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Recumbencies for thoracoscopic procedures in dogs - a systematic review of the current literature

Diplomarbeit

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List of abbreviations

intercostal space (ICS)

one lung ventilation (OLV)

patent ductus arteriosus (PDA)

thoracic duct ligation (TDL)

video-assisted thoracic surgery (VATS)

1 Introduction

The first paper concerning thoracoscopy in veterinary medicine was published in 1990 by MCCARTHY and MCDERMAID. The focus of this paper was on thoracoscopy as a diagnostic tool for veterinary medicine. As veterinary medicine progressed over the years, so did the equipment for the different procedures, as well as the demand for less painful techniques. In human medicine minimal invasive techniques were proven to result in reduced post-operative pain in the patient. Along with more specialised equipment available, this led to a rise in popularity of minimal invasive procedures in veterinary medicine in surgeons and owners alike. Furthermore, thoracoscopy as well as laparoscopy developed from being mainly diagnostic to playing an important part in the surgical treatment. However, laparoscopy was more commonly performed than thoracoscopy, mainly due to the easy access and a less specialised field. Nowadays, laparoscopic ovariectomy is a common procedure performed by veterinary surgeons, while thoracoscopic procedures require surgeons more experienced in minimal invasive surgery, as well as to some degree more specialized equipment. However, due to the advantages such as reduced postoperative pain and thus hospitalisation time, the demand is rising constantly. The necessary equipment as well as the training for surgeons and other personnel is more readily available, therefore minimal invasive procedures in the thorax are becoming more common.

Two different techniques for minimal invasive surgery access in the thorax do exist. Both techniques offer the main advantages of a superior illumination of the target structures, an enhanced image, especially of the small structures in the thorax, as well as reduced post-operative pain for the patient. The difference between the two access techniques lies in the use of only small intra-thoracic ports for thoracoscopy versus the use of an intercostal mini-thoracotomy for video-assisted thoracic surgery (VATS). The mini-thoracotomy is performed without rib retraction, which has previously been determined as the main cause for post-operative pain. (LANSDOWNE et al., 2005; BLEAKLEY et al., 2015) For both techniques, the use of variously angled telescopes offers an overview of the situs in the thorax in lieu of direct access. With VATS limited direct digital manipulation of the organs is possible, this offers an advantage if the target organ is located close to the thoracic wall, in which case digital manipulation facilitates the procedure. With thoracoscopy the only access to the thorax is via the instrument ports and no direct digital manipulation is possible. However, using minimal invasive surgery instruments, smaller structures can be manipulated under direct visualization compared to an open technique.

Minimal invasive procedures commonly performed in the thorax include pericardectomy, thoracic duct ligation, excision of masses in the lungs, the cranial mediastinum or the right auricle, as well as treatment for congenital vascular anomalies. RADLINSKY (2015) stated that approaches classically used with open surgery may be mimicked with thoracoscopy, offering some guidelines on how to place a patient for the varying procedures. However, in cases where multiple procedures are combined, for example pericardectomy together with ligation of the thoracic duct for the treatment of idiopathic chylothorax, this general guideline was revised to some degree.

The aim of this study is to review the literature in order to determine the optimal recumbency and port setup for the varying minimal invasive surgical interventions in the thorax. To reach that objective, part of the research is focused on the development of the different techniques over the course of the last 20 years, as well as on possible records on the feasibility of different approaches. Another part is to summarize already existing guidelines for minimal invasive thoracic procedures.

We also wanted to give a prospect of possible studies to be conducted in order to be able to recommend certain approaches for the different procedures.

1.1 Material and Methods

1.2 Literature Research

Literature research was done via the search engines PubMed and Scopus. The search terms used were thoracoscopy AND dog, as well as thoracoscopic surgery AND dog. The results were limited to the years 2000 to 2019, further limitations included the description of minimal invasive intrathoracic procedures in Veterinary medicine. The search yielded 114 results for the search terms "thoracoscopy AND dog" on Pubmed, as well as 92 results on Scopus, the search for the terms "thoracoscopic AND dog" yielded 114 results on Pubmed and 58 on Scopus, resulting in a total of 228 papers for the search on Pubmed and a total of 150 papers for the search on Scopus. For further screening of the results, a library on Zotero 5.0.92 (ROY ROSENZWEIG Centre for History and New Media) was created. During the screening 15 results were excluded because they only contained a book reference. 183 duplicates were found during the initial screening of the articles, the remaining ones were screened for the mention of recumbencies and portal placement during the procedures. During this screening process, papers were excluded for not mentioning recumbencies and ports at all. Further exclusion criteria were the articles not being in English, not being a surgical paper or describing techniques currently not feasible for standard procedures such as natural orifice transluminal endoscopic surgery, as well as those for which special equipment was built, those techniques were summed up as "other techniques". *Figure 1* describes the screening and exclusion process using "Preferred Reporting Items for Systematic Reviews and Meta-Analyses" (MOHER et al., 2009). The literature research was repeated every few months during the writing process, to include most resent papers as well. During one of these screenings one paper ((NAN et al., 2016)) was added.

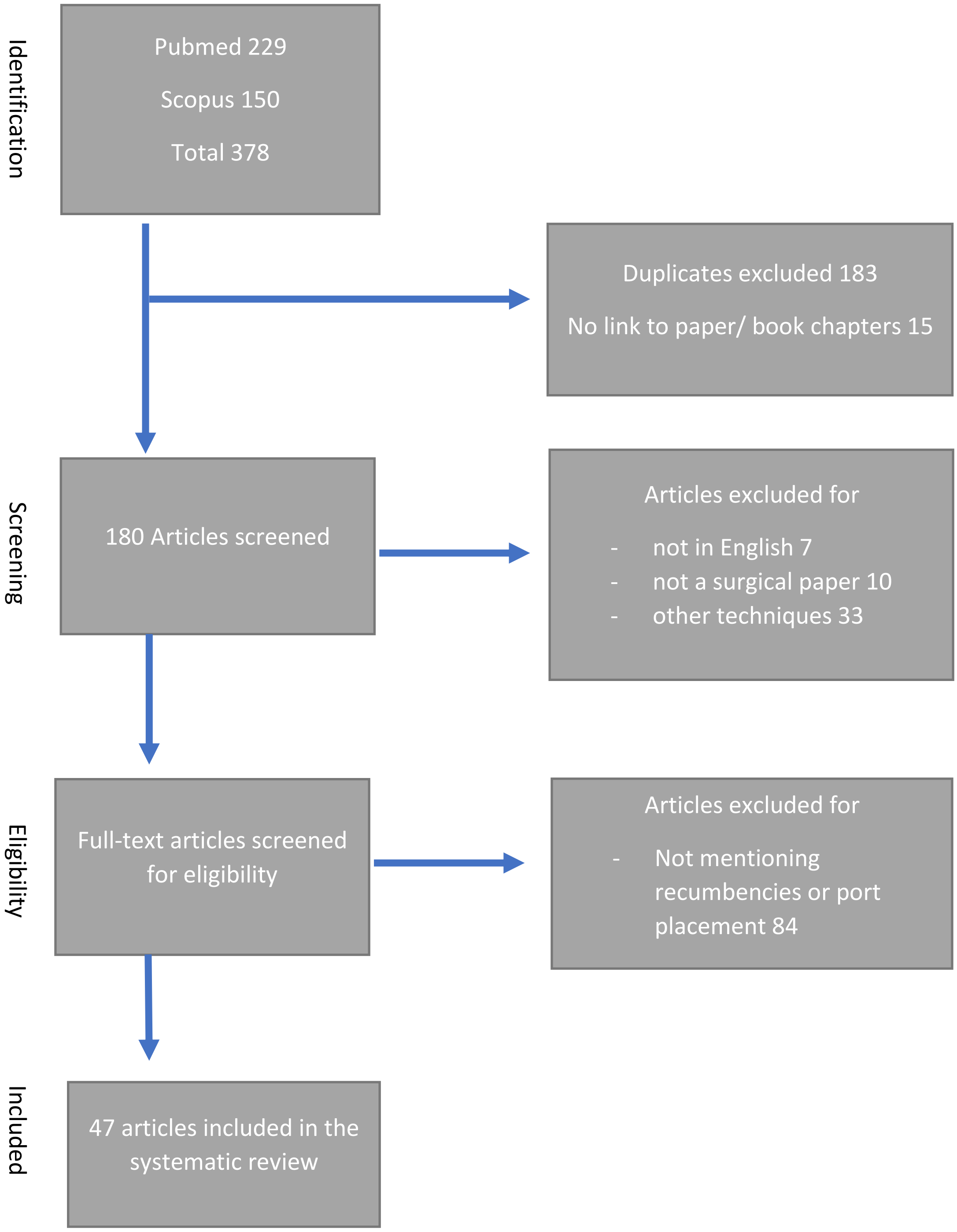

Figure 1: Flow chart describing the screening process.

2 Results

2.1 Creation of working space in the thorax

Thoracic space is limited by the organs inside the thorax, especially the lungs and heart. To gain more working space during intrathoracic procedures multiple techniques, such as establishment of a pneumothorax, tilting of the patient, one lung ventilation (OLV) and others, exist. Often these techniques are combined to achieve the best possible outcome.

To facilitate thoracoscopic procedures at all, recumbencies must be planned accordingly. For example, in dorsal recumbency the lungs gravitate towards the spine, resulting in working space in the ventral aspect of the thorax. Likewise, tilting the patient to one side will provide working space in the contralateral hemithorax.

Minimal pneumothorax is established upon dissection of the thoracic wall. Any penetration of the thoracic wall allows the lung surface to pull away from the thoracic wall and thereby creates some working space. (WALTON, 2001) During the thoracoscopic procedure itself, pneumothorax is most commonly maintained by leaving the valve of the trocar open, thus creating pressure equilibration between the room and the intrathoracic space. Additionally, a moderate amount of pressure (2-4 mmH_2O) can be applied to collapse lungs further and create even more working space. Close communication with the anaesthetist is required to ensure adequate ventilation during the procedure. (WALTON, 2001; BRISSOT et al., 2003; SCHMIEDT, 2009; FRANSSON et al., 2015)

Furthermore, in order to minimize the interference of the lungs, one-lung-intubation or intermittent ventilation can be employed. This is one of the most important techniques for gaining space for minimal invasive procedures in the thorax. In order to establish one-lung-intubation, various techniques are used, such as the use of bronchial blockers, selective intubation or double-lumen endobronchial intubation. (MACPHAIL et al., 2001; WALTON, 2001; RADLINSKY et al., 2002; LANSDOWNE et al., 2005; MAYHEW and FRIEDBERG, 2008; MAYHEW et al., 2009; LAKSITO et al., 2010; MAYHEW, et al., 2012; PELÁEZ and JOLLIFFE, 2012; MAYHEW et al., 2013; BLEAKLEY et al., 2015; STEFFEY et al., 2015; GOUDIE et al., 2016; MACIVER et al., 2017; SCOTT et al., 2017; NUCCI et al., 2018; MAYHEW et al., 2019)

The choice of technique for creation of intrathoracic working space might subsequently influence the recumbency and/or approach and is therefore included in the tables describing the various recumbencies and ports.

2.2 Thoracoscopic approaches

There are four different recumbencies, dorsal, sternal, right and left lateral. They each offer certain advantages in visualizing the structures inside the thorax.

Recumbency and port placement depend on the target of the surgery. Before any ports are placed the surgical field should be widely clipped and aseptically prepared and draped. To secure the patient on the table and prevent moving or even falling off the table during tilting, the forelimbs are pulled cranially and the hindlimbs caudally. The limbs are secured with either ties or medical tape depending on personal preferences. To add further stability sandbags and strips of surgical tape across the abdomen and neck can be used, to secure the patient on the table. In dorsal and sternal recumbency the patient can be placed on cushions or vacuum-based surgical devices to prevent patient discomfort from lying on their sternum or spine for prolonged periods.

