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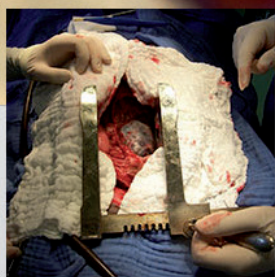
## Thoracic surgery

Not (always) as difficult as it seems

## The colourful consultation

Better for owners, pets and staff

## Anaesthesia in rabbits



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Each scientific article is classified with one or more icons.

These refer to the species (in green) of animal or the veterinary discipline (in blue) relevant for the article.

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	Dogs and Cats/ Small animals		Behaviour		Orthopaedics
	Rabbits		Cardiovascular		Practice Management
	Less common pets		Dental		Surgery
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			Diagnostic imaging		
			Digestive System		
			Ear Nose Throat		
			Genetics		
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## Commissioned paper

# Thoracic surgery - not (always) as difficult as it seems

*Jean-Philippe Billet<sup>1</sup> and Isabelle Testault*

## SUMMARY

With recent advances in diagnostic imaging, anaesthesia and analgesia, thoracic surgery has become increasingly accessible in small animal veterinary practice. The basic requirements for veterinarians contemplating thoracic surgery are: a good knowledge of the surgical anatomy, basic anaesthetic and analgesic knowledge, appropriate surgical instruments and anaesthetic equipment, awareness of the different disease processes and their surgical indications, and knowing how to choose the correct approach to the thorax. The first surgery that the surgeon should be familiar with is lung lobectomy via a lateral intercostal approach. Next comes the median sternotomy approach for exploratory thoracotomy, which is used in the treatment of spontaneous pneumothorax or pyothorax; exploration of penetrating thoracic wounds and reconstruction are also reasonably straightforward. Patent ductus arteriosus ligation and ligamentum arteriosum ligation and section are more advanced procedures due to the delicate dissection at the base of the heart. Other surgeries are much more complex and should be referred to a more experienced surgeon. Post-operative monitoring is crucial for a successful outcome, as well as in-depth knowledge of any possible complications.

Key words: Thoracic, respiratory, surgery, dog, cat

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Go to <http://www.fecava.org/ejcap>  
to see the online presentation of this paper.

## Introduction

Thoracic surgery used to be uncommon, but with the development of modern imaging, anaesthetic, and analgesic techniques, it is becoming increasingly available in veterinary practices. Access to the thorax is required for the investigation or treatment of a variety of conditions in dogs and cats. Biopsies (e.g. lung biopsy, mediastinal biopsy, lymph node biopsy), surgical treatment of a thoracic organ (e.g. patent ductus arteriosus ligation, ligamentum arteriosum division, lung lobectomy, thymectomy, thoracic duct ligation, pericardectomy, thoracic oesophageal

reconstruction) and treatment of the thoracic cavity and pleural space (chest wall mass removal and reconstruction, thoracic bite wound, foreign body removal) are the most common surgeries. Appropriate perioperative management is essential to success.

## Thoracic surgical anatomy

### Boundaries and skeleton

The thorax of dogs and cats comprises 13 pairs of ribs, 13 vertebrae, and 9 sternbrae. The costal cartilages of the first 9 ribs articulate with the sternum. The thoracic cavity is bounded caudally by the diaphragm. For reconstruction of caudal chest wall defects, the insertion of the diaphragm to the last ribs can be brought forward and attached as far forward as the 9th rib <sup>[1-6]</sup>.

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## Muscles

The latissimus dorsi muscle originates from the lumbodorsal fascia and thoracolumbar vertebrae and converges cranioventrally on the lesser tubercle of the proximal humerus. During the surgical approach to the lateral thoracic wall, the latissimus dorsi muscle can be divided, or elevated dorsally, to enable access to the intercostal muscles. It can also be sectioned at its thoracolumbar attachment to create a muscular or myo-cutaneous flap and rotated ventrally to close large defects in the thoracic wall [2-5, 7-9].

