Equine vet. J. (2001) **33** (3) 231-237

Equine thoracoscopy: normal anatomy and surgical technique

J. F. PERONI*, N. T. HORNER, N. E. ROBINSON and J. A. STICK

Pulmonary Laboratory, Department of Large Animal Clinical Sciences, Michigan State University, East Lansing, Michigan 48824-1314, USA.

Keywords: horse; thoracoscopy; normal anatomy; surgical technique

Summary

Six normal, healthy horses age 3–10 years underwent left and right thoracoscopic examination using a rigid telescope. A minimum of 30 days was allowed between procedures. Horses were restrained in stocks and sedated with a continuous detomidine infusion. After surgical preparation of the hemithorax elected for surgery, and administration of local or regional anaesthesia of the surgery sites, thoracoscopy was completed during two 15 min pneumothorax periods. During the procedures, the thoracic structures were viewed using a 57 cm, 10 mm diameter, 30° rigid telescope connected to a digital camcorder to allow computer capture of digital images. The telescope was inserted into the thoracic cavity via 3 different intercostal spaces. The 8th, 10th and 12th intercostal spaces were randomly selected and used among horses. The exploration of each hemithorax started from the dorsal-caudal quadrant continued toward the cranial thorax and was completed by observing the diaphragmatic and caudal pulmonary region.

Collapsed lung, aorta, oesophagus and diaphragm were viewed readily in either hemithorax. On exploration of the right hemithorax, the azygos vein, thoracic duct and pulmonary veins were also identified. Horses tolerated thoracoscopy well. Signs of discomfort, such as increased respiratory rate, coughing and decreased level of sedation, were associated with lung collapse in one horse, with pneumothorax on 2 occasions, and when the thorax was approached through the 8th intercostal space. Surgery performed via the 8th intercostal space was hindered by the rigidity of the 8th and 9th ribs, and by the presence of a greater musculature, which did not allow easy cranial and caudal movements of the telescope.

Introduction

The equine thorax has been examined safely and successfully with rigid and flexible endoscopes since the mid-1980s (Mackey and Wheat 1985; Mansmann and Bernard-Strother 1985). Case reports have described the use of this technique in the *antemortem* diagnosis of thoracic gastro-oesophageal squamous cell carcinoma, haemangiosarcoma and cholangiocellular carcinoma (Ford *et al.* 1987; Rossier *et al.* 1990; Mueller *et al.* 1992). Recently, thoracoscopy was used in the diagnosis and treatment of equine thoracic disease (Vachon and Fischer 1998). In normal, healthy horses, thoracoscopy was well tolerated and caused minimal cardiopulmonary alterations (Peroni *et al.* 2000).

In man, thoracoscopy carries the advantages of a shortened hospital stay, earlier return to function, and less intra- and postoperative pain when compared to thoracotomy (Ginsberg 1993). Small skin incisions coupled with specially designed endoscopic equipment allow observation of intrathoracic structures with minimal invasion of the chest cavity. Direct examination offers the advantage of close inspection of normal and diseased structures. In certain conditions, thoracoscopy complements traditional diagnostic methods, such as clinical evaluation, ultrasonography, radiography and endoscopy (Haasler 1995). The information reported here was generated during a study that evaluated cardiovascular and pleuropulmonary functions during thoracoscopy (Peroni *et al.* 2000). We describe the procedure used for thoracoscopy, the structures that are visible in healthy, awake, sedated horses and the complications encountered.

Materials and methods

Horses

The study was approved by the All-University Care and Use Committee at Michigan State University and was part of a larger study aimed to define the cardiovascular and respiratory changes associated with thoracoscopy performed in healthy standing horses. Six horses (3 mares and 3 geldings) age 3–10 years and 440–560 kg bwt were used in a study aimed to determine the cardio-pulmonary changes caused by the procedure (Peroni *et al.* 2000). Each horse underwent a left and right hemithoracoscopy with a minimum 30 day interval between procedures.

Patient preparation

Two hours before surgery, each horse was treated with flunixin meglumine (Banamine)[1] 1 mg/kg bwt i.v. and procaine penicillin G (20,000 iu/kg bwt i.m.). Blood was drawn to evaluate white blood count and fibrinogen concentration. Immediately before the procedures, horses were groomed and restrained in stocks and the tail wrapped with an elastic bandage to avoid contamination of the surgical field. A catheter (Angiocath)[2] was placed aseptically in the right jugular vein for

*Author to whom correspondence should be addressed. Present address: Large Animal Medicine Department, College of Veterinary Medicine, University of Georgia, Athens, Georgia 30602, USA.