Dorsal recumbency, also called supine position, allows both hemithoraces to be explored, however, the dorsal aspect of the lungs, as well as the accessory lobe and the caudal lung can be difficult to visualize, especially in deep and narrow chested dogs. To facilitate exploration the table can be tilted up to 15° to the left and right, which is then called oblique dorsal recumbency. The endoscopic tower is placed at the head of the dog slightly on the left or right, depending on the surgeon's position. The first portal to be placed is the telescope port. For visualization of both hemithoraces a subxiphoid trans-diaphragmatic port is suited best. With this recumbency median sternotomy can be mimicked. For procedures in dorsal recumbency the patient is clipped on both sides to the dorsal third of the thorax or even higher up, depending on the location of the ports, as well as from midneck to the umbilicus or even more caudally if access to the abdomen is needed.

Sternal recumbency, also called prone position, facilitates the exploration of the dorsal aspects of the thorax, because in this recumbency the lungs gravitate ventrally. Similar to the dorsal recumbency the patient can be tilted sideways, to make exploration easier. For accurate patient placement the thorax is supported by the forelimbs and the sternum. The abdomen needs to be supported by bone structures as well, to minimise pressure and allow the organs to gravitate ventrally. FRANSSON et al. (2015) achieve this by placing the pubis on soft gel forms or towels, special care has to be taken to place those not too cranially. For procedures in sternal recumbency a wide clipping from ventral to dorsal midline and from the scapular spine to mid abdomen is suggested, if a bilateral access is used, this has to be performed on both sides, otherwise the clipping is one sided only.

If the patient is placed in lateral recumbency the surgeon has access to only one hemithorax, in left lateral recumbency to the right hemithorax, in right lateral recumbency to the left hemithorax. However, if the involved side can be determined preoperatively with radiographs, ultrasound, or computed tomography, lateral recumbency is the preferred position due to its greater access potential in the hemithorax. (MONNET, 2009) To facilitate exploration of the dorsal aspects, the spine can be elevated up to 15°. For procedures in lateral recumbency the entire thorax and the cranial part of the abdomen are clipped from the ventral to the dorsal midline.

Port placement may be blind with sharp trocars, however, with this technique there is a high risk of injuring intrathoracic structures. A mini approach can be used with any type of trocar; a small incision is made through the skin and blunt dissection is used before port insertion. The two techniques mentioned before are commonly used for the camera port. Most commonly instrument or operative ports are placed under endoscopic guidance to reduce the risk of injuring intrathoracic structures. To achieve this technique the camera port has to be in place and if the patient is in dorsal recumbency the mediastinum has to be dissected, to visualize the thoracic walls on both sides. From outside the ports can be placed blindly or via mini thoracotomy, the entry point of the trocar in the thorax is displayed via the camera.

WALTON (2001) stated that port insertion is easiest caudally in the sixth or seventh intercostal space and cranially in the fourth intercostal space midway between the costochondral junction and the ventral border of the epaxial muscles. For a wide exploration of the hemithorax WALTON (2001) recommended trocar insertion in the sixth or seventh intercostal space.

However, without prior creation of an intrathoracic working space, exploration of the hemithorax would not be possible due to sight restriction by the lungs. As already stated above, induction of a pneumothorax is the most important measure to create intrathoracic working space. Further improvement in visualization can be achieved by selective lung ventilation and intrathoracic CO_2 insufflation. (WALTON, 2001)

2.3 Minimal invasive procedures of the lungs

The most commonly described thoracoscopic procedures of the lungs, include lung biopsies as well as complete or partial lung lobectomies. The procedures are part of the identification or treatment of the varying lung diseases, especially primary lung neoplasms. Thoracoscopy can also be used in cases of pneumothorax or pyothorax to evaluate lung and pleural surfaces.

Before every procedure extensive diagnostic imaging was performed, to locate the lesions as accurately as possible, to determine the necessary recumbency, as well as port positions for the surgery. Due to the varying target locations, sternal, dorsal as well as lateral recumbencies were described. (BRISSOT et al., 2003; LANSDOWNE et al., 2005; MONNET, 2009; LAKSITO et al., 2010; MOORE, 2010; MAYHEW, et al., 2012; PELÁEZ and JOLLIFFE, 2012; MAYHEW et al., 2013; BLEAKLEY et al., 2015; CASE et al., 2015; CASE, 2016; GOUDIE et al., 2016; SCOTT et al., 2017; FRATINI et al., 2018; SINGH et al., 2019) If the patient had diffuse lesions or the exact location could not be determined, the use of dorsal recumbency was recommended. In this recumbency most surfaces of the lung and pleura were accessible, except the hilar region, which was described as difficult or impossible to reach, depending on how narrow chested the patient was. Lateral recumbency was recommended if the lesion only affected one side. Sternal recumbency was most commonly described for lesions in the hilar region or dorsal aspects of the lung lobes. Generally, the most difficult lobes to access and manipulate were the caudal lobes as well as the accessory lobe. To gain access to the caudal lung lobe, the pulmonary-diaphragmatic ligament has to be dissected. (LANSDOWNE et al., 2005; MONNET, 2009; MAYHEW et al., 2013; CASE et al., 2015; CASE, 2016; SINGH et al., 2019) To create working space in the thorax most commonly OLV was used. BRISSOT et al. (2003) insufflated CO_2 into the thorax to improve visualization of the dorsal aspects of the lung surface in dorsal recumbency. Atelectasis due to OLV also helped with ligation of the lesion, because of the reduced size of the lung and furthermore, extraction from the thorax.

Lung biopsies were described as part of the staging and grading procedures of primary lung tumours, for the treatment of localized lung lesions, like bullae or blebs as the cause for pneumothorax, as well as important step to diagnosis in cases of diffuse lung lesions. For this procedure different techniques have been described. Most commonly lung biopsies were performed via thoracoscopy as well as via VATS, depending on the size and the location of the lesion. In tumours not only the lesion itself was biopsied, but also the sentinel lymph node. MOORE (2010) described partial lobectomy to gain lung biopsies for histopathology. MOORE (2010) also recommended taking the biopsy at the tip of the middle lung lobe, if the location of the lesion could not be pinpointed.

In peripheral lesions up to a size of 2 cm MONNET (2009) and MOORE (2010) described a loop ligature technique. For larger or more central lesions the authors recommended the use of a stapling device, however, for the use of a linear stapling device the cannula had to have a minimal size of 12 mm. (WALTON, 2001) Later, smaller diameter stapling equipment facilitated the use of 5.5 mm or 11.5 mm cannulas in video assisted lung lobectomy. (CASE, 2016) In general, VATS could be used up to a tumour size of 5 cm. With lager lesions, the advantage of a minimal invasive technique is lost because of the necessary dimensions of the incision and retraction.

For the extraction of the ligated tissue, the port incision was enlarged avoiding rib retraction. (LANSDOWNE et al., 2005; BLEAKLEY et al., 2015) The use of a retrieval bag for the specimen was recommended. If no histopathology was necessary, for example in cases of pneumothorax, the lung tissue was destroyed and retrieved without extension of the respective port.

Lung biopsies were most commonly performed with three or four cannulas. For access to cranial lung lobes CASE (2016) recommended placement of the cannulas in a triangle along the ninth and tenth intercostal spaces; for access to the caudal and middle lobes, the author's recommendation was to place the cannulas along the third, fourth or fifth intercostal spaces. In general, the location of the instrument ports depended on the location of the lesion. In cases of diffuse lesions, MOORE (2010) suggested that the ports are placed over the tip of the middle lobe.

For lung biopsies in dorsal recumbency MAYHEW et al. (2012) described the setup with the endoscopic tower near the dog's head on the left side. MOORE (2010) recommended to use a sub xiphoid camera port in dorsal recumbency, stating that the intercostal location restricts exploration to one hemithorax, as well as hindering exploration of the most caudal and cranial aspects of the pleural surfaces. To facilitate the exploration of both hemithoraces the use of a 30° scope was suggested by MOORE (2010).

CASE (2016), MONNET (2009) as well as MOORE (2010) described a thoracoscopically assisted technique for partial lung lobectomy in which the lung was exteriorized through an expanded cannula port: the abnormal part of the lung was resected outside the thorax. This technique was also possible in dogs too small for the intrathoracic use of a linear stapling device, also OLV was not necessary. The patient was placed in lateral recumbency. One of the authors, CASE (2016), recommended that the cranial lung lobes be explored from the ninth to twelfth intercostal spaces and the caudal lobes from the fourth to sixth intercostal spaces. Over the hilus of the affected lobe a mini-thoracotomy was made. CASE (2016) used a wound retractor to distract the wound. The affected lung was exteriorized under endoscopic visualization and the lobectomy performed with an endoscopic or traditional stapling device.

Thoracoscopic total lung lobectomy was not described as a common procedure, because of its complexity. Total lung lobectomies are described as a treatment for primary lung neoplasms and pneumothorax. MONNET (2009) described lateral recumbency with intercostal ports as the preferred technique. In oblique position hilar exposure was improved, due to gravitational displacement of the organs toward the sternum. The use of three to four cannulas was recommended by FRANSSON et al. (2015). If three cannulas were used, FRANSSON et al. (2015) recommended to place them all in the same intercostal space, to minimize post-operative pain. The fourth cannula was reserved for a thoracoscopic retractor and placed one intercostal space cranial or caudal to the other cannulas. LAKSITO et al. (2010) described VATS in two cases with primary lung neoplasms. In one dog a whole lobectomy as well as partial lung lobectomy was performed, in the other a partial lung lobectomy. The first patient was placed in left lateral recumbency. An 11 mm port was established in the dorsal third of the left eight intercostal space. A 5 cm mini-thoracotomy was performed in the left sixth intercostal space under thoracoscopic visualization. In this video assisted technique, the camera port is placed farther away from the hilus. And a mini-thoracotomy without retraction of the ribs is done over the hilus of the respective lung lobe. With this technique a regular stapling device may be used.

Minimal invasive procedures concerning the pleural space

Pyothorax is characterized by the presence of purulent effusion and is a potentially life-threatening, condition in dogs. SCOTT et al. (2017) reported fourteen cases of pyothorax, which were treated via VATS. Preoperative CT scans were performed to assist in predetermining the location of the foreign body as well as the severity of the disease. Thirteen patients were placed in dorsal recumbency. One patient with an abscess in the right caudal lung lobe, was placed in lateral recumbency. In this dog OLV was used. For the procedure three to four portals were used. The most common arrangement was a 6 mm paraxiphoid camera port and two to three instrument cannulas in the left and right fifth, eight or tenth intercostal space, with sizes ranging from 6 to 12 mm. PELÁEZ and JOLLIFFE (2012) described one case of mild pyothorax with mild pneumothorax in the right hemithorax. In this case report the patient was placed in lateral recumbency. A foreign body was removed and a middle lung lobectomy performed. A three-port technique was used. The camera port was located in the ventral third of the eight intercostal space, one instrument port in the dorsal third of the tenth, the other in the ventral third of the sixth intercostal space.

For thoracoscopic treatment of pneumothorax CASE et al. (2015) placed the patients in dorsal recumbency and used a three-port technique. The 5.5 mm camera port was located in a subxiphoid transdiaphragmatic location. The instrument ports were placed according to surgeon's preference as well as target location, the intercostal spaces ranged from third to tenth. One dog was rotated into right lateral recumbency, because the lesion was identified in the left caudal lobe. To facilitate observation of the pleural surfaces, the dog was tilted about 15 ° to the right or left. An angled telescope was used too, to access all surfaces.