The serratus ventralis muscle comprises several muscle bellies, which originate on the caudal edge of the first 7 to 8 ribs and insert on the medial surface of the scapula; these can be divided to enable access to the intercostal space. The scalenus muscle runs horizontally across the ventral thoracic wall from the caudal neck to its insertion on the 5th rib, which is a useful surgical landmark; the 4th intercostal space is accessed by dividing it along its musculotendinous junction.

The pectoral muscles originate on the sternum and insert on the medial aspect of the humerus. They are divided when performing a medial sternotomy. Branches of the internal intercostal artery and vein penetrate between the right and left deep pectoral muscles at the level of each sternebra and must be avoided or ligated. The deep pectoral muscle flap can be used for reconstruction and is elevated by incising its sternal attachment, undermining the muscle belly while preserving the cranial portion of the sternal attachment and as many branches of the internal thoracic artery as possible, and rotating the muscle flap across the ventral midline into a contralateral chest wall defect [5] or cranially into an ipsilateral cranial chest wall defect.

The intercostal muscles have an external and internal layer, connecting adjacent ribs. These muscles must be divided at their mid-point to avoid injuring the intercostal neurovascular bundles, which run caudal to the ribs.

The transverse thoracic muscle originates on the pleural surface of the thoracic wall and runs laterally from the sternum to the endothoracic fascia at the level of the costochondral junctions. It is a landmark for the internal thoracic artery that travels dorsal to it and these large arteries should be avoided.

## Innervation

The intercostal nerves originate from the thoracic spinal nerves and run ventrally along the caudal edge of each rib alongside the intercostal arteries and veins. Care should be taken not to include them with suture material when closing the intercostal space.

The left and right vagal nerves travel on their respective sides of the cranial mediastinum before giving off various visceral branches and the left and right recurrent laryngeal nerves which sweep medially around the aortic arch and the right subclavian artery. The vagal nerves divide into dorsal and ventral branches travelling on the dorsal and ventral surface of the oesophagus.

The left and right phrenic nerves travel on their respective sides of the cranial vena cava, pericardium, and caudal vena cava to supply the diaphragm. They should be avoided during subtotal pericardectomy.

## Blood vessels

The intercostal arteries run along the caudal borders of each rib.

The internal thoracic arteries travel on either side of the cranial mediastinum dorsal to the transverse thoracic muscles.

The external jugular veins and the brachial veins form paired brachiocephalic trunks that fuse in the cranial mediastinum to form the cranial vena cava.

In animals with normal embryological development, the aorta curves craniodorsally on the left side of the trachea and oesophagus as the aortic arch. Surgery of the trachea and oesophagus should therefore be performed from a right intercostal approach. The exception to this rule is in animals with a persistent right aortic arch.

## The lungs

In dogs and cats, the left lung is divided into cranial and caudal lobes. The left cranial lobe is divided into a cranial and caudal portion but shares a common lobar bronchus. The right lung is divided into right, middle, caudal and accessory lobes. The accessory lobe passes dorsal to the caudal vena cava and is located medial to the plica vena cava [10]. Pulmonary arteries and veins follow the lobar bronchus and are located on the craniodorsal and caudoventral aspect of the bronchus respectively. The lung lobes are only attached at the level of the pulmonary hilus; the caudal lobes are also attached to the caudodorsal aspect of the thoracic pleura at the level of the aorta and oesophagus by the pulmonary ligaments. To manipulate the caudal lung lobes, these avascular ligaments must be sectioned.

