

Fatal diaphragmatic rupture during recovery from general anaesthesia in a Standardbred horse

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Summary

A 23 years old Standardbred mare underwent elective enucleation of the left eye under general anaesthesia. Induction and maintenance of anaesthesia were unremarkable but the horse had a turbulent recovery phase twice rolling over on to its back. The horse showed agonal gasps and cardiopulmonary resuscitation was started immediately but ended with a fatal outcome. On the necropsy a fresh diaphragmatic tear was found with herniation of the colon and entire caecum into the thoracic cavity. This case illustrates an unusual complication during the recovery phase from general anaesthesia in the horse.

Keywords: horse / general anaesthesia / recovery / diaphragmatic rupture / fatality

Fatale Zwerchfellsruptur während der Aufstehphase nach Allgemeinanästhesie bei einem Traber

In der Klinik für Pferde der Veterinärmedizinischen Universität Wien wurde eine 23-jährige Stute mit seit zwei Jahren bestehendem Exophthalmus des linken Augapfels und wiederkehrenden Atemwegsobstruktion (RAO: recurrent airway obstruction) vorgestellt. Anhand radiologischer und sonographischer Untersuchungen der Augenhöhle wurde eine retrobulbäre Masse festgestellt und das Auge wurde einen Tag später in Allgemeinanästhesie enukleiert. Die Einleitung und Erhaltung der Narkose verliefen unspektakulär, aber die Stute durchlief eine turbulente Aufwachphase, wobei sie sich zweimal über ihren Rücken überschlug. Unmittelbar danach hat das Pferd nach Luft geschnappt, worauf sofort mit kardiopulmonaler Reanimation begonnen wurde. Die Trachea wurde erneut intubiert und das Pferd wurde mit 100% Sauerstoff über demand valve beatmet. Die Herzmassage wurde durch Thoraxkompression durch Springen auf den Thorax, 40-50 Mal pro Minute, vollzogen. Die Stute bekam zweimal Atropin und Adrenalin. Die Wiederbelebungsmaßnahmen, welche 12 Minuten lang durchgeführt wurden, blieben ohne Erfolg. Unmittelbar nach Todesfeststellung wurde die Sektion durchgeführt. Die pathologische Untersuchung ergab einen akuten Zwerchfellriss mit Vorfall von Colon- und Ceacum in die Brusthöhle. In diesem Fallbericht ist eine Zwerchfellruptur mit Zwerchfellhernie als seltene Komplikation während der Aufwachphase nach Allgemeinanästhesie beim Pferd präsentiert.

Stichwörter: Pferd / Allgemeinanästhesie / Aufwachphase / Zwerchfellruptur / Fatalität / Narkose

Introduction

The reported perianaesthetic death rate of horses undergoing general anaesthesia (excluding emergency abdominal surgeries) is 0.9% with 25.6% of the fatalities occurring in the recovery phase. Documented cases include post-operative cardiovascular collapse, fractures, myopathies and postoperative haemorrhage (Johnston et al. 2002). Diaphragmatic hernia occurring during recovery has, to the best knowledge of the authors, not yet been described. This report documents a fatality during recovery from general anaesthesia in a Standardbred horse which is highly likely have been caused by acute diaphragmatic rupture.

Case description

A 23 year-old 541 kg Standardbred mare was presented at the Clinic for Horses of the University of Veterinary Medicine in Vienna, with a two year history of right exophthalmos. The horse was previously diagnosed with a moderate recurrent airway obstruction and received clenbuterol, dembrenine and prednisolone on an irregular basis. On the basis of radiographic and ultrasound examinations, a diagnosis of a retrobulbar mass was made and the horse was scheduled for surgical extirpation of the right eye under general anaesthesia. During preanaesthetic physical examination, the mare was alert and responsive; rectal temperature (37.8°C), pulse rate (40 beats minute⁻¹), capillary refill time (<2 sec) and mucous

