were not included in this research.

Information obtained from the patient records included the reason for anaesthesia, anaesthetic duration, method of anaesthesia, body positioning, or area of body which was scanned, weight if documented, and occurrence of PAM.

MRI patients were always placed in lateral recumbency, so in order to better compare the surgical patients with the MRI patients, the data was grouped into different categories: MRI (*n=150*), surgery whereby the horse was placed in lateral recumbency (LR: *n=546*) and surgery whereby the horse was placed in dorsal recumbency (DR: *n=493*). Another category was added for the patients who underwent a CT scan (*n=74*). Some of the patients in the surgery group did not belong to either the LR or the DR group, and were placed in the category "other" (*n=7*). These were horses with colic that had been rolled, or the body positioning had not been recorded. These patients were not used in the statistical analysis. The total amount of horses assessed in each group can be seen in table 1. A detailed description of the horses that developed PAM can be seen in table 2.

TABLE 1: Number of patients reviewed in Surgery, MRI and CT that did not develop PAM and number of patients that did develop PAM

Year	Surgery								MRI		CT	
	No PAM				PAM				No PAM	PAM	No PAM	PAM
	DR*	LR**	Other***	Total	DR	LR	Other	Total				
2010	164	142	3	309	2	1	0	3	19	2	28	0
2009	153	211	2	366	1	0	0	1	21	1	22	1
2008	172	189	2	363	1	3	0	4	31	3	23	0
2007									28	1		
2006									30	1		
2005									13	0		
Total	489	542	7	1038	4	4	0	8	142	8	73	1

* DR=Dorsal recumbency, **LR= Lateral recumbency, ***Other=rolled/unknown

TABLE 2: Detailed description of the horses that developed PAM

Year	Group	Age (years)	Breed	Sex	Weight (kg)	Reason for anaesthesia	Method of anaesthesia	Duration of anaesthesia (min)	MAP (mmHg)	PAM
2010	DR	16	NRPS	Mare		Colic	combination	204	10 minutes <60	left triceps
2010	DR	14	KWPN	Mare		Colic	inhalation	210	>60	left triceps
2009	DR	19	KWPN	Mare	505	Colic	combination	115	>60	left triceps
2008	DR	8		Gelding		Bladder stones	combination	281	10 minutes <60	left triceps
2010	LLR	10	KWPN	Mare	633	PEH	inhalation	160		left triceps + left gluteus
2008	RLR	19		Gelding	630	Enucleatio bulbi	combination	87		right triceps
2008	RLR	7	KWPN	Gelding		Olecranon fracture	combination	270	>60	right triceps
2008	RLR	12	Hannoveraan	Mare	597	Transplantation v. saphena	combination	211	>60	right triceps
2010	MRI	6	KWPN	Gelding	600	Left & right front feet	intravenous	135		right triceps
2010	MRI	8		Mare		Right front foot	combination	105		right gluteus
2009	MRI	8	KWPN	Gelding	530	Head	combination	110		left triceps*
2008	MRI	7	KWPN	Mare	673	Left & right front feet	combination	130		right triceps
2008	MRI**	3		Gelding		Head	combination	210		left triceps
2008	MRI	9	KWPN	Gelding	605	Left & right front feet	combination	134		right triceps
2007	MRI	7	KWPN	Gelding		Right front foot	intravenous	90		right triceps + right gluteus
2006	MRI	10	KWPN	Gelding		Right front foot	intravenous	110		left triceps*
2009	CT***	10		Stallion		Right front foot	combination	105		left triceps

** Non-dependant limb, ** Received surgery after MRI, *** Received a cast after CT*

The data were entered into an Excel spread sheet and analysed using SPSS (Statistical Package for the Social Sciences). A chi-square test was used to compare the amount of horses with PAM after MRI to the horses with PAM after surgery in lateral recumbency.