## Anaesthesia

Controlled ventilation is mandatory when performing thoracic surgery. Intermittent positive-pressure ventilation

(IPPV) can be achieved by manually squeezing the reservoir bag gently and rhythmically, but in the majority of practices, a ventilator is used for mechanical ventilation. The recommended tidal volume is 10-20 ml/kg (this may be increased slightly if re-inflating collapsed lungs), inspiratory time of 1-1.5 sec, inspiratory to expiratory ratio of 1:2, peak inspiratory pressure of 8-20 cm H<sub>2</sub>O, with a respiratory rate of 8-14 for dogs and 10-14 for cats. Basic monitoring includes electrocardiography, indirect (Doppler or oscillometric) blood pressure, capnography, and pulse oximetry. Direct blood pressure measurement and blood gas analysis should be available for advanced thoracic surgery<sup>[11]</sup>. For more advanced thoracoscopic surgery, selective intubation may be needed for one lung ventilation. This technique should only be performed by experienced anaesthetists.

Abnormal fluid, air, organ or mass effects of the thoracic wall or pleura can result in hypoxaemia. Concurrent trauma, such as rib fracture and pulmonary contusions can impair ventilation. Pre-anaesthetic oxygenation via a mask is an easy and effective means of improving oxygenation during the preparation and the induction periods. Opiates can be used with tranquilisers;  $\alpha$ 2-agonists should be avoided as they can cause respiratory depression, resulting in decreased respiratory rate and tidal volume. Rapid induction is important to enable prompt control over the respiratory system.

## Analgesia

Thoracic surgery is associated with considerable postoperative pain in small animals, resulting in hypoventilation, increased morbidity, prolonged hospitalisation and delayed recovery. Appropriate analgesia is therefore essential. The choice of surgical technique and anaesthetic protocol may affect the analgesic outcome in dogs and cats after thoracic surgery<sup>[12]</sup>. Pre-emptive and multimodal analgesic protocols are thought to be the most effective ways of managing post-thoracotomy pain in small animals and should be continued during the post-operative period<sup>[13]</sup>.

## Regional Analgesia

### *Intercostal Nerve Block*

A selective intercostal block is used for lateral intercostal approaches to alleviate pain and improve pulmonary function. Due to the overlapping nerve supply, two or three nerves should be blocked on either side of the thoracotomy site<sup>[14-17]</sup>. A selective intercostal block with a 0.5% solution of bupivacaine provides analgesia for up to 12

hours; 0.3ml/site of 0.5% bupivacaine solution is injected caudal to the head of the rib near the insertion of the epaxial musculature and close to the intervertebral foramen<sup>[16]</sup>. The total dose of bupivacaine should not exceed 5 mg/kg. An intercostal nerve block is not recommended for pain control after median sternotomy.

### *Intrapleural Analgesia*

Bupivacaine is administered into the intrapleural space before intercostal thoracotomy and median sternotomy in dogs<sup>[18-20]</sup>. A 0.5% solution of bupivacaine (1.5 mg/kg) is instilled through a thoracostomy tube; the tube is then flushed with saline solution. The bupivacaine is dispersed by gravity; the animal should therefore be positioned with the incision site down for up to 5 minutes. Intrapleural bupivacaine administration provides analgesia for up to 12 hours<sup>[13]</sup>. During the post-operative period, re-administration every 6 hours should provide continued analgesia.

### *Epidural Analgesia*

Epidural morphine administered pre-emptively has been reported to provide long-lasting analgesia in dogs and cats and is at least as effective as intercostal bupivacaine after intercostal thoracotomy<sup>[17]</sup>; it provides superior analgesia to intravenous morphine<sup>[21]</sup>. Morphine at 0.1-0.2 mg/kg is combined with bupivacaine at 1mg/kg or saline in a total volume of 0.2 ml/kg.