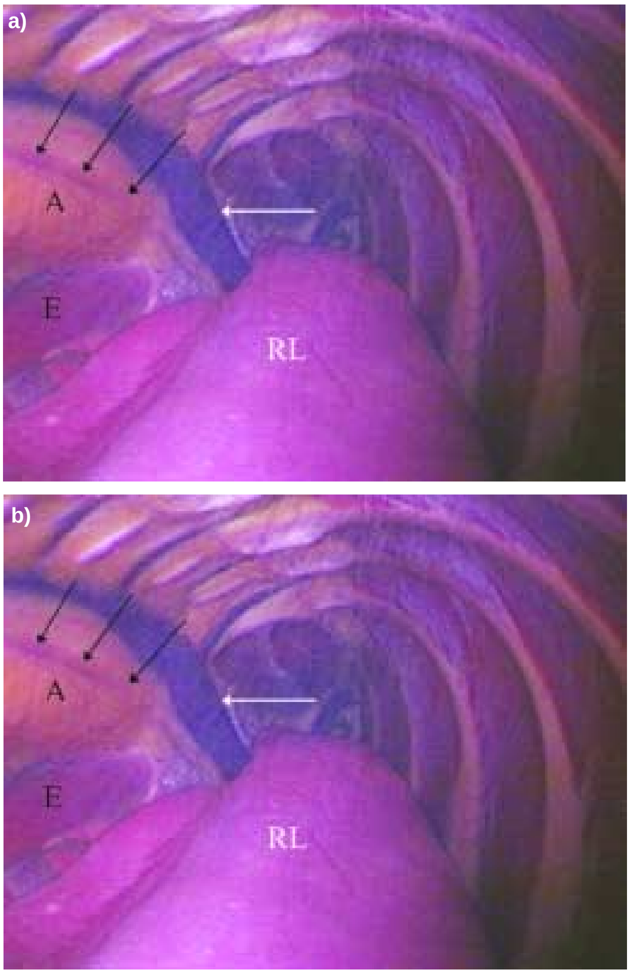

Fig 1: a) Thoracoscopic view of the cranial region of a right hemithorax showing, in the foreground, the collapsed right lung (RL). Mediastinal structures such as oesophagus (E), aorta (A), thoracic duct (black arrows) and azygos vein (white arrow) are also visible. b) Thoracoscopic view of the cranial region of a left hemithorax showing the collapsed left lung (LL) medial to which the aorta (A) with its vasa vasorum *(black arrows).*

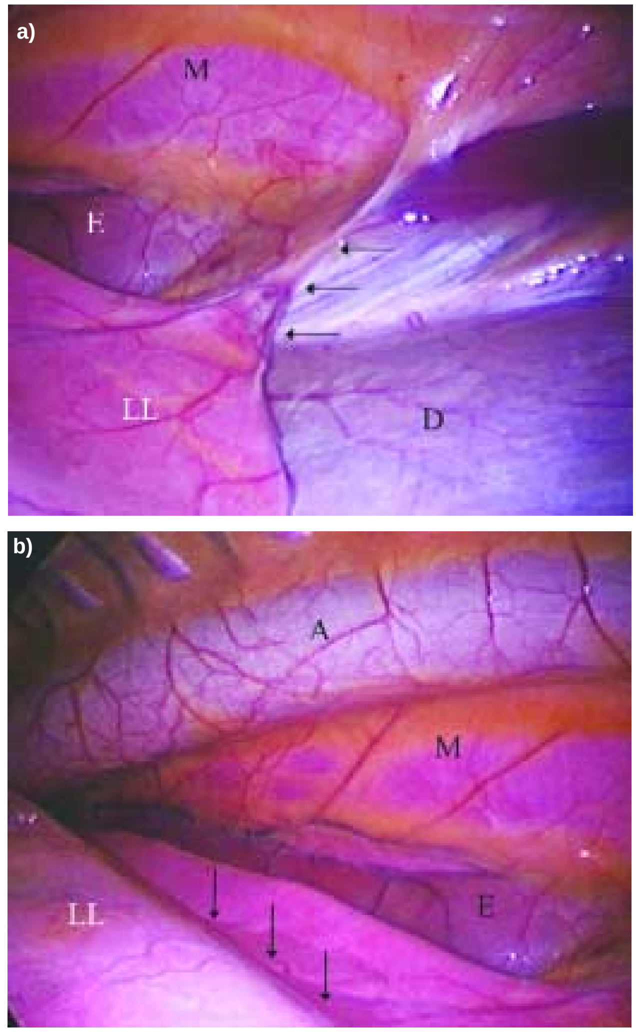

Fig 2: a) Thoracoscopic view of the caudal-dorsal region of a left hemithorax. The pulmonary ligament can be identified (black arrows) leading to the collapsed left lung (LL). The caudal edge of the lung lies on the diaphragm (D). The dorsal mediastinum (M), through which the inflated right lung can be seen, is located dorsally. Below the mediastinum the oesophagus (E) is found. b) Thoracoscopic view of the mid-dorsal region of a left hemithorax. With respect to Figure 2a, the telescope has been directed cranially and dorsally. In the foreground is the dorsal border of the collapsed left lung (LL) with the aortic impression (black arrows). Medial to the lung the oesophagus (E) is seen and the dorsal mediastinum (M), through which the inflated right lung can be seen, and the aorta (A) are identified dorsally.

the administration of the sedative-analgesic, detomidine (Domosedan)[3] HCl. A single i.v. bolus (6 µg/kg bwt) was administered and followed by a continuous i.v. infusion (0.8 mg/kg bwt/min). A square area, extending from just lateral to the dorsal midline to the point of the elbow and from the caudal scapular margin to the 15th rib, was clipped and prepared aseptically for surgery. A large disposable drape was used to cover the thorax and abdomen and a window was cut in the drape over the selected surgery site. The drape was secured by means of an adhesive plastic sheet (Ioban II)[4], which was attached to the drape and to the surgical site.