membranes (pale, pink and moist) were unremarkable. Respiratory rate was elevated (22 breaths minute⁻¹). The horse showed a mild mixed dyspnea. Increased bronchial sounds and wheezes were audible bilaterally on thoracic auscultation. Blood gas analysis of arterial blood samples taken from the carotid artery in the standing unsedated mare yielded physiologic values: PaO₂ 98 mmHg (13.03 kPa), PaCO₂ 39.7 mmHg (5.19 kPa), D(A-a)O₂ 14.8 mmHg (1.97 kPa). Routine preanaesthetic blood analysis showed mild leucocytosis (16 270 l⁻¹); all other parameters were within normal limits. Based on the results of the preanaesthetic examination, the mare was scored ASA 3 (American Society of Anesthesiologists).

A 12-gauge catheter was inserted in the left jugular vein and benzylpenicillin 30 000 IE kg⁻¹ IV (Penicillin G Natrium, Sandoz, Austria) and flunixin 1.1 mg kg⁻¹ IV (Finadyne RPS, Intervet, Germany) were administered 40 minutes prior to anaesthetic induction. The horse was given acepromazine 0.02 mg kg⁻¹ IV (Vana-stress, Vana, Austria) followed 25 minutes later by xylazine 0.6mg kg⁻¹ IV (Sedaxylan, Vana, Austria) and butorphanol 0.02 mg kg⁻¹ IV (Butomidol, richterpharma ag, Austria). Anaesthesia was induced 7 minutes later with midazolam 0.1 mg kg⁻¹ IV (Midazolam, Mayrhofer, Austria) and ketamine 2.2 mg kg⁻¹ IV (Narketan, Vetoquinol, Austria). The trachea was intubated with a 30-mm endotracheal tube. The horse was placed in left lateral recumbency and connected to a large animal circle breathing system. Anaesthesia was maintained with isoflurane in oxygen (4 L minute⁻¹) and continuous rate infusion (CRI) of a

mixture of xylazine, midazolam and ketamine. This CRI (250 mg xylazine, 15 mg midazolam and 1000 mg ketamine in 500 ml 0.9% NaCl) was started with a rate of 0.6 ml kg⁻¹ hour⁻¹. The end-tidal isoflurane concentration was maintained at approximately 1.0%. A balanced electrolyte solution was administered at a rate of 10 ml kg⁻¹ hour⁻¹. The metatarsal artery was catheterised to allow direct measurement of arterial blood pressure and arterial blood gas analysis (at 10 and 60 minutes after induction, table 1). A retrobulbar block with 15 ml of 2% lidocaine (Xylanest purum 2%, Gebro Pharma, Austria) was performed 15 minutes after induction. Standard surgical transpalpebral enucleation of the right eye was performed. Maintenance of anaesthesia and monitoring of vital parameters was unremarkable. The horse was disconnected from the circle breathing system 90 minutes after induction of anaesthesia. Butorphanol 0.02 mg kg⁻¹ IV (Butomidor, richterpharma ag, Austria) was administered 5 minutes prior to disconnection.

The horse was allowed to recover in a padded recovery box and 15 L minute⁻¹ oxygen insufflation was provided via endotracheal tube (ETT). The trachea was extubated 8 minutes after disconnection from the circle breathing system and oxygen at same rate was provided nasally. Ten minutes later, when the mare lifted her head, a benzodiazepine inverse agonist sarmazenil 2 mg IV (Sarmasol, Gräub, Switzerland) was administered. Subsequently, the horse was observed through the window of the recovery box door. The mare attempted to stand up three minutes later but fell onto the side and rolled over her back. Immediately afterwards, during a second attempt to stand, the mare fell again on the same side, rolled over onto her back and landed on in right lateral recumbency with her legs trapped against the wall. Several deep breaths considered agonal gasps were then observed. The trachea was immediately intubated with a 30-mm ETT and emergency ventilation (10-15 times per minute) was started using a demand valve providing pure oxygen. The pulse was weak and disappeared during intubation. Adrenaline 0.001 mg kg⁻¹ IV (Suprarenin, sanofi aventis, Austria) was administered. Cardiopulmonary-cerebral resuscitation (CPCR) was performed by two persons of 90 and 95 kg weight respectively, alternating every minute. Cardiac massage was carried out by rhythmically jumping onto the thorax 40-50 times per minute. After two minutes, 0.005 mg kg⁻¹ IV atropine (Atropinum sulfuricum "Nycomed", Nycomed, Austria) was administered followed two minutes later by 0.01 mg kg⁻¹ IV adrenaline (Suprarenin, sanofi aventis, Austria) and 0.01 mg kg⁻¹ IV atropine (Atropinum sulfuricum "Nycomed", Nycomed, Austria). During 12 minutes of attempted resuscitation, the pulse did not reappear and the procedure was stopped. After death had been confirmed, the mare underwent necropsy.