## Systemic analgesics

Multimodal analgesia is the best strategy to prevent overdosage and the side effects of systemic drugs. NSAIDs are particularly useful for pain relief after thoracic surgery because they have no respiratory depressant effects. They are used in combination with systemic opioids or as part of a multimodal approach to pain management after thoracotomy. Parenteral opioids are the primary form of systemic analgesia for thoracic surgery. Central respiratory depression is a potential side effect of opioid administration; however, because post thoracotomy pain may cause hypoventilation, systemic opioids may actually improve respiratory function by relieving the pain<sup>[15, 16, 22]</sup>. Adequate analgesia is obtained with a loading dose (0.2 mg/kg) of morphine administered before surgery, followed by perioperative- (0.2/kg/h) and postoperative (0.1mg/kg/h) continuous rate infusion (CRI). A similar protocol can be used with fentanyl: a loading dose (2 to 5  $\mu$ g/kg IV) before surgery, followed by perioperative (10 to 20  $\mu$ g/

kg/h) and postoperative CRI (2 to 5 µg/kg/h) <sup>[13, 23]</sup>. Low-dose ketamine infusion with a preoperative loading dose of 0.5 mg/kg IV, followed by perioperative (0.6mg/kg/h) and postoperative (0.3mg/kg/h) CRI has been used as an adjunct to perioperative fentanyl or morphine infusion <sup>[13, 23]</sup>. Low-dose lidocaine infusion administered as a loading dose (1 to 2 mg/kg IV) before surgery, followed by perioperative (50 µg/kg/min) and postoperative (50 µg/kg/min) CRI has been employed as an adjunct to morphine + ketamine or fentanyl + ketamine CRI <sup>[23]</sup>.

The morphine + ketamine + lidocaine CRI is discontinued 24 hours after surgery. NSAIDs, intrapleural bupivacaine, and systemic opioids such as trans-cutaneous fentanyl are continued into the longer post-operative period. The animal can be discharged with oral NSAIDs and tramadol (1-5mg/kg two to four times daily).

## Pre-surgical considerations

Patients should be stabilised before considering thoracic surgery. Respiratory rate and pattern, cardiac rate and rhythm, mucous membrane colour, capillary refill time, peripheral blood pressure, and pulse oximetry are monitored closely.

Pleural fluid or air resulting in hypoventilation should be eliminated by thoracocentesis or by thoracostomy tube placement in cases requiring repeated thoracocentesis<sup>[24]</sup>. In unstable animals, wire-guided placement of a fenestrated 14-gauge catheter or a 6 French nasogastric

tube through a 13-gauge needle can be performed under light sedation. Cardiac tamponade should be stabilised by draining any pericardial effusion via ultrasound-guided pericardiocentesis.

Careful surgical planning is important; emergency thoracic surgery is rarely required.

Tension pneumothorax is a life-threatening situation that most commonly occurs after significant trauma involving penetrating or blunt force trauma. It is a clinical diagnosis, and treatment should never be delayed to obtain laboratory or radiography results. Immediate thoracocentesis and/or chest tube placement is required to save the patient's life, but surgery is rarely needed.

## Approach to the thorax

There are three main approaches to the thoracic cavity: right or left lateral intercostal thoracotomy, median sternotomy, and thoracoscopy.

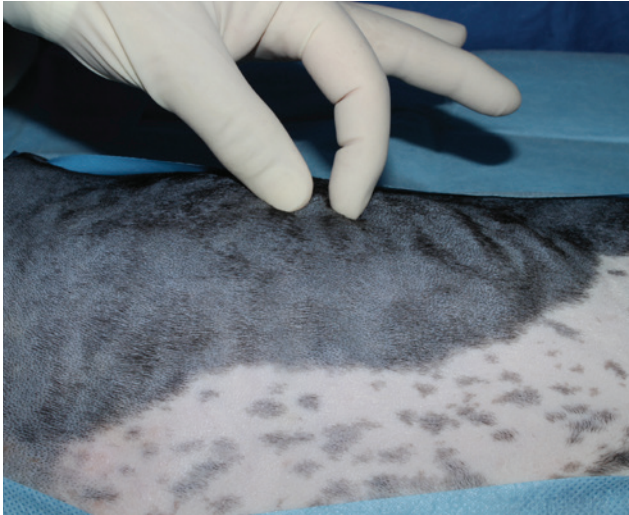
### Lateral thoracotomy

Indications for lateral thoracotomy include unilateral disease, biopsy or removal of lung lobes on one side, access to the oesophagus, access to the thoracic duct, ligation of the patent ductus arteriosus, division of the ligamentum arteriosum, and access to the heart and pericardium. The intercostal space is chosen depending of the location of the target organ (table 1).