Table 1: Overview of recumbencies and port setup in papers describing minimal invasive procedures on the lungs (intercostal space (ICS), one lung ventilation (OLV), not available (n/a))

	Recumbency	Number of port	Location of camera port	Location of instrument ports	Method of working space creation	Disease affecting the lungs
WALTON (2001)	n/a	3	paraxiphoid/ lateral	n/a	OLV	neoplasia, pneumothorax
BRISSOT et al. (2003)	dorsal	3	lateral of last sternebra at junction of costal arch and xiphoid process	3rd-10th ICS on the lateral side of the thorax	limited intrathoracic insufflation	pneumothorax
LANSDOWNE et al. (2005)	lateral	3/4	ventral aspect of 8th ICS for caudal lobe ventral aspect of 7th ICS for cranial lobe	4th-10th ICS triangulation for caudal lobes first port dorsally in 10th ICS, second port in 7th ICS for cranial lobes first cannula dorsally in 8th , second port in 5th ICS	OLV	neoplasia
MONNET (2009)	dorsal or lateral for partial lung lobectomy lateral for complete lung	n/a	subxiphoid/intercostal	triangulation over area of obvious disease	OLV recommended	lung abscesses, chronic lung disease, emphysematous bullae, neoplasia

	lobectomy or in animals with dyspnoea					
LAKSITO et al. (2010)	right lateral	n/a	n/a	left 8th ICS in dorsal third for mass in cranial lung lobe/ left 8th ICS in dorsal third 2 further ports in in middle of 8th and ventral third of 6th ICS for mass in cranioventral lung lobe	OLV	neoplasia
MOORE (2010)	dorsal/ lateral	n/a	subxiphoid/ intercostal	n/a	n/a	neoplasia, pneumothorax, pyothorax
MAYHEW et al. (2012)	dorsal	3	subxiphoid	ventral third of right 4th-6th ICS ventral third of 9th/10th ICS under direct observation	OLV	healthy
PELÁEZ and JOLLIFEE (2012)	left lateral with raised spine	3	ventral third of 8th ICS	dorsal third of 10th ICS ventral third of 6th ICS	OLV	pyothorax
MAYHEW et al. (2013)	lateral/ dorsal	2-3	n/a	7th-9th ICS for cranial lung lobes 3rd-5th for caudal lung lobes 5th, 9th and 10th ICS for middle lobe triangulation	OLV	neoplasia

BLEAKLEY et al. (2015)	lateral oblique	3-4	n/a	intercostal	OLV	neoplasia
CASE et al. (2015)	dorsal	n/a	subxiphoid	3rd-10th ICS varying locations→ surgeon's preference, affected lung lobe	surgeon's preference	pneumothorax
CASE (2016)	dorsal tilted 15° to the left/ right lateral	n/a	in lateral recumbency for cranial lobes 9th-12th ICS for caudal lobes 4th-6th ICS	in dorsal recumbency triangulation for cranial lobes in 9th and 10th ICS for caudal and middle lobes along 3rd, 4th or 5th ICS in lateral minithoracotomy over hilus of affected lobe	OLV recommended	neoplasia, pneumothorax
GOUDIE et al. (2016)	left lateral	2	8th/9th ICS	second port at 6th ICS access incision in the 4th/5th ICS	OLV	healthy
SCOTT et al. (2017)	dorsal	3-4	paraxiphoid	2-3 ports at 5th-11th ICS	OLV in one patient	pyothorax
FRATINI et al. (2018)	supine	n/a	paraxiphoid	according to location of tumour	none	neoplasia
SINGH et al. (2019)	lateral	1	middle third of the 9th and 10th ICS	mini-thoracotomy in the 4th-8th ICS on the right side mini-thoracotomy in the 5th-7th ICS on the left side	none	cadaver study

2.4 Minimal invasive pericardectomy

Pericardectomy is one of the most commonly performed thoracoscopic surgeries. Pericardioscopy is defined as the assessment of the epicardial surface, heart base, aortic root, and right atrial appendage. (CARVAJAL et al., 2019) Indications for this procedure are pericardial effusions as well as chylothorax. The procedure is regularly used as part of the surgical treatment of chylothorax in combination with the ligation of the thoracic duct and/or ablation of the cisterna chyli. Pericardial effusions are mostly idiopathic, in cases where effusions are malignant, pericardectomy is part of the palliative treatment. CASE (2016) reported that in case of an idiopathic effusion the entire heart has to be evaluated via pericardioscopy to eliminate any misdiagnosis. This should be followed by a pericardectomy larger than in cases with malignant effusions. FRANSSON et al. (2015) reported the first publication, describing a thoracoscopic pericardectomy, being published in 1999 (JACKSON et al., 1999).

The procedure is described for dorsal as well as lateral recumbency. However, due to the proximity of the heart to the thoracic wall, dorsal recumbency is more commonly described than lateral. In dorsal recumbency the surgeon can stand on either side of the patient with the video monitor at the head side of the patient. To facilitate access and manipulation of the pericardium, a slight tilt of the patient to the left or right is described by MONNET (2009). Another common method of creating working space in the thorax was OLV, used by MAYHEW et al. (2009), MAYHEW et al. (2012), CASE (2016) and MAYHEW et al. (2019). DUPRÉ et al. (2001) suggests, that pulmonary exclusion is not always necessary for pericardectomy; with the dog in dorsal recumbency the lungs fall dorsally by gravity, thereby allowing proper dissection and removal of the pericardium without compromising lung inflation and blood oxygen saturation. For dorsal recumbency the approach is described uni- or bilateral, with the bilateral one used more commonly.

Lateral recumbency offers the advantage of performing multiple procedures consecutively without the need to reposition the patient, however, due to reduced space manipulation is more difficult. Newer papers all only use dorsal recumbency. (BARBUR et al., 2018; CARVAJAL et al., 2019; MAYHEW et al., 2019)

For pericardectomy usually three to four intercostal portals are used. However, many different port locations are described depending mainly on recumbency or surgeon's preference as well as targeted area on the pericardium. Most commonly, the ports were located in the ventral third of the thorax due to the location of the phrenic nerve. The first or camera port was mostly described in a para-xiphoid location in both dorsal as well as lateral recumbency.

In the report of DUPRÉ et al. (2001) the patients were placed in dorsal recumbency. 1 cm lateral of the last rib at the junction between costal arch and xiphoid process on the left side a 1 cm skin incision was made. For the thoracoscopy a 1 cm diameter trocar was introduced into the thoracic cavity through the skin incision. After the camera was inserted through the trocar, it was directed cranially through the pars sternalis of the diaphragm lateral to the phrenicopericardial ligament. The instrument ports were both placed under endoscopic guidance ventrally in the sixth intercostal space on both sides of the thorax. For the irrigation-suction another 5 mm skin incision was made in the ventral third at the third or fourth intercostal space. Blunt dissection of the muscle tissue was performed under thoracoscopic guidance.

MAYHEW et al. (2012) described pericardectomy after ligation of the thoracic duct. For pericardectomy the patient was repositioned into dorsal recumbency. The camera was located in a subxiphoid location using a 5 mm cannula. The first instrument port was established on the left ventral side of the thorax at the fourth to sixth intercostal space. After dissection of the mediastinum the second port was placed under endoscopic guidance on the contralateral side ventral in the fourth to sixth intercostal space. For subtotal pericardectomy the patient was tilted to the right manually or with the motorized float table. For cases in which OLV was used, it was initiated at the point, where dissection close to the phrenic nerve was performed, to maximize visualization of the nerve.

A paper by BABUR et al. (2018) described experimental findings. All dogs were euthanized after surgery. After placing the dogs in dorsal recumbency a 2 cm skin incision in a right paraxiphoid location was made for the camera port. A threaded cannula with 6 mm in diameter was introduced through the incision on the right side of the xiphoid process. The cannula was directed craniodorsally and under endoscopic guidance the diaphragm was dissected and the 5 mm, 0° endoscope introduced into the right hemithorax. For the placement of further ports, a 5 mm, 30° endoscope was used. The first instrument port was established with a 6 mm threaded cannula in the ventral third of the eight to tenth intercostal space under endoscopic visualization. After dissection of the mediastinum the second instrument port was introduced under endoscopic guidance on the contralateral side slightly more cranially in the seventh to ninth intercostal space.

Both lateral and dorsal recumbencies for pericardectomy were described by MONNET (2009). In this paper subtotal pericardectomy was only performed in dorsal recumbency. For dorsal recumbency a unilateral as well as a bilateral approach was delineated. In dorsal recumbency the camera port was located in a para-xiphoid position and the camera was inserted through the diaphragm. The instrument ports were placed in the ninth and tenth intercostal space on either side of the thorax, however, placement was performed blindly, the mediastinum was dissected after all ports were in place. For the unilateral approach both instrument ports were placed on the right thorax in the sixth or seventh and ninth or tenth intercostal space. With this approach the dissection of the mediastinum was not necessary. For the lateral (intercostal) approach the patient was positioned in left lateral recumbency. The camera was located in the ventral third of the sixth or seventh intercostal space, the operative portals in the fourth and eight intercostal spaces.

Table 2: Overview of recumbencies and port setup in papers describing minimal invasive pericardectomy (intercostal space (ICS), one lung ventilation (OLV), not available (n/a))

	Recumbency	Number of ports	Location of camera port	Location of instrument ports	Method of working space creation
DUPRÉ et al. (2001)	dorsal	3	subxiphoid	under thoracoscopic guidance 2 portals ventral at 6th ICS on each side of the chest	moderate collapse of the lungs
WALTON (2001)	dorsal	n/a	paraxiphoid	under endoscopic guidance	n/a
MAYHEW et al. (2009)	dorsal	3	paraxiphoid	2 ports at 4th/6th ICS on either side of the thorax	OLV
MONNET (2009)	dorsal	3	paraxiphoid	on both sides of the thorax in 7th-9th ICS/ on right side in 6th/7th ICS as well as 9th/10th ICS	none
MONNET (2009)	lateral	3	in ventral third of 6th/7th ICS	in 4th and 8th ICS	none
ALLMAN et al. (2010)	dorsal	3-4	paraxiphoid	2 on right side in middle 3rd of the thorax in the 5th-7th ICS optional a further port on left side, same ICS	none
CRUMBAKER et al. (2010)	dorsal	3	subdiaphragmatic	bilateral in the 5th ICS	none
MOORE (2010)	n/a	n/a	subxiphoid	on one or both sides of thorax	n/a
MAYHEW et al. (2012)	dorsal	3	subxiphoid	first at 4th-6th ICS on left side second at 4th-6th on right side both in ventral third of thoracic wall	OLV in 4 patients
ATENCIA et al. (2013)	dorsal	3	paraxiphoid	first at left 6th/7th ICS, ventral to costochondral junction	none

				second at right 6th/7th ICS, ventral to costochondral junction	
SKINNER et al. (2014)	dorsal	3	subxiphoid	one at right 9th ICS second at 7th left ICS	none (cadaver study)
RADLINSKY (2015)	lateral or dorsal	3	paraxiphoid for dorsal recumbency	on both sides of the thorax in eighth to tenth intercostal spaces for dorsal recumbency	n/a
CASE (2016)	dorsal	n/a	n/a	n/a	OLV recommended for subphrenic pericardectomy
BARBUR et al. (2018)	dorsal	3	subxiphoid	ventral third of 8th-10th ICS contralateral side in 7th-9th ICS	none
CARVAJAL et al. (2019)	dorsal	3	subxiphoid	exact placement according to surgeon 2 ports in 7th-10th ICS ventral to the costochondral junction	n/a
MAYHEW et al. (2019)	dorsal	3-4	subxiphoid	variety of combinations in ventral third of thorax	OLV in 11 patients
MICHELOTTI et al. (2019)	dorsal	3-4	subxiphoid	2 right sided instrument ports caudal one at 8th-10th ICS, mid-to-dorsal third cranial one at 2nd-4th ICS, middle third	none

2.5 Minimal invasive right auricular mass resection

Thoracoscopic right auricular mass resection is in most cases performed to gain material for histopathology for cancer grading and staging. Furthermore, right auricular mass resection is combined with pericardectomy in order to reduce pericardial effusion caused by the mass. Due to the malignancy of heart base tumours, like hemangiosarcomas, and the poor prognosis for the patients, the procedure is not very commonly performed. In the timeframe set for this publication only two authors published their findings concerning the procedure. CRUMBAKER et al. (2010) describes one case in which a thoracoscopic resection of a right auricular mass as well as a subtotal pericardectomy was performed. PLOYART (2012) published a retrospective study including nine patients.