The endoscopic portal was placed ventral to the *serratus dorsalis* muscle (epaxial muscle group). The 8th, 10th or 12th intercostal space was selected randomly among horses. The accessory portal was located within the 8th or 11th intercostal space, approximately 10–15 cm below the endoscopic portal. Upon selection of the surgical site, regional or local anaesthesia was provided to the area. Four out of 12 procedures were performed under regional anaesthesia. Local anaesthetic was placed over the intercostal nerve that provided sensation to the intercostal space designated for surgery. In addition, sensation was abolished one intercostal space cranial and one caudal to the surgical site. Local anaesthetic (2% carbocaine; Carbocaine)[5] was placed subcutaneously as proximally as the selected rib could be digitally palpated. An 18 g 3.8 cm needle was then directed toward the caudal border of each rib and used to deposit 8–12 ml of local anaesthetic. An 18 g 8 cm spinal needle was necessary to provide anaesthesia for the 8th intercostal nerve. In the remainder of the procedures (8/12), anaesthesia of the surgery sites was achieved by infiltrating 8 ml of anaesthetic locally into the subcutaneous, muscular and pleural tissues.

TABLE 1: Equipment used for thoracoscopy

A) *Video imaging and recording equipment*		
Surgical camera, camera control unit, monitor		
Fibreoptic light cable and xenon light source		
Digital camcorder		
B) *Surgical equipment*	*Length (cm)*	*Diameter (mm)*
Rigid 30° telescope	57	10
Sharp trocar/cannula system	15	11 (cannula: - external diameter)
Sharp trocar/cannula system	15	11 (cannula: - external diameter)
Reducer	0.5	
Graduated blunt probe	50	5
Blunt teat cannula	12	
Suction unit and suction tubing		
General surgery pack		
Drapes		

Surgical technique

The endoscopic portal location was just ventral to the *serratus dorsalis* muscle (epaxial muscle group) and below the line of local anaesthetic. A No. 10 scalpel blade was used to create a 2.0–2.5 cm linear incision through the skin and subcutaneous tissues. Deeper blunt dissection of adipose tissue and external fascia was necessary when the endoscopic portal was placed through the 8th intercostal space. Once the external intercostal muscle was found, a blunt stainless steel teat cannula was passed through the intercostal muscles and parietal pleura to create a pneumothorax. Air was heard passing through the cannula into the thoracic cavity during each respiratory cycle. The teat cannula was removed after 3 to 4 respiratory cycles. A 15 cm long, 11 mm diameter, unguarded cannula containing a sharp trocar[6] was placed through the skin incision and directed caudally to avoid the intercostal neurovascular structures present at the posterior border of each rib. The instrument was advanced through the musculature and pleura using a gentle corkscrew motion. Following complete advancement of the cannula into the thoracic cavity, the trocar was removed. Passive influx of air was allowed through the portal to ensure lung collapse and allow inspection of the hemithorax. Suction tubing was attached via a coupling device to the side stopcock present on the cannula. A 30°, 57 cm long, 10 mm diameter rigid telescope[6], attached to a videocamera[6] and a xenon light[6] source cable, was passed through the cannula and used for the exploration. A list of the surgical equipment used to perform thoracoscopy is presented in Table 1.

Thoracoscopy was performed for 15 min, during which time the thoracic structures were examined. The procedures were recorded and saved using a digital camcorder[7] connected to the video-endoscopic camera unit. The images were then downloaded to a computer and saved as bitmap images for subsequent recall. Image editing, prior to printing, was performed using PhotoShop 3.0[8] for Windows. At the end of the examination, negative pleural pressure was re-established by applying suction to the pleural space. This was achieved by attaching a portable suction unit with sterile tubing to the stopcock present on the endoscopic cannula. During suction, complete reinflation of the lung was observed by retracting the telescope within the distal end of the endoscopic cannula. The telescope was then removed.

The skin incision for the accessory portal was made during a 5 min recovery period from the first thoracoscopy. Before inserting the accessory portal, a pneumothorax was recreated by opening the trumpet valve within the endoscopic cannula. This was achieved by placing a narrow surgical instrument (forceps or hemostatic clamps) through the cannula. The telescope was introduced into the thorax and directed toward the expected intrathoracic location of the accessory portal. A blunt stainless steel teat cannula was used to puncture the pleura at the site of the accessory portal while under endoscopic observation. Using a technique identical to that used for the endoscopic portal, an 11 mm diameter, 15 cm long trocar/cannula system with a 5 mm reducer[4] was advanced into the thorax. A 50 cm long, 5 mm diameter, blunt, graduated probe was passed through the secondary portal. A second 15 min thoracoscopic examination was performed as structures were probed and moved. Upon completion of the examination, the accessory portal was removed as a unit. As suction was applied to the thorax, the lung was observed to inflate progressively and reduce the volume of the pleural space. The endoscopic portal was removed a few seconds after the lung covered the end of the optics of the telescope. The skin and subcutaneous tissues were closed using 0 prolene[9] in a simple interrupted pattern.

Postoperative patient evaluation

Horses were returned to a stall in the Large Animal Clinic after recovering from detomidine and were monitored for 48 h. Horses continued to receive flunixin meglumine (1 mg/kg bwt b.i.d.) and procaine penicillin G (20,000 iu/kg bwt b.i.d.) throughout this period.