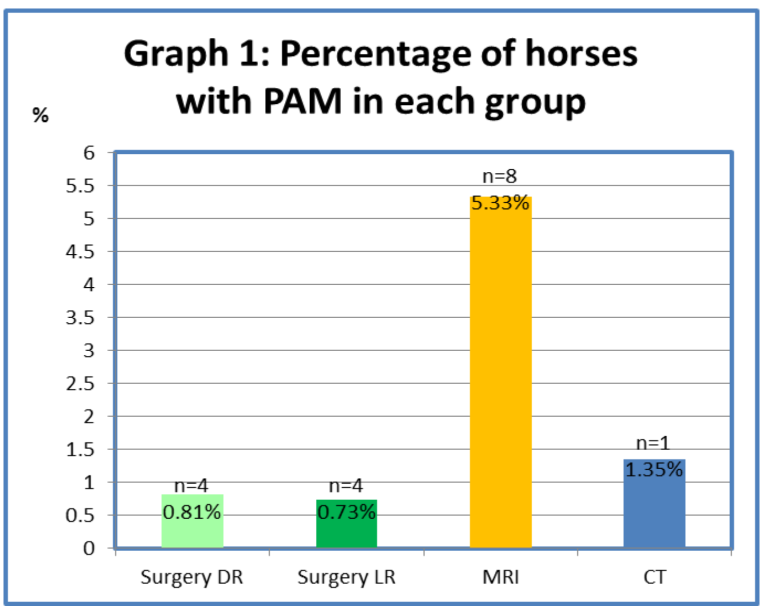
Another point of interest was the duration of anaesthesia, since a long anaesthetic duration may increase the risk of myopathies.[10] The duration of anaesthesia in the LR, DR and MRI groups who did not develop PAM were compared to the horses that did develop PAM within the same groups, using a two sample t-test. To determine if the variances were equal, Levene's Test for Equality of Variances was used.

If recorded, the weight of the horses undergoing anaesthesia was analysed. A higher weight may increase the ICMP, thus increasing the risk of PAM. The weight of the horses in the LR, DR and MRI group who did not develop PAM was compared to the weight of the horses in the LR,

DR and MRI group who did develop PAM, using a two sample t-test. Again, the variances were tested for equality using the Levene's Test for Equality of Variances.
Finally, the horses presented for surgery were further grouped into emergency surgery and elective surgery. Emergency surgery patients were presented with colic, wounds or fractures. All other surgical procedures were considered to be elective surgery. Due to the cardiovascular changes in horses with colic or blood loss, it was thought possible that there may be a higher risk of developing PAM. Using a chi-square test the horses in the emergency surgery group were compared to the horses in the elective surgery group.
The mortality due to PAM was calculated for all the horses that were anaesthetised.

Results

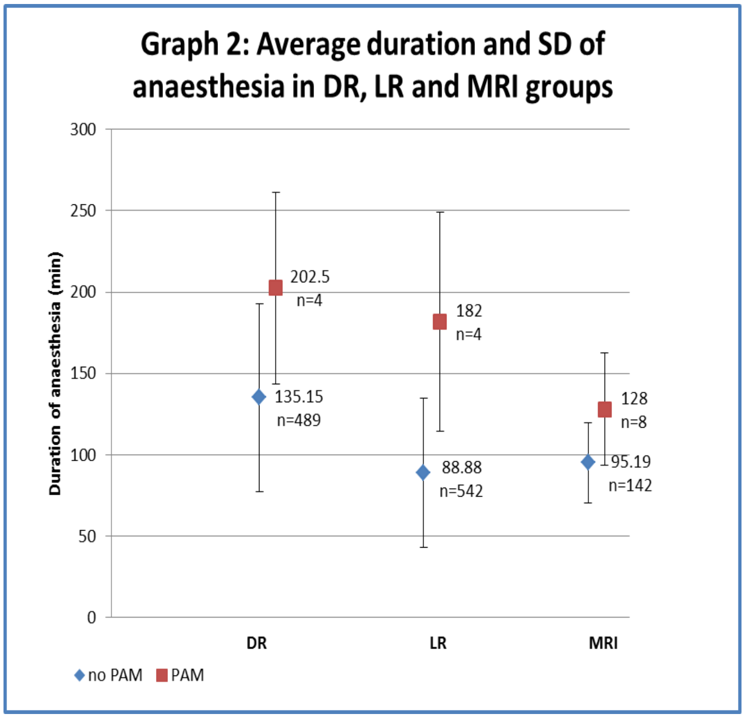
In the period reviewed a total of 1270 patient records could be used for this research project. A total of 17 horses developed PAM in this period. In the surgery DR group there were 4 horses with PAM, as were there in the surgery LR group. In the MRI group there were 8 horses that developed PAM. However, one of these horses received surgery immediately after the MRI scan. This has been kept in mind during the interpretation of the results. The CT group had one horse that developed PAM, but this was not a clear case, as the anaesthetic duration was prolonged to apply a cast to the horse's leg after it had been scanned.