The setup for a thoracoscopic right auricular mass resection is similar to a pericardectomy. CRUMBAKER et al. (2010) as well as PLOYART (2012) described the patients in dorsal recumbency. PLOYART (2012) placed the 5 or 10mm camera port in a paraxiphoid transdiaphragmatic location. The first instrument port, through which the right auricle was clamped, was located in the left sixth intercostal space. The second one, which was used for the stapler as well as the retrieval bag, was located in the left ninth intercostal space. The optional third instrument port was located in the right sixth intercostal space, this port was used to grasp the cranial border of the pericardium to facilitate auricle access. CRUMBAKER et al. (2010) used a similar approach with a 5 mm camera port in a subdiaphragmatic location and the two instrument ports on either side of the thorax at the fifth intercostal space.

PLOYART (2012) described no method of creating working space in the thorax for minimal invasive right auricular mass resection. CRUMBAKER et al. (2010) used controlled ventilation to improve visibility .

Table 3: Overview of recumbencies and port setup in papers describing minimal invasive right auricular mass resection (intercostal space (ICS), not available (n/a))

	Recumbency	Number of ports	Location of the camera port	Location of the instrument ports	Method of working space creation
CRUMBAKER et al. (2010)	dorsal	3	subdiaphragmatic	bilateral in the 5th ICS	controlled ventilation
PLOYART et al. (2012)	dorsal	3-4	paraxiphoid, transdiaphragmatic	left 3rd and 9th ICS right 6th ICS	n/a

2.6 Minimal invasive correction of persistent ductus arteriosus Botalli

Patent ductus arteriosus (PDA) occlusion is the most commonly performed cardiovascular surgery in dogs. (BORENSTEIN et al., 2004) However, the procedure is commonly performed via thoracotomy in dogs. BORENSTEIN et al. (2004) as well as MONNET (2009) were the only authors to publish papers concerning a minimal invasive technique for PDA occlusion in the timeframe set for this publication. However, MONNET (2009) did not publish his own data, but based the chapter on PDA occlusion of his publication on the findings of BORENSTEIN et al. (2004).

BORENSTEIN et al. (2004) compared two techniques using haemostatic clips for PDA occlusion in five dogs. In the first three patients a video enhanced technique was used. In the other two dogs the occlusion was performed thoracoscopically. All patients were placed in right lateral recumbency.

In dog one to three the camera port was located in the fifth intercostal space. After a small stab incision and blunt dissection of the thoracic wall, a 10 mm cannula was entered in the thoracic cavity. A 0° 10 mm telescope was used. The port for the lung retractor was located more ventrally at the fourth or fifth intercostal space. In the fourth intercostal space a 2 to 3 cm mini-thoracotomy was performed.

In patient four a small stab incision was made in the left fourth intercostal space halfway between spine and sternum. In patient five the incision was located an intercostal space more caudally. In both cases a 10 mm cannula was inserted in the thoracic cavity. Through the cannula a 10 mm 0° telescope connected to a video camera entered the left hemithorax. Through a further stab incision in the fifth intercostal space, at a more ventral location, 1 mm diameter 45° retractors entered the thoracic cavity. More dorsally in the fifth intercostal space a 10 mm cannula for the dissection hook and cautery was placed.

No conversion to thoracotomy was reported. However, the video enhanced occlusion proved to be less of a technical challenge, compared to the thoracoscopic technique. For the thoracoscopic technique a camera port in the third intercostal space in dogs over 7 to 8 kg was reported as the ideal situation, to offer sufficient distance between the thoracic wall and the patent ductus arteriosus.

Except for the initial pneumothorax no further method for creating working space in the thorax was used by either of the authors.

Table 4: Overview of recumbencies and port setup in papers describing minimal invasive correction of persistent ductus arteriosus Botalli (intercostal space (ICS), not available (n/a))

	Recumbency	Number of ports	Location of camera port	Location of instrument ports	Method of working space creation
BORENSTEIN et al. (2004)	right lateral	3	$3^{rd}/4^{th}$ ICS halfway between sternum and spine	first in 5^{th} ICS more ventrally than camera second in 5^{th} ICS more dorsally	n/a
MONNET (2009)	right lateral	3	$3^{rd}/4^{th}$ ICS midway between sternum and dorsal spinal process	in 5^{th} ICS one halfway between sternum and dorsal spinal process second in dorsal 3^{rd} of ICS	n/a

2.7 Minimal invasive correction of persistent right aortic arch and left ligamentum arteriosum

Vascular ring anomalies are rare congenital conditions, afflicted patients show symptoms early in life. A persistent right aortic arch in combination with a left ligamentum arteriosum is one of the most common vascular ring anomalies to cause clinical symptoms. Other concurrent anomalies are possible in combination with a right aortic arch. The symptoms are caused by a constriction of the oesophagus between the right aortic arch and the left ligamentum arteriosum, cranial to the constriction the oesophagus is dilated, which can lead to regurgitation after food uptake. Most patients present young, since the symptoms commonly start shortly after weaning.

TOWNSEND et al. (2016) described three-view radiographs as part of the diagnostic imaging, furthermore, a computed tomography with contrast material was performed in selected cases. An esophagoscopy directly prior to the thoracoscopic procedure was described as gold standard to diagnose the condition. During esophagoscopy a right aortic pulse may be identified as well as the exact location of the constriction of the oesophagus. The illumination of the oesophagus also acts as a guide during the procedure.

Due to the anatomic setup of the condition, the patient is placed in right lateral recumbency, to facilitate access to the left ligamentum arteriosum. FRANSSON et al. (2015), CASE (2016) and NUCCI et al. (2018) recommended a right lateral oblique recumbency with an upward rotation of the dorsal midline up to 30°.

The port's locations ranged from fourth to eleventh intercostal space, as well as from the costochondral junction up to the dorsal third of the thorax according to the surgeon's preference. FRANSSON et al. (2015) recommended to place the cannulas as caudal as possible as well as perpendicular to the axis of the ligamentum to make dissection easier. No author described port placement under endoscopic guidance, ISAKOW et al. (2000) and MACPHAIL et al. (2001) delineated a 1 cm skin incision at the port side, followed by blunt dissection with haemostats. NUCCI et al. (2018) described dissection with sharp trocars.

To gain access to the ligamentum three to four intercostal ports were placed, with the fourth port for retraction of the lung lobe. ISAKOW et al. (2000) described five ports in the first patient, the fifth port was needed to improve visualization of the oesophagus and the heart base, in the second patient a four-port technique was applied. The location of the camera port, if recorded, ranged from fourth to ninth intercostal space according to surgeons preference. ISAKOW et al. (2000), MACPHAIL et al. (2001), RADLINSKY (2015) and TOWNSEND (2016) described triangulation for the setup of the instrument ports. FRANSSON et al. (2015) recommended locations for the telescope and operative ports in the dorsal third of the left eighth or ninth intercostal space to, with the fourth optional port for the retraction of the lung lobe more cranially in the sixth or seventh intercostal space.

ISAKOW et al. (2000) and MACPHAIL et al. (2001) used a 0° telescope for visualization of the ligamentum arteriosum, FRANSSON et al. (2015), TOWNSEND et al. (2016) as well as NUCCI (2018) used a 30° telescope for the same purpose. The telescope sizes varied between 3.5 and 5 mm. FRANSSON et al. (2015) recommended the use of the 30° scope to facilitate visualization.

OLV was used by MACPHAIL (2001) in their case report. TOWNSEND et al. (2016) used it according to surgeon's preference, but not depending on the size of the patient. NUCCI (2018) mentioned that if OLV was not performed, the left cranial lung lobe had to be retracted.

Table 5: Overview of recumbencies and port setup in papers describing minimal invasive correction of persistent right aortic arch and left ligamentum arteriosum (intercostal space (ICS), one lung ventilation (OLV), not available (n/a))

	Recumbency	Number of ports	Location of camera port	Location of instrument ports	Method of working space creation
ISAKOW et al. (2000)	right lateral	4-5	4th/5th ICS at costochondral junction	first dog 4 ports dorsal in the 4th and 6th ICS second dog 3 ports dorsal in the 3rd, 5th and 6th ICS	none
MACPHAIL et al. (2001)	right lateral	4	7th ICS at costochondral junction for initial exploration 5th ICS at costochondral junction	costochondral junction 3rd and 5th ICS dorsolateral 5th ICS	OLV in all patients
MONNET (2009)	right lateral	3-4	junction of middle to dorsal third of left 6th/7th ICS	on either side of the camera port fourth port in 6th/7th ICS at costochondral junction	n/a
RADLINSKY (2015)	right lateral	4	n/a	3rd, 5th, 7th ICS triangulation/ 6th and 7th ICS	n/a
CASE (2016)	right lateral	4	dorsal and ventral 7th/8th ICS	dorsal and ventral 7th/8th ICS	n/a
TOWNSEND et al. (2016)	right lateral	n/a	middle third of 5th-9th ICS surgeon's preference	3rd-10th ICS triangulation surgeon's preference	surgeon's preference
NUCCI et al. (2018)	right oblique	3-4	n/a	dorsal third of 4th-11th ICS surgeon's preference	OLV in 4 patients

2.8 Minimal invasive thoracic duct ligation

Thoracoscopic thoracic duct ligation (TDL) belongs to the more commonly performed minimal invasive thoracic surgeries. TDL is part of the standard therapy for idiopathic chylothorax, in combination with pericardectomy and ablation of the cisterna chyli. CASE (2010) described a success rate of 80% to 100% for the surgical treatment, if a combination of the procedures was used. The aim of TDL is to prevent chyle from entering the thorax via the thoracic duct. For the ligation of the thoracic duct the patient was placed in either sternal or lateral recumbency. Sternal recumbency offered the advantage of the lungs gravitating ventrally, which gave the surgeon access to the dorsal mediastinum and the thoracic duct, without OLV, with exception of RADLINSKY et al. (2002). A further advantage of sternal recumbency was that TDL as well as cisterna chyli ablation are possible without repositioning the dog; only for pericardectomy the patient had to be placed in dorsal recumbency. ALLMAN et al. (2010) described the patient being tilted to the left to facilitate right sided thoracic access to the heart in sternal recumbency.

The thoracic duct is the thoracic continuation of the cisterna chyli. Generally the duct is situated dorsal to the aorta in the right hemithorax in dogs and crosses the ventral aspect of the fifth thoracic vertebra to enter the cranial mediastinum. (FRANSSON et al., 2015) However, there are many possible variations, such as multiple left sided branches. The anatomic location of the duct led to the ports placed in the dorsal third of the intercostal spaces. To minimize the risk of chylothorax recurrence, the duct was ligated as caudally as possible. Most authors described the ports on the right side of the thorax, except the group of MAYHEW et al. (2019). In this paper two cases with different approaches in sternal recumbency were described, in one case a bilateral approach was used, in the other a left sided approach. The bilateral access offered the ability to ligate multiple branches of the thoracic duct in both hemithoraces.

Due to the location of the thoracic duct, as well as the targeted ligation point, there were some restrictions on possible port locations.

RADLINSKY et. al (2002) placed the patient in sternal recumbency. The operating room was set up with the video monitor on the left and the surgeons on the right side of the patient. To create more working space in the thorax, OLV was established. Three intercostal ports were described. The first one entered the thorax via a 2.5 cm mini-thoracotomy as well as blunt dissection of the pleura with a Kelly forceps in either the fifth or seventh intercostal space at midthoracic level. Through this port an 8 mm, 30° endoscope was introduced into the thorax. Before further ports were placed, the entire hemithorax was examined via the endoscope. The second and third intercostal portal were placed similarly to the first, however, under endoscopic visualization to prevent any intrathoracic damage or bleeding. In this paper three different port configurations were described. In the first procedure the endoscopic port was located in the fifth intercostal space at mid-thorax, the instrument ports in the sixth and seventh intercostal spaces at middle to dorsal third of the thorax. Because of intrathoracic instrument interference, the second port was moved to the eight intercostal space. For the second case the camera port was located in the seventh intercostal space at mid-thoracic level and the instrument ports in the sixth and seventh intercostal spaces at the at junction of middle to dorsal thirds. The third option described the camera port in the seventh intercostal space at mid-thorax, the instrument ports slightly more dorsal in the eighth and ninth intercostal spaces. The authors described minimal instrument interference with the last two options, however, ligation was easier with the ports in the seventh, eighth and ninth intercostal spaces.