Results

Thoracoscopy was completed successfully in all horses. The technique used allowed the exploration of each hemithorax and horses tolerated the procedures well. The thoracic structures could be evaluated more easily when the endoscopic portal was at the 10th and 12th intercostal spaces. The ribs associated with these spaces have less soft tissue and muscle coverage and are not as firmly attached to the sternum as the more cranial ribs. Cranial and caudal movements of the rigid telescope were tolerated well when the more caudal approaches were used and the telescope could be advanced without complications into the cranial aspects of both hemithoraces (Figs 1a,b). By rotating the 30° lens in a cranial direction, a panoramic view of the cranial thorax was obtained. Similar telescope movements could not be achieved when the 8th intercostal space was selected for the approach. In this space, the telescope could be moved vertically (up and down), but cranial and caudal motions were physically hindered by the rigidity of the cranial thorax. Physical restraint in stocks was adequate to confine the horses during thoracoscopy. An adequate level of sedation and analgesia was maintained with the i.v. infusion of detomidine HCl. Horses showed occasional signs of discomfort when the 8th intercostal space approach was used. Distracting the ribs and advancing the telescope was a source of pain for the horses in which the cranial approach was used, particularly when trying to angle the telescope to explore the cranial thorax. This occurred despite the use of regional and local anaesthesia. Horses demonstrated agitation, restlessness and a decreased level of sedation. These signs diminished rapidly when the telescope was returned to a 90° angle with the thorax.

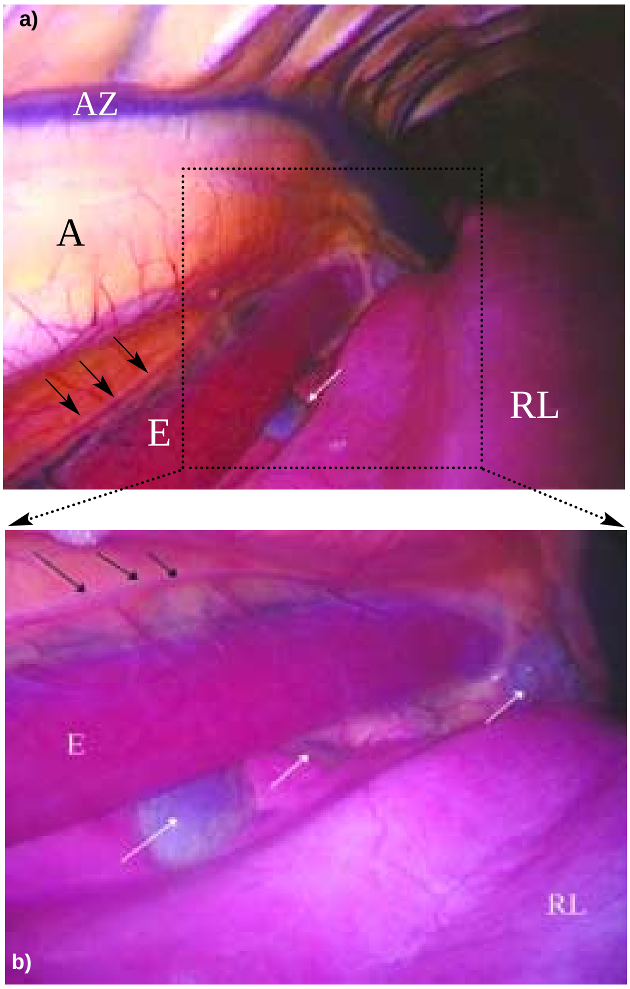

Fig 3: a) Thoracoscopic view of the cranial region of a right hemithorax. The dorsal border of the right lung (RL) is seen. The oesophagus (E) with its vasculature and the vagus nerve (black arrows) partially covers the right pulmonary veins (white arrow). The aorta (A) and azygos vein (AZ) are observed dorsally. b) Thoracoscopic view of the cranial region of a right hemithorax. Close-up view of the pulmonary veins (white arrows) seen in Figure 3a. The collapsed lung (RL) with the aortic impression, the oesophagus (E) and vagus nerve (black arrows) are also seen.