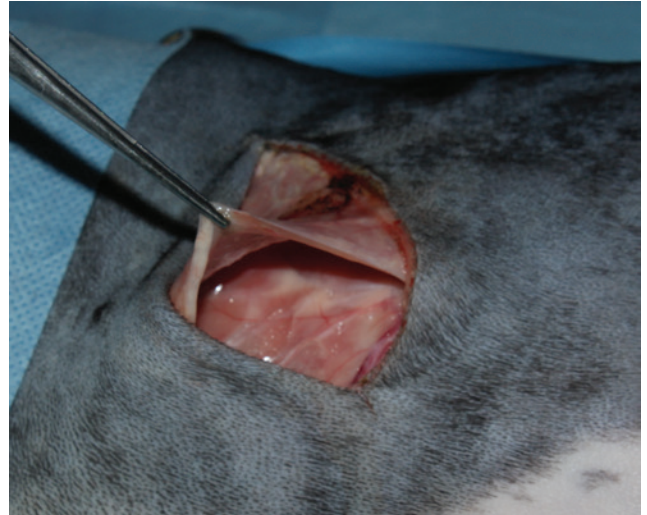
Table 1. Recommended approaches to the thorax

Target organ/Procedure	Conventional surgical approach	Thoracoscopic approach
<b>Trachea</b>	Right 3rd to 4th intercostal space	
<b>Patent ductus arteriosus</b>	Left 4th intercostal space	Left lateral
<b>Ligamentum arteriosum</b>	Left 4th intercostal space	Left lateral
<b>Lung lobectomy</b> Cranial Middle Caudal Accessory	Right or left 5th intercostal space Right 5th intercostal space Right or left 5th intercostal space Caudal sternotomy or right 6th intercostal space	Right or left lateral
<b>Pericardectomy</b>	Right or left 5th intercostal space or caudal sternotomy	Paraxiphoid transdiaphragmatic
<b>Oesophagus</b> Cranial Caudal	Right or left 4th intercostal space Right or left 9th intercostal space	Right or left lateral
<b>Thoracic duct</b> Dog Cat	Right 10th intercostal space Left 10th intercostal space	Right lateral (and left) Left lateral
<b>Mediastinal mass</b>	Median sternotomy	Paraxiphoid transdiaphragmatic
<b>Pyothorax</b>	Median sternotomy	Paraxiphoid transdiaphragmatic





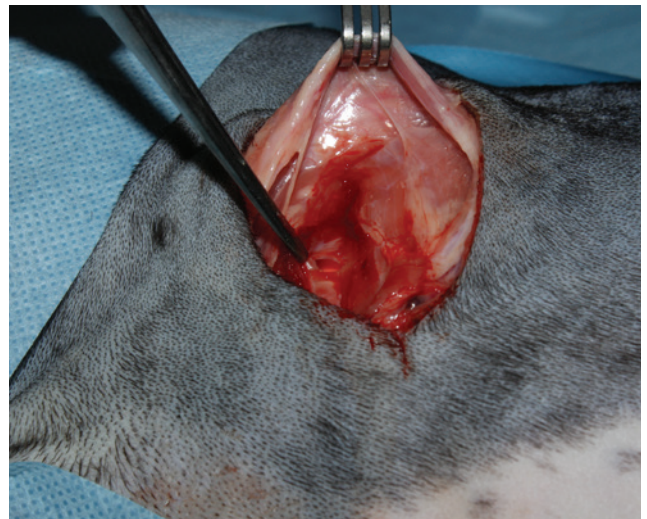
*Fig.1. A 3-month-old Brittany spaniel with a patent ductus venosus is positioned in right lateral recumbency. The intercostal spaces are counted backwards from the 12th to the 4th.*