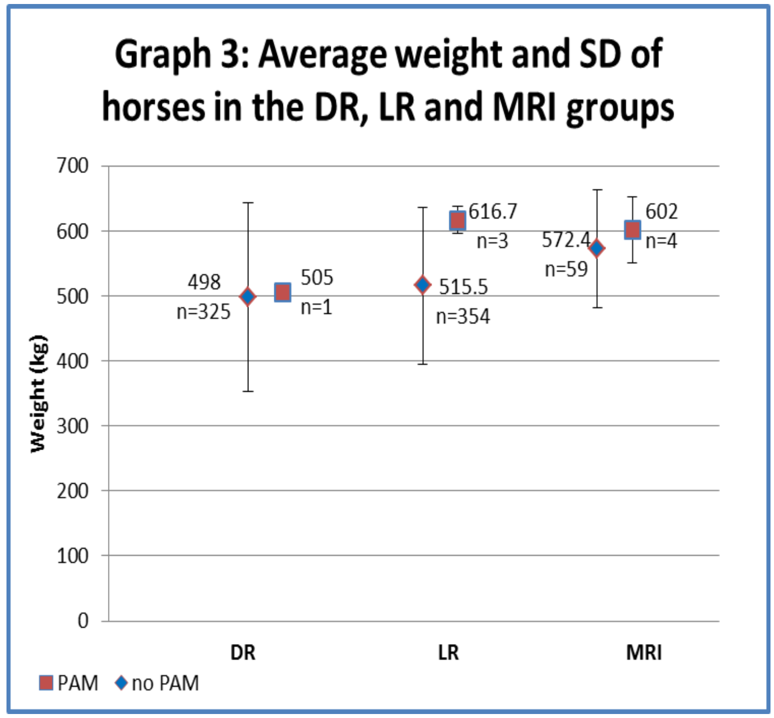


Graph 1: *The incidence of PAM in the MRI group is higher than the incidence of PAM in the surgery LR group (P<0.001) DR: dorsal recumbency, LR: lateral recumbency*

The percentages of horses that developed PAM in each group can be seen in graph 1.
The difference in the occurrence of PAM in the surgery LR group compared to the MRI group was calculated and there was found to be a significant difference (P< 0.001). This graph includes the one horse that received surgery directly after MRI. If we exclude this horse, the percentage of horses with PAM in the MRI group is 4.7% but the occurrence of PAM in the MRI group is still significantly higher (P<0.001) than the occurrence of PAM in the surgery LR group.

The average duration of anaesthesia with the standard deviation (SD) can be seen in graph 2. The variances of the different groups are equal, as assessed by Levene's test (DR: P=0.944, LR: P=0.12, MRI: P=0.354). There was a significant difference between the duration of anaesthesia of horses that developed PAM and horses that did not develop PAM in all groups. (DR: P=0.021, LR: P<0.001, MRI: P=0.001).

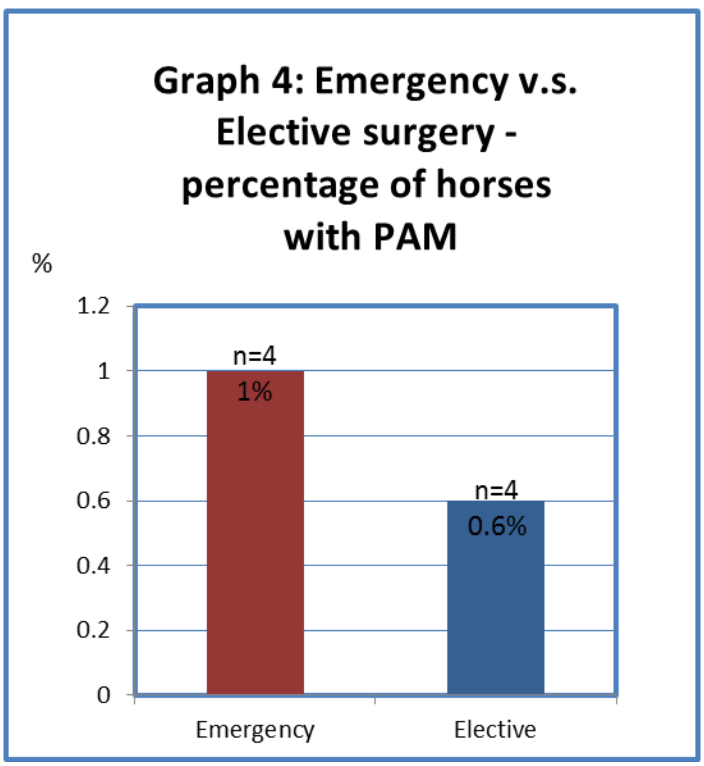




Graph 2: *Horses that developed PAM had a significantly longer anaesthetic duration when compared within groups (DR: P=0.021, LR: P<0.001, MRI: P=0.001) SD: standard deviation, DR: surgery in dorsal recumbency, LR: surgery in lateral recumbency*