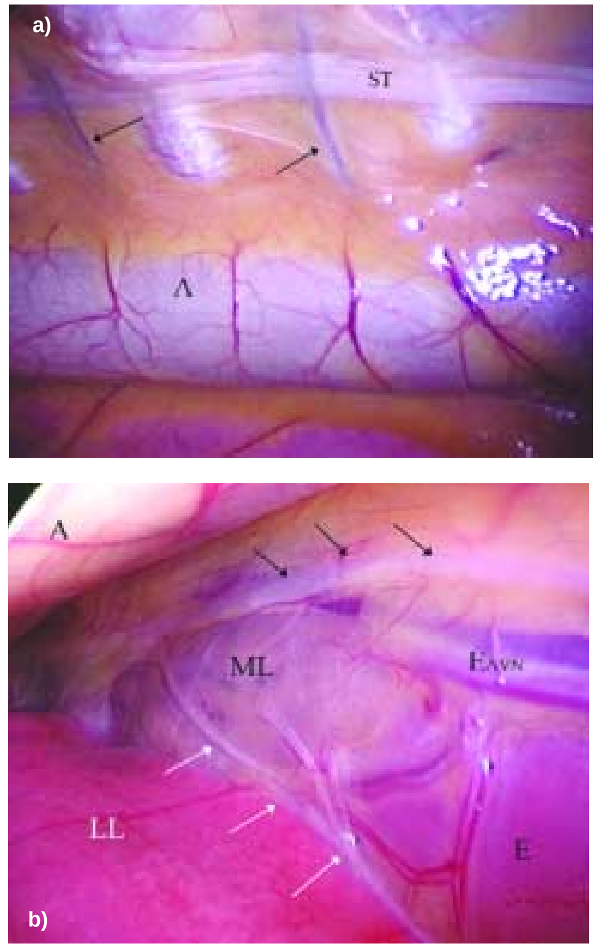

Fig 4: a) Thoracoscopic view of the dorsal-medial region of a left hemithorax. Detail view of the sympathetic trunk (ST) coursing dorsal to the aorta (A) and over the intercostal vasculature (black arrows). b) Thoracoscopic view of the cranial-medial region of a left hemithorax. Located between the aorta (A) and the collapsed medial lung lobe (LL) is a mediastinal lymph node (ML). The white arrows and the black arrows respectively identify the ventral and dorsal branches of the vagus nerve. The oesophagus (E) and the broncho-oesophageal artery, vein and nerve (EAVN) are also seen.

Inadequate lung collapse led to pulmonary parenchymal perforation in one horse. One horse became distressed when its lung collapsed. In addition, extreme lung collapse was the probable cause of agitation in 2 other horses during the second pneumothorax period. The rapid induction of pneumothorax caused the horses to cough and become restless. This was corrected by applying suction to the hemithorax, thereby momentarily interrupting lung collapse and allowing a more gradual pneumothorax to occur. Bilateral pneumothorax never occurred during or after the procedure. All horses recovered uneventfully from thoracoscopy. Postoperative complications included mild subcutaneous emphysema associated with the surgical site (2/12 procedures), and subclinical pneumothorax (1/12 procedures).

Thoracoscopic anatomy

The collapsed lung was readily visible when either left or right hemithoracoscopies were performed (Fig 1a,b). Depending on the degree of lung collapse, additional structures could be seen such as the aorta, the oesophagus and the azygos vein in the right hemithorax. When a caudal approach was used (10th or 12th intercostal spaces), the collapsed lung was observed to be attached dorsally to the mediastinum by the pulmonary ligament (Fig 2a). The pulmonary ligament appeared as a thin triangular fold of pleural tissue containing a tortuous branch of the broncho-oesophageal artery, which coursed along the caudal margin of the lung. Above the pulmonary ligament the dorsal mediastinal membrane was seen, through which the opposite lung could be observed moving during the respiratory cycles. In all cases, the contralateral lung was observed in complete inflation through the thin dorsal mediastinum, indicating the absence of a bilateral pneumothorax.

By advancing the telescope cranially within the left hemithorax, over the collapsed lung and toward the mediastinum, the aorta, thoracic oesophagus and collapsed lung with the aortic impression could be observed (Fig 2b). When the same region of the right hemithorax was in view the same structures were found,

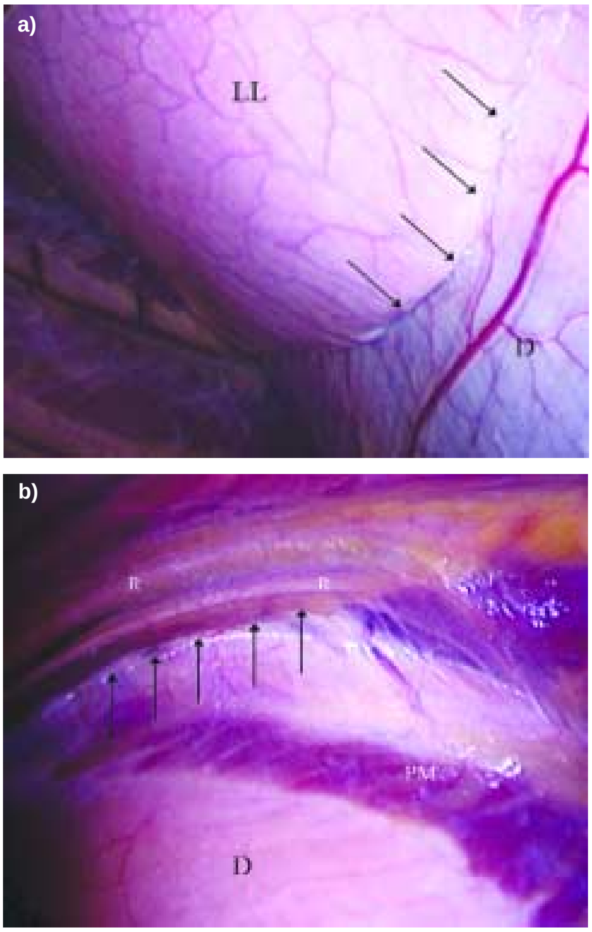

Fig 5: a) Thoracoscopic view of the caudal-ventral region of a left hemithorax. The telescope is directed between the thoracic wall and the diaphragm (D). The collapsed lung is seen (LL) and the black arrows identify the caudal (diaphragmatic) lung edge. b) Thoracoscopic view of the caudal-dorsal region of a right hemithorax. The dorsal-most aspect of the diaphragm (D) is seen where it attaches to the rib cage (black arrows). Ribs 14 and 15 can be identified (R). PM = psoas major muscle.