*Fig.2. The latissimus dorsi muscle has been dissected from the surrounding tissues and elevated to be retracted dorsally.*



*Fig.3. The latissimus dorsi muscle is retracted dorsally with a Senn retractor. The caudal insertion of the scalenus muscle on the 5th rib is pointed out with DeBakey tissue forceps.*



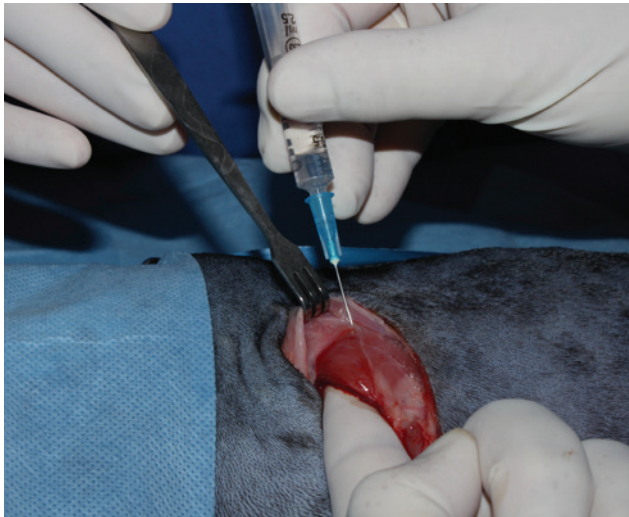
*Fig.4. The pleura has been punctured and collapsed lungs can be identified through the small hole which is pointed out with DeBakey tissue forceps.*

The animal is placed in lateral recumbency with his forelimb tied cranially. To determine the location of the skin incision, the intercostal spaces are counted backwards from the 12th until you reach the site of surgery (fig.1). The skin is incised vertically along the intercostal space. The cutaneous trunci muscle is incised. The subcutaneous tissue and latissimus dorsi muscle are dissected. The tissue underlying the latissimus dorsi muscle is bluntly dissected using fingers or a swab (fig.2), then the muscle is retracted dorsally using an Army-Navy retractor or the muscle can be divided.

To check the location of the intercostal incision, the surgeon can slide a finger cranially under the latissimus dorsi muscle until the first rib is located and then count the ribs or the intercostal spaces. An alternative landmark is the caudal insertion of the scalenus muscle, which is

on the 5th rib (fig.3). The scalenus muscle is incised over the intercostal space. The serratus ventralis muscle is split between its muscle bellies, a branch of the intercostal artery may bleed and should be coagulated. The external then internal intercostal muscles are carefully incised, followed by the pleura (fig.4). An intercostal nerve block is then performed two to three ribs cranial and caudal to the intended incision (see analgesia section) (fig.5). A moist abdominal swab can be placed on each side of the chest to protect the intercostal muscles and ribs. A Finochetto rib retractor is placed and the ribs are spread. In small dogs and cats Weitlaner retractors can be used instead of Finochetto. Increased exposure can be gained by sectioning the cranial or caudal rib at its centre. Chest wall retraction using a Finochetto retractor has been associated with severe postoperative pain because





*Fig.5. Same dog as in figures 1-4. The intercostal nerve block is performed. The left index finger of the surgeon is placed in the thoracic cavity to feel the correct position of the needle caudal to the rib.*

of the non-selective pressure applied to ribs and nerves. A smart robotic rib retractor, which is able to sense the forces on the muscles and ribs and adjusts the retraction rather than applying non-specific forceful retraction may be available for companion animals in the near future<sup>[25]</sup>. The cranial or caudal lung lobe (after dissection of the pulmonary ligament connecting the caudal lung lobe to the mediastinum) can be packed in a moist swab to facilitate visualisation of the underlying structures.