Graph 3: *There was no significant difference between the weight of the horses with or without PAM in any group (DR: P=0.962, LR: P=0.147, MRI: P=0.528)*

The average weight of the horses in each group with the standard deviation can be seen in graph 3. The weight of the horse with PAM in the CT group had not been recorded. Therefore the CT group has not been incorporated in the graph. The variances of the different groups are equal, as assessed by Levene's test (DR: P could not be calculated because there was only one horse of which the weight was recorded in the DR PAM group. LR: P=0.136, MRI: P=0.591). There was no significant difference between the weight of the horses with or without PAM in any of the groups. (DR: P=0.962, LR: P=0.147, MRI: P=0.528)



Graph 4: *The incidence of PAM is significantly higher in the emergency surgery group (P<0.05)*

In graph 4 the percentages of horses with PAM in the groups emergency surgery and elective surgery are shown. There was a significant difference in the incidence of PAM in the two groups. PAM has a higher incidence in the emergency surgery group. (P<0.05)

Of the seventeen horses that developed PAM, three received intravenous anaesthesia and fourteen received either inhalation (n=2) or a combination of inhalation and intravenous anaesthesia (n=12).
The arterial blood pressure was measured in six of the horses that developed PAM. Only two of them had MAP below 60 mmHg for no longer than 10 minutes.

Six of the seventeen horses that developed PAM were euthanised, but four of the six were euthanised for reasons unrelated to PAM. The two horses that were euthanised due to the severity of the myopathy were in the surgery group (DR:1, LR:1). One of these horses had developed laminitis of the contralateral limb, which also influenced the decision to euthanize this horse.

Discussion

This study demonstrated that horses undergoing an MRI scan have an increased risk of developing post anaesthetic myopathy compared to horses undergoing surgery in lateral recumbency. These two groups were most comparable, since the horses undergoing MRI are always placed in lateral recumbency. In another study by Franci et al. (2006) the MRI group was compared to the surgery group with DR and LR combined, and no significant difference was found.
In this study 1.35% of all horses developed a myopathy, with a mortality due to PAM of 0.16%. If we only look at the MRI group, the incidence of PAM was 4.7% and the mortality 0%.
In studies published between 1978 and 1993 the incidence of PAM was found to be 1-6.4% [12, 19, 27] In studies published between 2004 and 2007, the incidence was lower; 0.8-1.6%[15, 8, 22] , presumably due to improved anaesthetic management. This data corresponds to the overall incidence of PAM in our study. The incidence of PAM in the MRI group in our study is higher than the incidence in a similar study comparing horses anaesthetised for MRI to horses anaesthetised for surgery, where the incidence of PAM in the MRI group was 2.3%.[8]
Mortality due to PAM was found to be 0.06%[14], 0.02% [4], 0.12%[15] and 0.3%[27] of all horses anaesthetised. These figures were 7%, 14.3%, 7% and 44% of all anaesthetic related deaths, respectively. In this study there is no data available of all anaesthetic related deaths, so no comparison can be made to the portion of deaths related to myopathy. However, many studies have published anaesthesia related mortality rates of approximately 1%.[13] If we compare our results to this data, the portion of deaths due to myopathies would be 16%. It appears that quite a large portion of anaesthetic related deaths are caused by PAM. And even if PAM doesn't result in euthanasia, it is a very painful condition causing the horse a great deal of discomfort.
Post anaesthetic myopathy is a complex phenomenon, and there are many risk factors involved. The most important are the length of procedure, body positioning, ICMP and blood pressure.
In this study the duration of anaesthesia was found to be significantly longer in the horses that developed PAM when comparing the duration of anaesthesia within the groups. However, if we