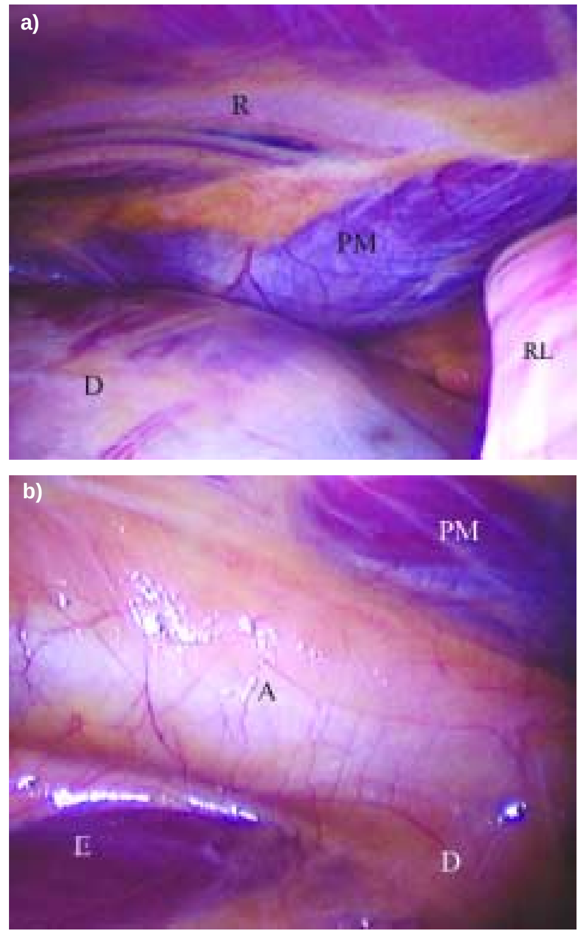

Fig 6: Thoracoscopic view of the diaphragmatic hiatus region of a right hemithorax. The psoas major muscle (PM) defines the hiatal area of the diaphragm (D) as it connects to the rib cage in the area of the 14th rib (R). The collapsed right lung (RL) can also be seen. b) Thoracoscopic view of the diaphragmatic hiatus region of a left hemithorax. The aorta (A) is located ventrally to the psoas major muscle (PM) as it passes into the abdominal cavity through the diaphragm (D). The oesophagus (E) is seen below the aorta.

with the addition of the azygos vein, thoracic duct and pulmonary veins (Fig 3a). The azygos vein appeared as a dark blue vessel dorsal to the aorta. Intercostal veins joined the azygos vein from the caudal border of each rib. The proximal portion of the azygos vein descended ventrally along the mediastinum and disappeared medial to the dorsal border of the lung. Just caudal to the descending azygos, the right pulmonary veins were seen partially covered by the oesophagus. The pulmonary vessels were large and triangle-shaped and emerged from the cranial-dorsal border of the lung (Fig 3b). The pulmonary veins could not be seen within the left hemithorax. The oesophagus was observed ventral to the aorta as a dark red, flaccid, tubular structure. Occasionally, peristalsis was seen in the oesophagus. Close inspection of the oesophagus showed the dorsally located broncho-oesophageal artery and vein and the vagus nerve (Fig 3b).

The aorta was seen as a large pulsating vessel located dorsally next to the costovertebral arch in both hemithoraces (Fig 4a). Vessels stemmed from the dorsal aspect of the aorta and formed the dorsal intercostal arteries coursing along the caudal border of each rib. The aortic *vasa vasorum* were seen upon close inspection. Above the aorta, the sympathetic trunk and its major branch (splanchnic nerve) were seen in both hemithoraces as a flat band of nerve fibres coursing along the thoracic vault, lateral to the costovertebral articulations and dorsal to the aorta (Fig 4a). The aorta could be followed cranially to the aortic arch and caudally to the aortic hiatus of the diaphragm. A large mediastinal lymph node (tracheobronchial lymph node) could be found in both hemithoraces within the mediastinum below the aorta and above the oesophagus (Fig 4b). The vagus nerve was closely associated with the mediastinal lymph node and, in this location, divided into dorsal and ventral branches. This could be found in both hemithoraces but was best seen when performing a left hemithoracoscopy. Additional caudal mediastinal lymph nodes could be found above the dorsal mediastinum.

Approximately two-thirds of the costal surface of each lung was easily observed. The lung margins could be followed starting from the pulmonary ligament proceeding along the caudal-most aspect and on to the ventral (costal) margin (Fig 5a). Associated with the dorsal border of right and left lungs were the oesophageal groove medially and the aortic groove laterally. The diaphragmatic surface of the lung was inspected after guiding the telescope beneath the pulmonary ligament. The telescope could

TABLE 2: Anatomical findings during thoracoscopy divided for right and left hemithoraces

Anatomy	Left hemithorax	Right hemithorax
Pleural surfaces of ribs 4th through 15th	Yes	Yes
Intercostal muscles	Yes	Yes
Dorsal intercostal arteries	Yes	Yes
Caudal lung lobe	Yes	Yes
Lateral and dorsal lung surfaces	Yes	Yes
Diaphragmatic and mediastinal lung surfaces	Yes	Yes
Pulmonary ligament	Yes	Yes
Broncho-oesophageal artery and vein	Yes	Yes
Dorsal mediastinum	Yes	Yes
Thoracic oesophagus	Yes	Yes
Oesophageal artery and vein	Yes	Yes
Aorta and aortic arch	Yes	Yes
Aortic *vasa vasorum*	Yes	Yes
Azygos vein	No	Yes
Pulmonary veins	No	Yes
Thoracic duct	No	Yes
Tracheobronchial lymph node	Yes	Yes
Caudal mediastinal lymph nodes	Yes	Yes
Sympathetic trunk (splanchnic nerve)	Yes	Yes
Dorsal and ventral branches of vagus nerve	Yes	Yes
Diaphragm (hiatal and costal regions)	Yes	Yes
Heart base area (pericardial adipose tissue)	Yes*	No
Mainstem bronchi	Yes	No

*Not consistently seen.

easily glide over the diaphragmatic surface remaining under the lung and could be advanced cranioventrally to observe the pericardial adipose tissue. This manoeuvre was accomplished bilaterally; however, the pericardial area was not distinctly observed when approaching the thorax from the right side.