#### Closure:

The thorax is lavaged with warm saline, being careful to avoid causing marked general atelectasia of the lungs<sup>[26]</sup>. The lungs are inspected for re-inflation and leakage. A thoracic drain is placed.

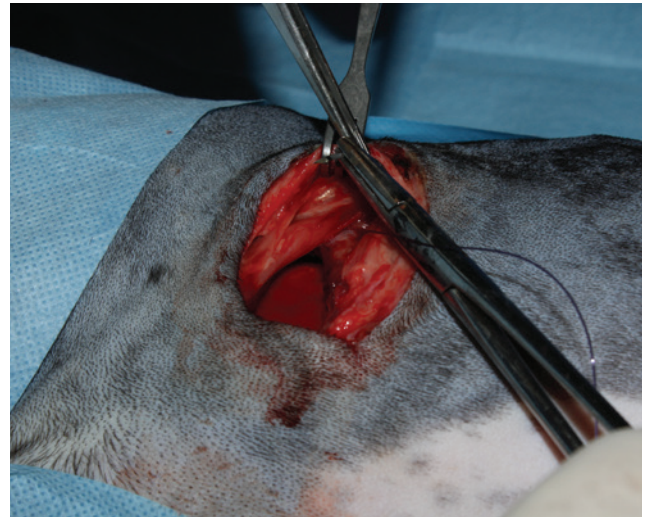
Four to six circumcostal sutures of 4 to 3.5 (Metric) polydioxanone are preplaced, the needle being passed around the rib during expiration, as close as possible to the rib, and using the blunt end of the needle to avoid damaging the neurovascular bundle (fig.6 and 7). The serratus ventralis and scalenus muscles are repaired using a continuous suture pattern. The latissimus dorsi is sutured back to the subcutaneous tissue. The cutaneous trunci and skin are sutured routinely.

### Median sternotomy

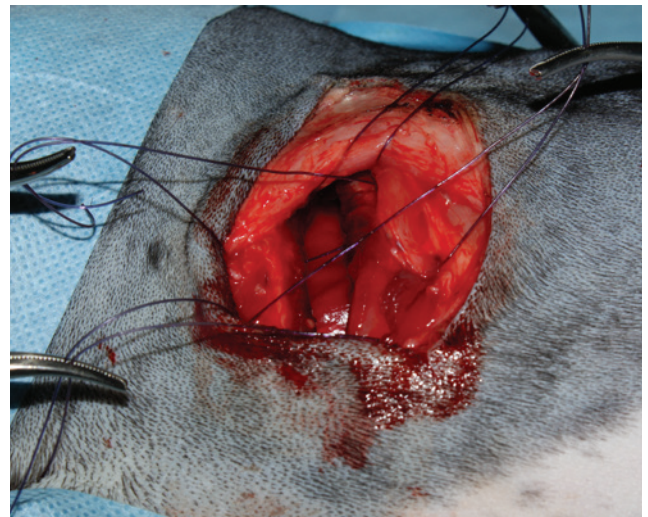
Indications for median sternotomy include exploratory thoracotomy, pyothorax, spontaneous pneumothorax in dogs, and mediastinal mass (thymoma, etc).

The animal is placed in dorsal recumbency with the fore limbs tied loosely caudally.

A ventral midline skin incision is made over the sternum.



*Fig.6. Using the blunt end of the needle, a circumcostal suture is preplaced. The needle is passed around the rib during expiration as close as possible to the rib.*



*Fig.7. Four circumcostal sutures have been preplaced and are placed alternatively on each side of the incision.*

The subcutaneous tissue is dissected using electrocautery, the pectoral muscles are separated in the midline until the sternbrae are reached. Haemorrhage from the perforating vessels from the internal thoracic artery and vein are controlled using cautery. The sternbrae are scored midline using electrocautery or a scalpel blade to prevent the oscillating saw from sliding off the midline (fig.8). The sternbrae are cut using an oscillating saw. To limit bone movement in the healing phase, the first or last sternbra is kept intact depending on the site of the surgical procedure. A moist swab is placed over the sectioned sternbrae on each side of the chest, the Finochetto retractor is placed and the sternum opened (fig.9).