compare the duration of anaesthesia between the two groups (MRI and surgery LR), the duration of anaesthesia is longer in the LR group than in the MRI group.
There did not seem to be a correlation between body weight and the occurrence of PAM in this study. In other studies body weight also did not appear to be a risk factor[19], but it has been suggested that horses with a greater muscle mass have higher ICMP during anaesthesia. [26]
As we expected, the incidence of PAM in emergency surgery was slightly higher than in elective surgery (1% and 0.6% respectively, P<0.05). The reason for this could be due to the cardiovascular, respiratory or hematologic changes as a result of colic or blood loss, but the patient data needs to be critically analysed to draw any further conclusions.
Another risk factor is body positioning, which is definitely an important technical difference between the two groups. In both groups soft padding is used, but during surgery the placement of the limbs can be easier than during MRI. The restriction of blood flow to the muscles due to an incorrect placement of a limb can result in a myopathy.
To further assess microcirculation in muscles, Doppler flowmetry can be used. However, only relative changes in muscle blood flow can be measured using Doppler flowmetry. This limits the use of this method to measuring changes in perfusion, for example when comparing isoflurane with halothane anaesthesia, or after administering dobutamine.[20] It would be interesting to see the absolute blood flow in muscles during varying anaesthetic protocols, body positions and duration of anaesthesia.
A minimally invasive way to monitor the metabolic events in the muscle during anaesthesia is the use of microdialysis. In one horse the interstitial concentration of lactate was high during anaesthesia. The mean arterial blood pressure did not drop below 70 mmHg and the oxygen saturation did not drop below 99%. Interestingly, this horse developed a post anaesthetic myopathy, meaning lactate could be an indicator of local ischaemia.[7]

Horses are especially sensitive to the cardiovascular effects caused by inhalation anaesthetics. The hypotension caused by inhalation anaesthesia should be dealt with by reducing the amount of inhalation anaesthetic, administering i.v. fluids or administering inotropic drugs. The inhalation anaesthesia can be combined with intravenous anaesthesia (usually an alpha-2 agonist) to minimize the amount of inhalation anaesthesia needed and still maintain an adequate depth of anaesthesia.[25] Aggressive treatment of hypotension with fluid therapy and drugs might not lower the incidence of PAM but it does reduce the severity.[27]
In this study seventeen horses developed PAM, of which three horses received intravenous anaesthesia and fourteen received either inhalation (n=2) or a combination of inhalation and intravenous anaesthesia (n=12). The two horses with a short period of hypotension were anaesthetised with combined inhalation and intravenous anaesthesia. In this clinic it is rare to use only inhalation anaesthesia. It would be interesting to see how many of the horses needed inotropic drugs to maintain adequate MAP during anaesthesia.
In the surgery DR and LR groups, 6 of the 8 horses with PAM had been monitored for hypotension, of which 2 horses were hypotensive for only 10 minutes. Hypotension does not seem the most likely reason for PAM in the surgery groups. Hypotension is definitely a risk factor for PAM, because it is associated with perfusion of the muscles, but as Raisis et al. (2005) say; CO may be more important than MAP in maintaining adequate blood flow in the muscle. If

the hypotension was caused by vasodilatation, but CO was maintained, it is possible that the perfusion of the muscles was still adequate. This shows again that post anaesthetic myopathy is a multifactorial affliction.
Monitoring a patient during MRI is difficult due to the MR environment. The mean arterial pressure and oxygen saturation was not measured in any of the MRI patients, because MRI compatible equipment was not available in the clinic during the period of this study. It is possible that long periods of hypotension or hypoxemia are going unnoticed and untreated in MRI patients.

In conclusion, this study demonstrated that the incidence of PAM was higher in horses anaesthetised for MRI compared to those anaesthetised for other reasons. The overall incidence of PAM was comparable to other studies, as was the mortality. Anaesthetic duration was significantly longer in horses that developed PAM when compared within groups. When compared between groups, the duration of anaesthesia was longer in the surgery LR group, indicating other factors are of importance in the development of PAM. Body weight did not appear to be an important risk factor, as other studies have also shown. Hypotension has been linked to PAM for a long time. There is still much that needs to be discovered about the relationship between anaesthesia, hypotension, muscle perfusion and the development of PAM. When there is a way to measure quantitative blood flow in skeletal muscles, this relationship can be better understood. In the meantime, an interesting way to monitor metabolic events directly in the muscle is microdialysis, though this also cannot be done during MRI.
It seems that monitoring blood pressure and treatment of hypotension in surgery patients in the nineties reduced the incidence of PAM. Maybe the same will be true for the incidence of PAM in MRI patients. For now, appropriate monitoring of the patient and correct placing of the limbs with good support can help prevent PAM, whether the patient is being anaesthetised for surgery or for MRI.
When considering general anaesthesia for MRI the outcome of this study should be kept in mind.

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