When moving the telescope ventrally, the ribs and associated internal intercostal muscles and vasculature could be followed and the caudal edge of the collapsed lung was seen gliding on the pleural surface of the diaphragm (Fig 5a). Directing the telescope caudally, the costal attachment of the diaphragm to the rib cage could be found (Fig 5b). The diaphragmatic hiatus was limited on each side by the combined psoas minor and major (Fig 6a,b). The diaphragm was partially covered by collapsed lung and, in most horses, the hiatal region was surrounded by adipose tissue not allowing a distinct view of the oesophagus, the aorta and the thoracic duct coursing into the abdominal cavity. In the left hemithorax the hiatal region was clearer and the aorta could be found easily with the oesophagus below (Fig 6b).

The trocar/cannula used for the accessory portal was inserted while the pleural aspect of the selected intercostal space was in view of the telescope. This avoided accidental lung perforation and allowed accurate portal placement. With the blunt tissue palpation probe, the distance from the costal surface and accessibility of the thoracic anatomical structures could be assessed. The accessory instrument could be placed on the lung (costal, caudal and dorsal surfaces), aorta, oesophagus, vagus and sympathetic nerves, mediastinal lymph nodes and diaphragm (costal muscular attachments and hiatal region). The majority of the muscular portion of the diaphragm was covered by the collapsed lung. However, the probing instrument could be directed beneath the lung surface to elevate the lung parenchyma and inspect a greater portion of the tendinous diaphragm. The probe also aided in inspecting the medial (diaphragmatic) surface of the lung. This was achieved by elevating the pulmonary ligament with the probe and advancing the telescope in the space formed between the lung and the diaphragm. The normal anatomical structures viewed during thoracoscopy are reported in Table 2.

Discussion

The endoscopic examination of the normal equine thorax was completed successfully using a 57 cm long rigid telescope and video assistance. Physical restraint was performed effectively with the horses standing in stocks. The combination of i.v. detomidine for sedation and analgesia and local anaesthesia allowed 12 (6 right and 6 left) thoracoscopic surgeries to be completed safely. Two different methods of local anaesthesia were utilised. Local anaesthetic was either infiltrated within the tissue layers of the selected surgery sites or regional anaesthesia was performed. The use of regional anaesthesia was elected when the thorax was entered via the 8th intercostal space. When using this cranial approach, the rigid telescope could not be easily moved cranially and caudally without causing the horses to show signs of discomfort, such as agitation, groaning and decreased level of sedation. These signs of discomfort were observed when caudal to cranial manipulations of the rigid telescope distracted the more rigidly fixed cranial thoracic ribs. We speculated that anaesthetising the region of interest, rather than just the surgery sites, would provide better analgesia and allow the telescope to be moved freely. It was necessary to provide regional anaesthesia to 3 intercostal spaces in order to maximise the area of desensitisation and include both the endoscopic and accessory portal surgical sites. The 7th, 8th and 9th intercostal nerves were difficult to anaesthetise due to large amounts of subcutaneous adipose tissue and heavier muscular coverage in the cranial thoracic regions. An 8 cm, 18 gauge spinal needle helped deliver the local anaesthetic appropriately to these nerves. In one instance, additional intraoperative local anaesthesia was required to place the accessory portal. The authors recommend the use of regional anaesthesia if a cranial approach to the thorax is necessary. The exploration of the thorax, including the cranial-most thoracic regions, was completed without any signs of discomfort for the horses when using a more caudal approach via the 10th or 12th intercostal spaces. When the caudal approaches were used, regional anaesthesia was not necessary and the telescope could easily be advanced cranially and caudally for its entire length, without eliciting a painful response.

A blunt stainless steel teat cannula inserted through the parietal pleura generally provided the necessary degree of pneumothorax to introduce the trocar/cannula system. Pneumothorax, however, was inadequate in one horse and parenchymal perforation occurred during insertion of the trocar. The perforated lung was inspected once the telescope was placed within the pleural space. The laceration was approximately 6–7 mm long and involved the visceral pleura and a portion of the lung parenchyma. Minimal haemorrhage was associated with the injury site and the exploration of the thorax proceeded uneventfully. Postoperatively, thoracic radiographs indicated the presence of a closed pneumothorax, which was not associated with clinical signs such as respiratory distress or tachycardia. The horse remained asymptomatic, was observed for 7 days postoperatively and then released from the Large Animal Clinic. Guarded, disposable cannulas coupled with blunt trocars could be an additional safety measure employed to prevent pleural damage although ensuring adequate lung collapse will allow safe trocar placement.