MAYHEW et al. (2012) described the ligation of the thoracic duct in lateral recumbency. The patient was placed on a C-arm-compatible motorized float table. The endoscopic tower was placed directly opposite the surgeon on the contralateral side of the dog. The first port was located at middle to dorsal third of the thorax in the eighth or ninth intercostal space. This location allowed inspection of the caudal mediastinum. The first instrument portal was placed in the seventh or eighth intercostal space slightly more dorsal than the camera port. The second instrument port was similarly introduced into the thorax in the ninth or tenth intercostal space, which led to a triangular pattern. For the ports 5 mm as well as 11.5 mm cannulas were used.

Table 6: Overview of recumbencies and port setup in papers describing minimal invasive thoracic duct ligation (intercostal space (ICS), one lung ventilation (OLV), not available (n/a))

	Recumbency	Number of ports	Location of camera port	Location of instrument ports	Method of working space creation
RADLINSKY et al. (2002)	sternal	3	mid-thorax at 5^{th} ICS/ mid-thorax at 7^{th} ICS	first port at junction of dorsal to middle third at 6^{th} ICS second port mid-thorax in $7^{th}/8^{th}$ ICS/ second port at junction of dorsal to middle third in 9^{th} ICS	OLV
MONNET (2009)	sternal	n/a	8^{th} ICS at dorsoventral midpoint on right side	between camera port and dorsal end of the ribs 9^{th} and 10^{th} ICS	n/a
ALLMAN et al. (2010)	sternal tilted to the left	3	middle of 10^{th} ICS	dorsal third of $9^{th}/10^{th}$ ICS dorsal third of $11^{th}/12^{th}$ ICS	none
MOORE (2010)	sternal	n/a	n/a	right lateral intercostal approach	n/a
LEASURE et al. (2011)	left lateral	3	dorsal third of the 9^{th} ICS	$8^{th}/10^{th}$ ICS more dorsally than the camera port	none
MAYHEW et al. (2012)	left lateral	3	middle to dorsal third of 8^{th} /9^{th} ICS	7^{th} /8^{th} ICS $9^{th}/10^{th}$ ICS dorsal of the camera port triangulation	none
RADLINSKY (2015)	sternal/ lateral	n/a	n/a	n/a	n/a

CASE (2016)	left lateral	3	8^{th} /9^{th} ICS in middle or dorsal third	dorsal third of 9^{th}/10^{th} ICS dorsal third of 7^{th}/8^{th} ICS	n/a
STEFFEY and MAYHEW (2018)	lateral/ sternal	3	n/a	mid to dorsal third of thorax 7^{th} -10^{th} ICS triangulation	none
MAYHEW et al. (2019)	lateral/ lateral oblique/ sternal	3-4	n/a	many different combinations placed in dorsal third of 7^{th} -12^{th} ICS	none

2.9 Mediastinal mass resection

The most common cranial mediastinal neoplasms are lymphomas and thymomas, thymic carcinomas occur less commonly. Lymphomas are treated systemically via chemotherapy. Thymomas as well as thymic carcinomas may be treated surgically. The anatomic location of mediastinal masses is complex, with many structures obscured by fat. (FRANSSON et al., 2015) Further difficulties include the possible size of these kind of masses, which leads to difficulties in manipulation as well as in removal through a port. Furthermore, important structures like the phrenic nerve are in close proximity and have a high risk of iatrogenic damage. Due to the reasons mentioned above, the thoracoscopic removal of mediastinal masses is not a very common procedure. CASE (2016) described dogs heavier than 20 kg having a non-invasive mass smaller than 7 cm as being good candidates for a thoracoscopic cranial mediastinal mass resection.

For the procedure the dogs were positioned in dorsal recumbency with the exception of one dog who was placed in lateral recumbency by MACIVER et al. (2017). MAYHEW and FRIEDBERG (2008) placed their patients on a motorized float table, the table was tilted 15° to the right to elevate the dog's left side. To gain further working space inside the thorax, OLV was established if possible by MAYHEW and FRIEDBERG (2008) and MACIVER et al. (2017).

MAYHEW and FRIEDBERG (2008) placed the camera port in a paraxiphoid location via a 1 cm stab incision. In dog one a 5 to 12 mm trocar/ cannula assembly was used, in the second dog a 6 mm trocarless threaded cannula. In the left eighth intercostal space the first instrument port was established with a 5 mm trocar/ cannula assembly. The second instrument port was located in the left fourth intercostal space and through a 3 cm skin incision an 11.5 mm blunt tipped thoracic cannula was inserted. The cannula was later removed to allow direct manipulation of the tumour with an index finger or to facilitate insertion of instruments.

FRANSSON et al. (2015) described the setup for the procedure with the patient in dorsal recumbency and the camera port in a subxiphoid location. The first instrument port was placed in the ventral sixth intercostal space on the right side of the thorax. Up to three additional instrument ports on both sides of the thorax were feasible. The instrument ports should be placed under endoscopic guidance. If the mass was located in the left cranial quadrant an instrument port in the fourth intercostal space was recommended.

Table 7: Overview of recumbencies and port setup in papers describing minimal invasive mediastinal mass resection (intercostal space (ICS), one lung ventilation (OLV), not available (n/a))

	Recumbency	Number of ports	Location of the camera port	Location of the instrument ports	Method of working space creation
MAYHEW and FRIEDBERG (2008)	dorsal	3	paraxiphoid	left 8th ICS left 4th ICS in the dorsal third of the thorax	OLV
CASE (2016)	dorsal	n/a	n/a	4th ICS for finger- assisted retraction and extraction of the mass	n/a
MACIVER et al. (2017)	dorsal/ lateral	n/a	n/a	n/a	OLV in 6 patients

2.10 Minimal invasive diagnostic procedures

Thoracoscopy has been used as a diagnostic and therapeutic tool in human and veterinary medicine. (KOVAK et al., 2002) Thoracoscopic diagnostic procedures include lymph node biopsies, biopsies of the pericardium, lungs and pleura, as well as taking samples of fluids in the thorax. Biopsies are an important part of the staging of tumours, which determine the treatment of the patient. Thoracoscopy offers minimal invasive access to the intrathoracic organs and may be used as a diagnostic tool. However, most papers concerning staging and grading are nonsurgical papers, which do not record the recumbency and location of the ports.

STEFFEY et al. (2015) described thoracoscopic access to the tracheobronchial lymph nodes. They are the sentinel lymph node of the lungs and are often biopsied or removed for the staging of lung neoplasms. However, tracheobronchial lymph nodes are very challenging to access for percutaneous preoperative fine needle aspiration or biopsy because of their location at the pulmonary hilus, dorsal to the heart, and intimately associated with major neurovascular structures. (STEFFEY et al., 2015) Currently the sample is most commonly taken after resection of the affected lung lobe. However, the biopsies should be taken before the surgery to help with staging of the tumour and preoperative planning. In this randomized study the patients were assigned to one of two groups. Four dogs were placed in right lateral recumbency and four in left lateral recumbency. In all dogs, OLV was attempted bronchoscopically-assisted. The camera port was placed in the fifth intercostal space. The additional two to three ports were placed caudal to the camera port. All ports were placed via 11.5 mm disposable threaded cannulas. The thorax was explored with a 5 mm laparoscope. The best configuration determined in this paper were ports in the third, fifth, seventh or eighth intercostal space. The caudal port was placed slightly more dorsal than the rest. In six dogs the table was tilted by 15° to facilitate access to the lung hilus. In one patient of the left sided approach the left tracheobronchial lymph nodes was not identified, in the right sided group the right tracheobronchial lymph nodes could be accessed in all patients. The central lymph nodes were only accessed from the right sided approach, whereas the oesophagus limited access to the lymph node from the left side.

Another diagnostic procedure not yet described is taking samples of pleural effusions and neoplasms. KOVAK et al. (2002) performed a retrospective study to collect data on a minimal invasive approach. The procedures were performed without pulmonary exclusion. The patients were placed in dorsal recumbency. A pneumothorax was created through a Veress needle in the fourth to eight intercostal space near the costochondral junction. The camera port was located 1 to 2 cm lateral to the xiphoid process on the same side. The cannula size ranged between 2.7

and 10 mm. A rigid endoscope was inserted through the cannula for exploration of the thorax. Further instrument ports were placed along the costochondral junction between the fourth and eighth intercostal space.

Table 8: Overview of recumbencies and port setup in all papers describing minimal invasive diagnostic procedures (intercostal space (ICS), one lung ventilation (OLV), not available (n/a))

	Recumbency	Number of ports	Location of camera port	Location of instrument ports	Method of working space creation
KOVAK et al. (2002)	dorsal	n/a	lateral to the xiphoid process	at costochondral junction 4^{th}-8^{th} rib	none
STEFFEY et al. (2015)	lateral	3-4	5^{th} ICS	cranial and caudal of the camera port	OLV

3 **Discussion**

Our study focused on studies published in the last 20 years. In this period minimal invasive procedures have become available more commonly in veterinary surgery. However, thoracic procedures, especially minimally invasive ones, are not part of the standard repertoire of many veterinary surgeons and are commonly performed by specialists. Furthermore, expensive special equipment is necessary for thoracoscopy. This equipment includes angled scopes, as well as angled or articulated graspers and other instruments. However, to some degree instruments used in laparoscopy are repurposed for thoracoscopy.

The aim of this study was to review guidelines for patient recumbencies as well as port setup for the varying intrathoracic surgical procedures. In the set period only one randomized study was published (SINGH et al., 2019). All other studies were of retrospective nature, describing recorded details of already performed surgeries. In those retrospective studies the number of ports were often not recorded.

Recumbencies for minimal invasive procedures

Dorsal and lateral recumbency were most commonly used, in the studies included in this paper. Dorsal recumbency was described for minimal invasive procedures on the lungs, pericardectomy, removal of right auricular as well as mediastinal masses. Lateral recumbency was delineated for minimal invasive procedures on the lungs, pericardectomy, thoracoscopic patent ductus arteriosus occlusion, minimal invasive correction of vascular ring anomalies, ligation of the thoracic duct and removal of mediastinal masses. Sternal recumbency was used for ligation of the thoracic duct.

The use of specific recumbencies, such as tilting depended largely on surgeon’s preference.

Creating a working space in the thorax

WALTON (2001) listed induction of pneumothorax, selective lung ventilation and intrathoracic insufflation as techniques to create working space in the thorax. Pneumothorax is induced upon first dissection of the thoracic wall. An open pneumothorax is established by leaving the valve of the trocar open and enables the surgeon to visualize intrathoracic structures at all.

Insufflation of the thorax is only described by BRISSOT et al (2003), here thoracoscopy without pulmonary exclusion in dorsal recumbency for the treatment of pneumothorax in dogs is used. The authors stated that single lung intubation had minimal adverse cardiopulmonary effects in anaesthetized healthy dogs, however at this date no studies concerning patients with abnormal ventilator status had been published. Usually location the lesions (blebs or bullae) is not reliable with diagnostic imaging methods (AU et al., 2006; REETZ et al., 2013), thoracoscopy was used as an adjunctive diagnostic tool. Here both lungs needed to be ventilated, to enable identification of the blebs or bullae. Most of the lung surface could easily be inspected, however, in dorsal recumbency the dorsal aspects of the lungs were not readily accessible. Intrathoracic carbon dioxide insufflation with a pressure of 3 to 5 cm H2O under capnographic monitoring was used in combination with tilting of the patient for better evaluation of the more dorsal lung aspects.