Pathologic findings

Necropsy revealed low-grade haemothorax and medium grade haemoabdomen. Any of main arteries were ruptured. There was a 20 cm long tear with haemorrhagic and ragged edges in the right ventral portion of the diaphragm at the level of connection between the muscular and the tendinous part. Through this tear, the entire caecum, pelvic flexure and the left ventral colon were herniated into the thoracic cavity. The lungs showed small atelectic areas. There was no macroscopic evidence of pulmonary embolism. A modest amount of blood was found in the large bronchi and there was evidence of mild

chronic bronchitis and peribronchitis. The heart was unremarkable. The spleen showed acute congestion. Histopathological examination of the torn muscular part of the diaphragm revealed acute bleeding. On basis of these findings, it was considered that an acute diaphragmatic rupture with a displacement of large parts of colon and the entire caecum into the thorax and significant fresh bleeding into thoracic and abdominal cavities caused the death of the mare.

Discussion

Diaphragmatic hernias occur sporadically in horses. They may be congenital or acquired (Wimberly et al. 1977, Pauwels et al. 2007). In the described case, congenital hernia seems to be unlikely because the horse had no previous history of acute or recurrent episodes of colic as in cases described by Proudman and Edwards (1992) and Pauwels et al. (2007). Acquired hernias typically occur secondary to blunt trauma or an increase in intra-abdominal pressure following a fall, unobserved pasture confinement, natural covering, heavy exercise or parturition (Pearson et al. 1977, Wimberly et al. 1977). Theoretically, a sudden increase in abdominal pressure after induction of anaesthesia when the horse falls abruptly could cause diaphragmatic tear and herniation. The authors do not believe this happened in the present case because adoption of recumbency during induction of anaesthesia was smooth and gradual, controlled by four people pushing and maintaining the horse against the wall during induction. Furthermore, it is likely that a diaphragmatic hernia occurring during induction would interfere with at least pulmonary function during the subsequent anaesthetic period. In one case series two of seven horses undergoing general anaesthesia that had large colon herniation into the thorax died shortly after anaesthesia induction because of inability to ventilate (Pearson et al. 1977). In another case series, complications encountered during anaesthesia in horses with diaphragmatic hernia are listed as follow: hypoventilation, "abdominal breathing", low compliance, hypoxaemia, inadequate anaesthesia (Clutton et al. 1992). Another case report showed that the presence of large colon in the thorax caused difficult ventilation during anaesthesia that normalized immediately after reduction of herniated content (Branson and Kramer 2000). In the latest case report, a horse with diaphragmatic hernia had a marked hypoxaemia 15 minutes after induction which could be treated with continuous positive airway pressure (CPAP) but the horse died shortly after end of anaesthesia (Mosing and Junot 2011). The mare presented here was breathing spontaneously throughout anaesthesia and adequate pulmonary function and gas exchange were confirmed with capnography, pulse oximetry, spirometry and arterial blood gas analysis (table 1).