Lung collapse associated with the onset of pneumothorax may be an additional source of discomfort for horses undergoing thoracoscopy. The induction of pneumothorax caused coughing and distress in one case and may have been associated with the sudden pressure exerted by the lung parenchyma on the mediastinal vascular and nervous structures. The lung can be gradually collapsed by intermittently opening and closing the teat cannula used to create the pneumothorax. In addition, the degree of lung collapse can be varied during the procedures by applying suction to the pleural space. It is important to regulate the degree of pneumothorax depending upon the anatomical region to be inspected and the overall cardiopulmonary status of the horse. In order to ensure appropriate control of the pneumothorax, it is critical to use endoscopic cannulas manufactured with a side stopcock to which the suction tubing can be attached. This will allow rapid control of intrapleural pressure and relief of the pneumothorax if needed.

Mediastinal integrity is an important issue when performing thoracoscopy. The caudal and cranioventral mediastinum are thought to be occasionally incomplete in the mature horse (Hare 1975; A. T. Fischer, personal communication), allowing the pleural cavities to be in direct communication. Bilateral pneumothorax did not occur in our horses. Throughout both left and right hemithoracoscopic procedures, the fully inflated contralateral lung could be seen through the dorsal mediastinum. The dorsal mediastinum could be clearly observed and was never found to be fenestrated in these horses. The cranial ventral mediastinum is not visible in the standing horse. We speculate that fenestrations of the cranial mediastinum may become obliterated by the presence of the collapsed lung which, during pneumothorax, tends to deflate ventrally and in the anterior portion of the hemithorax.

Endoscopic portal placement requires additional considerations. Portal site incisions should involve only skin and subcutaneous tissues. Large or deep incisions may not provide an adequate seal around the cannula. This may make it difficult to maintain a negative pleural pressure following the use of suction and may cause peri-incisional postoperative subcutaneous emphysema. Following selection of the intercostal space, the sharp trocar point should be directed toward the cranial aspect of the rib to avoid the intercostal neurovascular bundle located on the caudal aspect of each rib. The trocar should be rotated gently while advanced until a sudden decrease in resistance indicates entry into the pleural cavity.

The results of this and previous studies determined that thoracoscopy can be safely performed in the standing, sedated horse, and is not associated with clinically important complications. Using normal horses we were able to provide a detailed evaluation of more than two-thirds of the thoracic anatomy. Thoracoscopy has the advantage of being performed through small surgical incisions, limiting exposure and possible contamination of the delicate pleural structures. Thoracoscopy can be recommended as an adjunctive procedure to traditional diagnostic and therapeutic measures undertaken to address equine pleuropulmonary disease and the low morbidity of the procedure in normal horses justifies its application in the early stages of thoracic disease. The main disadvantages of the procedure relate to the expense associated with the equipment and the time needed to be familiar with the surgical technique. These potential drawbacks, however, may be compensated for by the versatility of the instrumentation which is commonly used for laparoscopic procedures, during which similar surgical principles are applied, increasing the familiarity with endoscopic surgery and the cost-effectiveness of the equipment.

Manufacturers' addresses

[1]Schering Plough, Kenilworth, New Jersey, USA.
[2]Becton Dickinson, Sandy, Utah, USA.
[3]Pfizer Animal Health, Exton, Pennsylvania, USA.
[4]3M Health Care, St. Paul, Minnesota, USA.
[5]Sanofi-Winthrop, New York, USA.
[6]Storz Veterinary Endoscopy, Goleta, California, USA.
[7]Sony Electronics Inc. New York, USA.
[8]Adobe Software Inc. San Jose, California, USA.
[9]Somerville, New Jersey, USA.

References

Ford, T.S., Vaala, W.E., Sweeney, C.R., Skand, D. and Saik, J. (1987) Pleuroscopic diagnosis of gastro-oesophageal squamous cell carcinoma in a horse. *J. Am. vet. med. Ass.* **190**, 1556-1558.

Ginsberg, R.J. (1993) Thoracoscopy: a cautionary note. *Ann. Thorac. Surg.* **56**, 801-803.

Haasler, G.B. (1995) Video-assisted thoracic surgery. In: *Laparoscopic and Thoracoscopic Surgery*, Ed: C. T. Frantzides, Mosby, St. Louis. pp 253-284.

Hare, W.C.D. (1975) Equine respiratory system. In: *The Anatomy of the Domestic Animals*, 5th edn., Eds: S. Sisson and J.D. Grossman, W.B. Saunders Co., Philadelphia. pp 564-567.

Mackey, V.S. and Wheat, J.D. (1985) Endoscopic examination of the equine thorax. *Equine vet. J.* **17**, 140-142.

Mansmann, R.A. and Bernard-Strother, S. (1985) Pleuroscopy in horses. *Mod. vet. Pract.* **66**, 9-17.

Mueller, P.O.E., Morris, D.D., Carmichael, K.P., Henry, M.M. and Baker, J.J. (1992) Antemortem diagnosis of cholangiocellular carcinoma in a horse. *J. Am. vet. med. Ass.* **201**, 899-901.

Peroni, J.F., Robinson, N.E., Stick, J.A. and Derksen, F.J. (2000) Pleuropulmonary and cardiovascular consequences of thoracoscopy performed in healthy, standing horses. *Equine vet. J.* **32**, 280-286.

Rossier, Y., Sweeney, C.R., Heyer, G. and Hamir, A.N. (1990) Pleuroscopic diagnosis of disseminated hemangiosarcoma in a horse. *J. Am. vet. med. Ass.* **196**, 1639-1640.

Vachon, A.M. and Fischer, A.T. (1998) Thoracoscopy in the horse: diagnostic and therapeutic indications in 28 cases. *Equine vet. J.* **30**, 467-475.