WALTON (2001), SCHMIEDT (2009) and FRANSSON et al. (2015) mentioned the theoretical concept of this technique, but practical applications are not described. FRANSSON et al. (2015), stated that intrathoracic CO2 insufflation was not well tolerated even in healthy dogs; the patients showed significant cardiopulmonary compromise resulting from hypoventilation and hypoxemia. Should the same complications occur with OLV, this can normally be compensated by a higher ventilation frequency or establishment of positive end-expiratory pressure ventilation (PEEP), which keeps the degree of atelectasis in the ventilated lung at a minimum while using OLV, which is unfortunately not the case with CO_2 insufflation.

OLV was used by the majority of the authors. (MACPHAIL et al., 2001; WALTON, 2001; RADLINSKY et al., 2002; LANSDOWNE et al., 2005; MAYHEW and FRIEDBERG, 2008; MAYHEW et al., 2009; MONNET (2009); LAKSITO et al., 2010; MAYHEW, CULP, MAYHEW, et al., 2012; PELÁEZ and JOLLIFFE, 2012; MAYHEW et al., 2013; BLEAKLEY et al., 2015; STEFFEY et al., 2015; CASE (2016); GOUDIE et al., 2016; MACIVER et al., 2017; SCOTT et al., 2017; NUCCI et al., 2018; MAYHEW et al., 2019) Most commonly this technique was applied for minimal invasive interventions on the lungs in order to improve visibility as well as facilitate ligation and extraction of the lesion through atelectasis of the diseased lung lobe. For minimal invasive pericardectomy OLV was used by MAYHEW et al. (2009), MAYHEW et al. (2012), CASE (2016) and MAYHEW et al. (2019). However, DUPRÉ et al. (2001) proved that pericardectomy was feasible without OLV. The technique was not applied for minimal invasive right auricular mass resection, despite the similarities to pericardectomy. For the correction of vascular ring anomalies OLV was used by MACPHAIL (2001), TOWNSEND et al. (2016) and NUCCI (2018). Only RADLINSKY et al. (2002) described the use of OLV for TDL. IF TDL and pericardectomy were performed, OLV was established upon repositioning for pericardectomy. To increase working space during mediastinal mass resection, the technique was used by MAYHEW and FRIEDBERG (2008) and MACIVER et al. (2017). STEFFEY et al. (2015) used it for minimal invasive diagnostic procedures. If available, more detailed information on OLV for the different procedures, is included in the respective paragraphs concerning those procedures.

To establish OLV a flexible bronchoscope is needed. Use of bronchial blockers, selective intubation and double-lumen endobronchial intubation are described as techniques to achieve one lung ventilation. SCHMIEDT (2009) recommends the procedure to be performed after patient positioning to prevent migration of the bronchial blocker. In order to have direct visual confirmation of OLV, MAYHEW et al. (2013) established one lung ventilation via bronchial blocker, selective intubation or double-lumen endobronchial tube during thoracoscopic access.

OLV facilitated intrathoracic procedures in nearly all reports. Failure to establish OLV, especially for minimal invasive procedures concerning the lungs, was one of the main reasons for conversion to an open technique. (MAYHEW, 2011)

Minimal invasive procedures of the lungs

For minimal invasive procedures of the lungs, VATS, thoracoscopy and thoracoscopically assisted technique with exteriorization of the affected organ may be used. All of these techniques offer the advantages of a minimal invasive procedure with reduced morbidity and faster patient recovery.

Thoracoscopy offers the possibility to evaluate the whole lung surface in greater detail, compared to open surgery, due to the camera magnification. However, thoracoscopy requires highly trained veterinary surgeons and still has a steep learning curve in the beginning. Most authors ((WALTON, 2001; LANSDOWNE et al., 2005; LAKSITO et al., 2010; MAYHEW, et al., 2012; PELÁEZ and JOLLIFFE, 2012; MAYHEW et al., 2013; BLEAKLEY et al., 2015;

CASE et al., 2015; GOUDIE et al., 2016; SCOTT et al., 2017)) used OLV to create intrathoracic working space. However, none of the authors did mention how content they were with their chosen method. MONNET (2009) and CASE (2016) recommended the use of OLV for beforehand mentioned purposes as well.

VATS avoids the need for OLV according to SINGH et al. (2019) and oftentimes, instrumentation designed for open surgery can be used (for example, regular staplers for lung lobe resection). The method is therefore more suitable for beginners and generally less expensive.

Another minimal invasive technique not in need of special equipment or OLV is the thoracoscopic assisted technique with exteriorization of the affected lung lobe described by MONNET (2009), MOORE (2010) and CASE (2016). The difference to VATS being, that the affected lobe was pulled through an intercostal incision and ligated outside of the thorax, while during VATS the lobe was ligated inside the thorax and exteriorized afterwards. The thoracoscopically assisted technique offers a viable option for partial or whole lung lobectomy in patients with intercostal spaces too small for the use of an endoscopic stapler. However, the maximum size of the lesion is defined by the intercostal space of the patient, because rib retraction should be avoided to reduce post-operative pain. Also, procedures can only be performed in organs that can be exteriorized from the thorax.

All of the techniques can be performed in lateral as well as in dorsal recumbency. Sternal thoracotomy was mimicked by subxiphoid or paraxiphoid camera placement.

Treatment of pneumothorax

Two studies concerning minimal invasive treatment of pneumothorax were published in the set timespan for this study by BRISSOT et al. (2003) and CASE (2015). In both studies the patients were placed in dorsal recumbency for the procedure. The main difference between these two studies was first of all the case number, with BRISSOT et al. (2003) describing only three cases of pneumothorax, contrary to twelve patients from different clinics in the study published by CASE (2015). The technique used for the procedure varied as well: CASE et al (2015) used VATS, with the camera port in a subxiphoid transdiaphragmatic location, while BRISSOT et al. (2003) performed thoracoscopy and placed the camera port in a paraxiphoid location. The method of creating working space in the thorax varied as well: BRISSOT et al. (2003) did insufflation of the thorax with CO2 in one patient, while CASE et al. (2015) used OLV at surgeon's preference. Furthermore, BRISSOT et al. (2003) used a 0° telescope, CASE et al. (2015) a 30° telescope. However, in both papers the instrument ports were placed from the third to the tenth intercostal space on the lateral side of the thorax and were arranged according to surgeon's preference. (CASE et al., 2015)

Conversion to an open technique

BRISSOT et al. (2003) report no conversions to thoracotomy.

CASE et al. (2015) report the reasons for conversion as the inability to locate the leak in six dogs, however, only in one of those dogs an active leak was found during thoracotomy. In the other six dogs no conversion was performed, however, two had to be euthanized 48 hours after surgery due to reoccurrence of the pneumothorax. One was euthanized during surgery after the leak was not identified and the owner not willing to allow conversion. CASE et al. (2015) listed various reasons for failure to detect the leakage during thoracoscopy as well as pneumothorax reoccurrence after the surgery. These include buoyancy of the lungs in the saline solution even after partial collapse, inability to reach the most cranial parts of the lungs with caudally placed instruments, as well as leakage through the ligature site.

Due to the small number of cases our recommendation is, to perform further studies to gain further insights into problems of minimal invasive treatment of pneumothorax and to find possible solutions.

Treatment of pyothorax

PELÁEZ and JOLLIFFE (2012) and SCOTT et al. (2017) published studies concerning a minimal invasive treatment of pyothorax. The two studies had a very different case number, PELÁEZ and JOLLIFFE (2012) describe the procedure on one patient, while SCOTT et al. (2017) included fourteen dogs in their study.

Recumbencies

PELÁEZ and JOLLIFFE (2012) performed thoracoscopic middle lung lobectomy in left lateral recumbency with OLV, to extract the foreign body in their patient along with the affected lung lobe. SCOTT et al. (2017) used VATS in dorsal recumbency in thirteen patients, one patient was placed in lateral recumbency. In both studies, chest radiographs were performed, SCOTT et al. (2017) added computer tomography scans in seven dogs, which were not available for the other group. SCOTT et al. (2017) performed OLV via variable techniques according to surgeon's and/or anaesthesiologist. PELÁEZ and JOLLIFFE (2012) used a double-lumen endobronchial tube in their patient.

Conversions and complications

PELÁEZ and JOLLIFFE (2012) were successful with their technique. SCOTT et al. (2017) reported only two conversions to an open procedure, the reason for conversion was the inability to effectively débride all of the proliferative mediastinal tissue. The major complication described by SCOTT et al. (2017), was an iatrogenic diaphragmatic tear, no minor complications were reported.

Still more studies concerning pyothorax are necessary to determine if the results support the earlier findings. Furthermore, SCOTT et al. (2017) stated that with the exception of two patients, all of their cases had uncomplicated pyothorax, without severe mediastinitis, pleuritis or a chronic history of pleural effusion, followed by the speculation that in such cases VATS may not be successful. This leads to our recommendation of broadening the case load for further studies, to determine if the speculation was correct.

Lung tumours

The most common application of partial or complete lobectomies were cases of primary lung tumours. The procedures were performed in both lateral and dorsal recumbency according to radiographic findings as well as surgeon's preference. A great variance of port setups was reported. The only commonality in thoracoscopy was that for caudal lung lobes the instrument ports were placed in the cranial aspects of the thorax, while for cranial lobes the instruments were located in the caudal aspects. For VATS as well as the thoracoscopic assisted technique the mini thoracotomy was located over the hilus of the affected lobe. In general, the procedure for partial or whole lung lobectomy was the same, in either cases of pneumothorax or pyothorax as well as primary lung tumours. However, in cases of lung tumours the location was easier to determine, but the tissue could not be destroyed to make extraction from the thorax easier, because histopathology was necessary to confirm the type of cancer involved as well as determine if the margins were clear.

Conversion to an open technique

Access to the hilus of a lung lobe is necessary, if total lobectomy is performed. Depending on the location of the lesion, partial lobectomies face similar problems. One option for reducing the likelihood of failure to perform either partial or total lobectomy was the careful planning of the procedure, with chest radiographs in three directions as well as a computer tomography if possible. Further factors include the experience of the surgeon and which lobe is concerned. The most difficult lobes to treat were the caudal lung lobes, as well as the accessory lobe. The most common reason for failure to reach the hilus or the target location on the lung was failure of OLV. In those cases conversion was necessary, with the exception of a lesion on the tip of a lung lobe.

For the maximum size of the tissue to be excised there exist varying descriptions, influenced by surgeon's experience, oncological considerations as well as size of the patient. FRANSSON et al. (2015) recommended limiting the maximum tumour size to between 5 and 7 cm as to not lose the advantages of a minimal invasive procedure due to rib retraction. MAYHEW et al. (2013) limit the size of a lung mass in a 30 kg dog for VATS to 8 cm. Most masses resected in the represented studies lay in between 5 to 8 cm, bigger lesions were excluded due to the losing the benefit of the minimal invasive approach.

Complications of minimal invasive procedures on the lungs

The most common complications were leakage and post-operative pneumothorax, as well as haemorrhage.

The most common cause of leakage directly after ligation was an improper use of the stapling device, which was either not correctly positioned or too small for the job. (MAYHEW et al., 2013) The most difficult task is the correct positioning of the stapling device, when the thoracoscopic stapler was introduced through an instrument port, while VATS where the stapler is applied through the mini-thoracotomy, is much easier to perform due to increased manoevrability of the instruments. (Lea Liehmann, personal communication) In both techniques, the ribs and surrounding intrathoracic tissue limited the manoeuvrability of the device. With VATS a bigger stapler could be introduced, however, if the mini-thoracotomy was not placed correctly, manoeuvrability and visibility were seriously impacted. LANSDOWNE et al. (2005) used the middle of the sixth intercostal space for stapling caudal lung lobes in lateral recumbency thoracoscopically and the dorsal half of the eighth intercostal space for the cranial lobes. MAYHEW et al. (2012) introduced the Ligasure® vessel-sealing device used for partial lung lobectomy, through a port in the ventral third of the left ninth to tenth intercostal space.