Particularly in horses, recovery from general anaesthesia has long been recognized as one of the most dangerous phases of the procedure. Some of the injuries associated with recovery include fractures, breakdown of orthopaedic repairs, dislocation of joints, lacerations, haemorrhage, head trauma and dehiscence of surgical wounds (Johnston et al. 2002). Horses recovering from ocular surgery are at a greater risk for an unsatisfactory recovery. This may be related to pain from the surgery or, in some animals, following disorientation due to loss of vision in one eye (Parviainen and Trim 2000). The mare in this case report experienced a difficult recovery falling down twice and rolling over her back. Sudden increase in intra-abdominal

Table 1 Arterial blood gas analysis (FiO_2 =fraction of inspired oxygen; $PaCO_2$ =carbon dioxide arterial tension; PaO_2 =arterial oxygen tension; $D(A-a)O_2$ =alveolar arterial difference; BE=actual base excess; BE_{ecf} =standard base excess; HCO_3^- = bicarbonate)
Ergebnisse der arteriellen Blutgasanalyse (FiO_2 =Fraktion des eingeatmeten Sauerstoffs; $PaCO_2$ =arterielle Kohlendioxidspannung; PaO_2 =arterielle Sauerstoffspannung; $D(A-a)O_2$ =alveolär-arterielle Differenz; BE=Aktueller Basenüberschuss; BE_{ecf} =Standad Basenüberschuss; HCO_3^- =Bicarbonat)

	10 minutes after induction	60 minutes after induction
FiO_2	0.74	0.85
pH	7.31	7.31
$PaCO_2$ mmHg (kPa)	54.6 (7.18)	61.2 (8.14)
PaO_2 mmHg (kPa)	149.5 (19.88)	212.3 (28.24)
$D(A-a)O_2$ mmHg (kPa)	311.8 (41.47)	320.6 (42.64)
BE (mmol l ⁻¹)	-0.1	2.7
BE_{ecf} (mmol l ⁻¹)	0.9	4.5
HCO_3^- (mmol l ⁻¹)	27.1	30.6

pressure during the fall is assumed in this case to have caused the diaphragmatic rupture, followed by herniation of the colon and caecum into the thorax. This presumably led to compression of the lungs, hypoxia, cardiogenic shock and cardiac arrest. Cases of cardiogenic shock caused by herniation of bowel or stomach into the thoracic cavity have also been reported in human medicine (*Devbhandari et al. 2007, McKeown and Sischek 2010*). The severity of clinical signs depends on the size and the degree of visceral herniation. The 20 cm long tear in this case allowed herniation of entire caecum and colon into the thorax and dramatically reduced the thoracic volume. Reports of herniation of the large colon through the diaphragm are uncommon (*Pearson et al. 1977, Wimberley et al. 1977, Branson and Kramer 2000, Bryant et al. 2002*).

CPCR in this case was performed immediately by providing intermittent positive pressure ventilation with pure oxygen and compression of the chest wall. This is a traditionally accepted method for maintaining blood flow during cardiopulmonary arrest in horses. The compression is accomplished with the horse preferably in lateral recumbency and performed by forcefully and rapidly thrusting the knee into the horse's chest (*Hubbell et al. 1993*). In the case presented here, chest compression was performed in left lateral recumbency and in order to generate as much compressive force as possible in this large sized horse, a person jumped rhythmically on the thorax. It is unclear if the herniation of the caecum and colon occurred during turbulent recovery directly after diaphragm had ruptured or CPCR.

Both pathologic and histopathologic findings strongly suggest the presumption of the authors that the diaphragmatic tear was acute. In contrast to more chronic cases where numerous fibrous adhesions are found and the edges of the tear are rounded (*Wimberley et al. 1977*), the torn edges of the diaphragm were irregular, haemorrhagic and there was a lack of inflammatory infiltrates. The localisation of the tear complies with the majority of traumatic cases, which are reported to occur in the tendinous portion of the diaphragm, usually where the tendinous portion blends into the muscle portion (*Wimberley et al. 1977*).

In conclusion, the findings of the preanaesthetic examination, the smooth induction and unremarkable maintenance of general anaesthesia together with the results of pathologic findings suggest that the diaphragmatic tear occurred acutely during the turbulent recovery phase. The herniation of caecum and colon into the thorax could have occurred either immediately after the rupture or may have been caused by the forceful CPCR.

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