The cause for bleeding lays most commonly in an incorrect application of the stapling device, however, tissue manipulation and the tip of the trocar caused iatrogenic bleeding as well. If the cause could not be found or if it proved to be impossible to reach the bleeding vessel, this was one of the main reasons for conversion to an open technique, where more space is available and haemorrhage can be stopped by pressure and/or direct ligation. The same was true to some degree in VATS depending on the size of the patient and its intercostal space. In thoracoscopy bleeding had to be localized through careful manipulation of the tissue and then sealed with an endoscopic vessel-sealing device. In both VATS and thoracoscopy, a bleeding intercostal vessel that was perforated during initial port placement, reduced visibility severely.

To gain more detailed recommendations on port setup and recumbencies for minimal invasive procedures on the lungs, further studies are necessary. In the author's opinion randomized studies are needed, to compare different setups and improve knowledge for veterinary surgeons. With more knowledge and experience fewer conversions to an open technique are going to be necessary, because some of the reasons for conversion will be avoided.

Pericardectomy

For pericardectomy, the size of the patient was not such a strong limitation for the procedure. Pericardectomy was always performed thoracoscopically. The procedure was reported as one of the most common minimal invasive procedures in the thorax.

Pericardectomy was performed in either lateral or dorsal recumbency, depending on the patient's disease and further procedures. Minimal invasive pericardectomies had a high success rate, conversion to an open technique was not a common occurrence. However, CARVAJAL et al. (2019) pointed out, that with thoracoscopy the pericardium could not be palpated and the instruments are restricted by the location of their port, which could lead to limitations in examining the cardiac surface, despite of superior magnification and illumination during the procedure.

Dorsal recumbency

Dorsal recumbency was used more often than the lateral one. Most surgeons used a three port technique, only MAYHEW et al. (2019) and ALLMAN et al. (2010) used a fourth port for manipulation of the pericardium in some cases. A subxiphoid or paraxiphoid camera port location was chosen by all surgeons for a pericardectomy in dorsal recumbency. This approach offered the best possible visibility during the procedure. A one sided (ALLMAN et al., 2010; MICHELOTTI et al., 2019) as well as a two sided technique (DUPRÉ et al., 2001; WALTON, 2001; MAYHEW et al., 2009; MAYHEW et al., 2009; MONNET, 2009; MOORE, 2010; MAYHEW, et al., 2012; ATENCIA et al., 2013; SKINNER et al., 2014; RADLINSKY, 2015; CASE, 2016; BARBUR et al., 2018; CARVAJAL et al., 2019) for pericardectomy in dorsal recumbency was described.

By performing the unilateral technique dissection of the mediastinum is avoided, thus the risk of iatrogenic bleeding is reduced. ALLMAN et al. (2010) and MICHELOTTI et al. (2019) offer a detailed description of the port setup used in their respective study. The authors did not report on instrument interference or visibility. Furthermore, MICHELOTTI et al. (2019) reported good visibility of the phrenic nerve. Previous to the study by MICHELOTTI et al. (2019) subtotal pericardectomies had only been attempted with a two sided technique. MICHELOTTI et al (2019) reported no challenges to visualization or mobility due to body conformations or size of their patients.

Which leads to the conclusion that more studies concerning the one sided technique are necessary, to gain more information on its advantages as well as limitations and to determine the optimal port setup for this technique.

In studies reviewed here the two sided technique was more commonly used compared to the one sided technique. MONNET (2009) described the two sided technique as the easier one. Furthermore, with the two sided technique a subtotal pericardectomy was possible, which according to FRANSSON et al. (2015) was the preferred technique, because a bigger part of the pericardium can be excised. There is a multitude of different recorded instrument port setups. The instrument port locations ranged from fourth to tenth intercostal spaces. With the exception of MAYHEW et al (2009) as well as MAYHEW (2012) the authors placed the instrument ports in the more caudal intercostal spaces. During the procedure the thoracoscope and the instruments switched ports to facilitate the resection of the pericardium. For this technique OLV was required.

One lung ventilation

The study by MAYHEW et al. (2009) focused on the use of a double-lumen endobronchial tube for alternating OLV. The main problem with OLV, is the possibility of hypoxemia in the patient. MAYHEW et al. (2009) described two cases of severe hypoxemia in their study, even though in both patients the endobronchial tube was placed correctly. Furthermore, special equipment as well as trained personal was necessary, to establish OLV and still it had a high chance of failure during establishment or during the procedure. Previously DUPRÉ et al (2001) had reported that OLV was not necessary for pericardectomy in dorsal recumbency using two instrument port in the ventral third of the thorax, which was adhered to by most authors. In cases where the ventilated lung made inspection of the region around the phrenic nerves impossible, most commonly the ventilation was slightly reduced to gain more space for the iatrogenic pneumothorax. However, the report by DUPRÉ et al. (2001) did neither include patients under ten kilograms, nor dogs with a low depth to width ratio of the thorax. Both situations would, according to MAYHEW (2011), make OLV necessary.

The author concludes that more studies need to be conducted to determine further conditions, in which OLV or at least reduced ventilation is necessary in order to perform thoracoscopic pericardectomy. Furthermore, this report could not determine if an ideal port setup exists for the bilateral approach in dorsal recumbency, because none of the papers included, recorded how content the surgeon was with the chosen port locations and the chosen method of creating working space, regarding visibility of all target structures, as well as manoeuvrability of the surgical equipment. Which leads to the author's suggestion of performing randomized studies to compare the different port setups to each other with and without OLV, to determine the best possible locations for visibility and manoeuvrability.

Lateral recumbency

Lateral recumbency was only described by MONNET (2009) and RADLINSKY (2015). MONNET (2009) described the advantages of lateral recumbency in better access to the right atrial appendage and the aortic root in cases of heart base tumours. However, in lateral recumbency OLV was necessary to improve visibility. Furthermore, only one side of the pericardium was accessible. If pericardectomy was combined with the ligation of the thoracic duct where no tilting table was available, the technique offered an option to perform both procedures without rearranging the patient. However, most authors prefer to place the patient in dorsal recumbency after ligation of the thoracic duct.

Tilting table

With dorsal recumbency examination of the pericardium is facilitated by the possibility of tilting the patient either manually or with the help of a tilting table. MICHELOTTI et al. (2019) used an articulating table to increase visibility in the dorsal and lateral aspects of the pericardium. The patients were tilted to the left and right, as well as in reversed Trendelenburg. MAYHEW et al. (2009) and MAYHEW et al. (2012) described tilting the patient away from the side of the pericardium on which they operated with the help of a motorized float table. MAYHEW et al. (2019) mentioned the use of a motorized float table. MONNET (2009) reported that tilting the patient ten to fifteen degrees to the right and left, during the procedure, facilitated the minimal invasive pericardectomy. However, the rest of the authors (DUPRÉ et al., 2001; WALTON, 2001; ALLMAN et al., 2010; CRUMBAKER et al., 2010; MOORE, 2010; ATENCIA et al., 2013; SKINNER et al., 2014; FRANSSON et al., 2015; RADLINSKY, 2015; CASE, 2016; BARBUR et al., 2018; CARVAJAL et al., 2019) did not report the use of either a special table for tilting their patient to facilitate the procedure.

This controversy leads to the question to what extent a tilting table can ease the facilitation of thoracoscopic pericardectomy, reflecting in duration of the procedure and improvement of visualization. To answer this question further studies are necessary.

Complications

The main complications of thoracoscopic pericardectomy were described by MAYHEW (2011) as lung laceration, phrenic nerve transection and haemorrhage. However, all of these complications were a rare occurrence.

Lung laceration happened most commonly upon entering a trocar into the thorax or during manipulation of the lungs to improve visibility of the pericardium.

Damage to the phrenic nerve was associated with subtotal pericardectomy rather than the creation of a pericardial window, because in a subtotal pericardectomy all tissue ventral to the nerve is removed, with only a small stripe of pericardium around the nerve.

Iatrogenic bleeding can be caused by the trocar damaging an intercostal blood vessel or by instruments puncturing the myocardium or a large blood vessel. If the bleeding was too excessive to be stopped thoracoscopically or impaired visibility, conversion to an open technique became necessary. This occurred in one case described by MAYHEW et al (2009).

All the beforehand mentioned complications may be avoided with careful manipulation as well as placing the trocars under endoscopic guidance.

Right auricular mass removal

Recumbencies

Pericardectomy was part of the palliative treatment for cases of malignant pericardial effusion. This effusion was most commonly caused by tumours in the right atrium. However, heart base tumours were described as having a very poor prognosis due to their malignancy, furthermore, even with a multimodal treatment patients had a short survival span. Only two authors described the thoracoscopic removal of right auricular masses in the set timespan. The setup in both studies was very similar to pericardectomy, however, no OLV was performed. CRUMBAKER et al. (2010) performed a subtotal pericardectomy in combination with the removal of the right auricular mass. In this paper a two sided approach in dorsal recumbency was used, while in the paper published by PLOYART (2012) a one sided approach was described.

Complications

During the procedure the most common complication was haemorrhage of the mass due to manipulation, which in the study by PLOYART (2012) resulted in the death of one patient.

With the improvement of chemotherapeutics, as well as more owners seeking cancer screening for their pets to detect cancer early on, more patients will receive palliative or in early stages even curative surgical treatment for right auricular masses, which in turn will offer more opportunity for studies concerning right auricular mass removal.

Correction of right aortic arch and left ligamentum arteriosum

Vascular ring anomalies are another rare congenital condition for which minimal invasive treatment is a possibility. The procedure is reported by ISAKOW et al. (2000), MACPHAIL et al. (2001), MONNET (2009), RADLINSKY (2015), CASE (2016), TOWNSEND et al. (2016) and NUCCI et al. (2018) in either retrospective studies or case reports.

Recumbencies

All authors placed the patient in right lateral recumbency, but varied in the port setup for the procedure. TOWNSEND et al. (2016) and MACPHAIL et al. (2001) recorded excellent visibility of all target structures. The only paper, in which some problems with the initial port setup were identified, was published by ISAKOW et al. (2000).

One lung ventilation

OLV was used to improve visibility and working space in the thorax by MACPHAIL et al. (2001), TOWNSEND et al. (2016) and in some cases NUCCI et al. (2018). If no OLV was used, the left cranial lung lobe was reflected caudally to gain more working space. (ISAKOW et al., 2000; FRANSSON et al., 2015; RADLINSKY, 2015; NUCCI et al., 2018) NUCCI et al. (2018) had the highest conversion rate to an open technique (five/fifteen dogs), one possible reason was that OLV was not used, however, this was the biggest study concerning vascular ring anomalies. None of the authors stated how content they were with OLV as method of creating more working space in the thorax.

We therefore suggest to perform further randomized studies, to compare the different setups for determination of the one with the best visibility of the target structures and if OLV is necessary to increase the success chance of the thoracoscopic correction of vascular ring anomalies.

Complications

The main complication recorded was haemorrhage. The most common causes included incomplete dissection of the left ligamentum arteriosum, injuring another blood vessel during manipulation or upon entering the thorax. Incomplete dissection is described by TOWNSEND et al. (2016) and NUCCI et al. (2018), who failed to fully dissect a ligamentum with a diameter over seven centimeters with a vessel sealing device. TOWNSEND et al. (2016) recommended the use of vascular clips or suturing silk for vessels of that size. Haemorrhage after attempted sealing of the ligamentum, as well as due to laceration of an intercostal artery was described by NUCCI et al. (2018) as reasons for conversion to an open technique.

Further studies are necessary to determine possible other complications as well as to gain more information of the probability of such complications arising.

Thoracoscopic patent ductus arteriosus Botalli occlusion

Recumbencies

Thoracoscopic patent ductus arteriosus occlusion was the rarest surgical intervention in this study. The procedure was only described in one study, published by BORENSTEIN et al. (2004). Although the condition is only rarely treated thoracoscopically in animals, in human medicine minimal invasive treatment of this anomaly is described as routine in some surgical centers. The aim was to see if they could be applied with a minimal invasive technique to reduce patient discomfort after the surgery. The author reported good visibility in the thorax in dog five, where the camera port was located in the third intercostal space in lateral recumbency.

With only five cases recorded in the set timespan for this study the authors suggestion is, to perform further studies to analyse if the suggestion of BORENSTEIN et al. (2004) were correct and furthermore, to determine a more accurate patient mortality and morbidity for the minimal invasive techniques, as well as determine case selection parameters.

Thoracic duct ligation

Recumbencies

One of the more common procedures for this study was thoracic duct ligation, which was described as part of the standard surgical intervention to treat idiopathic chylothorax, either on its own or in combination with pericardectomy. For this procedure the patients were placed in either left lateral or sternal recumbency, depending on surgeon's preference, as well as further interventions planned. RADLINSKY et al. (2002), MONNET (2009) and ALLMAN et al. (2010) describe placing the patient in sternal recumbency for ligation of the thoracic duct. LEASURE et al. (2011), MAYHEW et al. (2012) and CASE (2016) report the patient in left lateral recumbency. RADLINSKY (2015), STEFFEY and MAYHEW (2018) as well as MAYHEW et al. (2019) describe both recumbencies for the procedure. To facilitate the procedure, variations are described for both recumbencies; for lateral recumbency the spine is elevated leading to a lateral oblique recumbency, for sternal recumbency ALLMAN et al. (2010) describe tilting the patient to the left. One important consideration is that in sternal recumbency multiple bilateral branches of the duct are easier identified with the help of a bilateral approach, compared to left lateral recumbency.

Identification of thoracic duct branches

For identification of the thoracic duct branches multiple techniques have been described. Pre surgery a computer tomography lymphangiography can be to get an overview of the anatomy of the duct. (STEFFEY and MAYHEW, 2018; MAYHEW et al., 2019) Intraoperatively injection of methylene blue in the mesenteric lymph nodes is most commonly used to identify the duct and its branches. A newer technique was described by STEFFEY and MAYHEW (2018), who used indocyanine green to illuminate the thoracic duct. According to the authors indocyanine green lasted longer than methylene blue, however, no specific timings were published. To confirm the ligation of the duct intraoperatively a repeated injection of methylene blue or a intraoperative lymphangiography are described, however, confirmation was only sought after in some cases and furthermore, was not always definitive. MAYHEW et al. (2012) suggested that not all branches needed to be ligated to prevent the reoccurrence of chylothorax, when the ligation of the thoracic duct was combined with subtotal pericardectomy.

Nevertheless, the best optimal outcome was reached, if all or as many branches as possible were ligated. Due to the anatomy of the duct, the ligation via hemostatic clip or via a vessel sealing device was performed as caudal as possible.

Further studies with clear parameters on the techniques are necessary, to better compare the different options for identification of multiple thoracic duct branches.

<u>One lung ventilation and port setup</u>

OLV was described by RADLINSKY et al. (2002) to facilitate the access to the duct. ALLMAN et al. (2010), LEASURE et al. (2011), MAYHEW et al. (2012), STEFFEY AND MAYHEW (2018) and MAYHEW et al. (2019) did not require OLV and stated that bilateral lung ventilation did not impair visibility. With the exception of MAYHEW et al. (2019), three intercostal ports were used for ligation of the thoracic duct. MAYHEW et al. (2019) describe the use three to four ports according to surgeon’s preference.

RADLINSKY et al. (2002) describe interference of instruments and endoscope in their first patient. The camera port was located in the fifth intercostal space at mid-thoracic level, the instrument port in the sixth intercostal space at the junction of the dorsal to the middle third. The port for the clip applier was in the seventh intercostal space at mid-thoracic level. For the following patients the setup was reviewed and changed. For the optimal setup described in this study the camera port was located in the seventh intercostal space at mid-thoracic level and the two instrument ports at the eighth and ninth intercostal space, slightly more dorsal. RADLINSKY et al. (2002) did not state, how their method of creating working space in the thorax influenced the port setup and how contend they were with OLV as method of creating more working space in the thorax.

<u>Patient size limitations for ligation of the thoracic duct</u>

MAYHEW et al. (2012) reported a size limitation for the ligation of the thoracic duct. In this paper the procedure was performed in a dog weighting five point one kilograms, which according to the authors, lead to some difficulty in applying the hemostatic clips between vertebral artery branches.

Complications

The main complications for this procedure were failure of OLV if required and reoccurrence of the chylothorax after surgery. The latter was most commonly the result of failure to ligate all main branches of the duct, which could happen independently of the port setup. To avoid this complication pre surgical lymphangiography and intraoperative injection of methylene blue are commonly performed.

The author's suggestion is to perform a randomized study focusing on comparing the different setups to further optimize this procedure. Furthermore, in this study the necessity of OLV for this procedure may be determined.

Removal of mediastinal masses

Minimal invasive resection of mediastinal masses was one of the rather rarely described procedures included in this study. MAYHEW (2011) reported that a careful case selection, as well as experience in this field were necessary for this surgical intervention. Furthermore, as mentioned in the results part, not all mediastinal masses required surgery as part of the therapy. This resulted in a small case load, which was further reduced, if the mass was too big to be removed via thoracoscopy or VATS, especially in cases with malignant tumours, where the necessary margins have to be considered. Other factors included the size of the patient, which CASE (2016) recommended to be over 20 kilograms. Furthermore, the bigger or malignant masses had severe clinical effects on some of the dogs, resulting in a higher risk during and after the procedure. The clinical sings included paraneoplastic syndrome, as well as signs attributable to compression or invasion of surrounding structures, such as couching, altered breaching or signs of congestions associated with occlusion of the cranial vena cava. (MAYHEW and FRIEDBERG, 2008)

Recumbencies

Minimal invasive resection of mediastinal masses was described by MACIVER et al. (2017) and MAYHEW and FRIEDBERG (2008), both papers combined reported a total of 20 cases in the timespan of our study. MAYHEW and FRIEDBERG (2008) placed their patients in dorsal recumbency, which was repeated by MACIVER et al. (2017) with the exception of one patient, who was placed in lateral recumbency.

One lung ventilation

OLV was recommended by MACIVER et al. (2017) in patients with a smaller intrathoracic volume to increase visibility and working space and by MAYHEW and FRIEDBERG (2008) in both their patients. MACIVER et al. (2017) used OLV in six out of eighteen patients. FRANSSON et al. (2015) recommended the use of OLV as well, however, mentioned that endobronchial blockage sufficed and the use of double lumen endobronchial tubes for alternating OLV was not necessary in their experience. The authors did not specifically state if the working space in the thorax did suffice.

Complications

MAYHEW and FRIEDBERG (2008) had no intraoperative complications, however, both dogs suffered from aspiration pneumonia after surgery. MACIVER et al. (2017) reported one patient with haemorrhage after laceration of the vena cava, which resulted in the death of the dog. Five patients in this study were reported with aspiration pneumonia post surgery.

Due to the small case load as well as the complexity of this procedure, the author's recommendation is to record further cases with a focus on port setup and the use of OLV to gain more data and information on this procedure. Furthermore, if more port setups have been recorded, a randomized study may be performed to compare them and determine the one with the best performance.

Diagnostic procedures- biopsies

Thoracoscopy started out as a diagnostic tool for veterinary medicine, nowadays the spectrum includes many surgical interventions for diseases affecting the thorax. However, diagnostic procedures are still a part of this study. In most procedures samples for histopathology were gained, for example during pericardectomy the excised pericardium was checked for any signs of malignancy, after partial lung lobectomy, excision of mediastinal masses or right auricular masses histopathology was performed as well. In the timespan set for this paper two studies concerning diagnostic procedures were published by KOVAK et al. (2002) and STEFFEY et al. (2015). KOVAK et al. (2002) focused on gaining samples of pleural effusion, STEFFEY et al. (2015) published an experimental study on tracheobronchial lymph node extirpation. FRANSSON et al. (2015) described a technique for tracheobronchial lymph node biopsy as well. Both procedures were part of pre-surgical staging and grading of tumours. However, most commonly diagnostic procedures, were part of the surgical treatment and not performed on their own.

4 Conclusion

A lot of development in minimal invasive surgery in the thorax has been achieved over the course of the last 20 years. In this timespan thoracoscopy has become a more widespread therapeutic tool for veterinary surgeons. Furthermore, a lot of experience was gained, which lead to a flattening of the learning curve and shorter operative times. However, most of the studies were of a retrospective nature and did not focus on port setup or patient recumbencies, especially the port set up was commonly not recorded in great detail. This led to a great variance in port setups for the varying procedures, based on varying surgeon's preference due to previous experiences. The same is true for patient recumbencies, which were in general not described in great detail. Due to the established facts, no guidelines for patient recumbency and port placement for minimal invasive surgery in the thorax could be formulated or documented. The author's recommendation is to perform randomized studies with the focus on patient recumbencies and port placement, to compare different approaches and determine guidelines for the varying procedures. This will help to advance beginners of minimal invasive surgery, as well as offer some common ground for more experienced surgeons, as well as help flatten the learning curve further, by eliminating port placement errors.

5 English summary

This study is based on literature research concerning thoracoscopy in dogs, with the focus on recumbencies and port setup. The aim of the study is to give an overview of current minimal invasive procedures in the thorax and furthermore, to determine the best possible port setup for these procedures. For the literature research, the search engines "Pubmed" and "Scopus" were used. For screening and sorting the articles a database in "Zotero" was created. Exclusion criteria for the articles included duplicates, non-surgical topic, not mentioning recumbencies or port setup and not being written in English. After careful screening 46 articles were included in this study.

For the writing process the articles were sorted by the surgical procedures. Due to some procedures being conducted rather uncommonly, the number of articles per procedure varied a great deal. The chapters in the "results" part of this study are based on the different procedures. The findings concerning the varying procedures are described. Furthermore, a tabellaric overview of the different articles is included at the end of each chapter.

The study offers an overview of current minimal invasive procedures in the thorax of dogs. However, due to a great variance of port setups described by the varying authors and due to the fact that the authors on whether they were content with their chosen setup, no optimal port setup could be determined. Prospective studies are therefore recommended in order to identify the best possible approaches and port setup for the different procedures, leading to the best possible quality of visualization.

6 German summary

Bei der Arbeit handelt es sich um eine Literaturstudie zu Thorakoskopien mit dem Fokus auf Lagerung des Patienten und Zugängen bei Hunden. Das Ziel der Arbeit ist, eine Übersicht über gängige Methoden zu erlangen und für diese Methoden die bestmögliche Lagerung, sowie das bestmögliche Portsetup zu bestimmen. Für die Literatursuche wurden die Suchmaschinen „Pubmed“ und „Scopus“ benutzt. Die Artikel wurden zur weiteren Bearbeitung und Sortierung in eine Datenbank in „Zotero“ eingespielt. Dort wurden Duplikate, sowie nicht chirurgische Artikel aussortiert. Danach wurden alle Artikel auf die Erwähnung von Lagerungen, sowie gesetzte Zugänge durchsucht. Artikel, die diese nicht erwähnten, wurden aussortiert. Zusätzlich wurden Artikel, die nicht in englischer Sprache waren, ebenso aussortiert. Nach sorgfältiger Bearbeitung wurden 46 Artikel in die Arbeit inkludiert.

Diese 46 Artikel wurden auf die verschiedenen Eingriffe aufgeteilt. Die Menge der zugeordneten Artikel variierte stark, da einige der beschriebenen Eingriffe sehr selten sind. Die Eingriffe begründeten die Unterkapitel des „Results-Teil“ der Arbeit. Dort wurden die Ergebnisse beschrieben, sowie ein tabellarischer Überblick gegeben.

Die Arbeit gibt einen Überblick über gängige minimalinvasive Eingriffe im Thorax von Hunden. Leider konnten für diese Eingriffe keine optimalen Zugänge beschrieben werden, da zwischen den Autoren eine starke Varianz besteht und die meisten nicht kommentiert haben, ob sie mit ihren gesetzten Zugängen zufrieden waren. Aus diesem Grund sind prospektive Studien zum Vergleich von verschiedenen thorakoskopischen Zugängen und der daraus resultierenden Qualität der möglichen Visualisierung notwendig, diese werden in der Arbeit angesprochen.

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