The internal thoracic artery and vein, and the cranial vena cava should not be damaged during intrathoracic dissection.

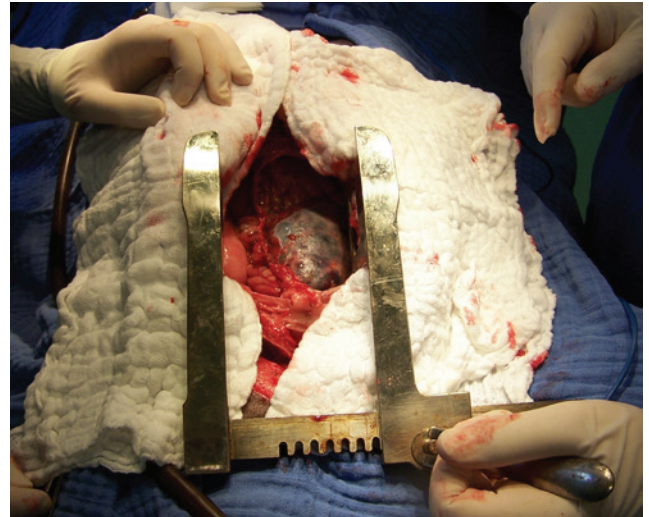




*Fig.8. A cat in dorsal recumbency undergoing a cranial median sternotomy. The oscillating saw is positioned in a small groove created with electrocautery on the midline of each sternebra.*

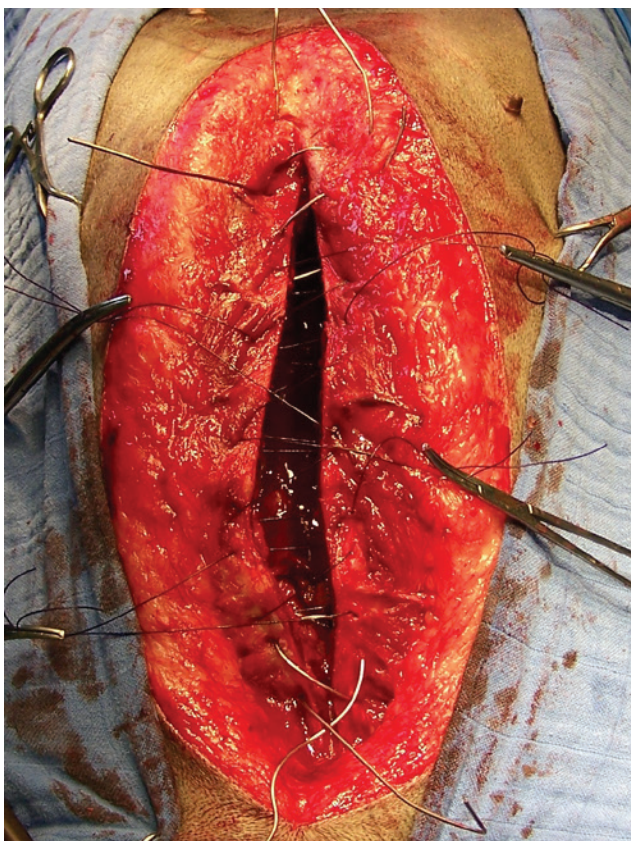
#### Closure:

The thorax is lavaged with warm saline (marked lung atelectasia should be avoided [26]). The lungs are inspected for re-inflation and leakage. A thoracic drain is placed. Cruciate sutures of stainless steel wire (>10kg) or 3.5 (Metric) polypropylene or polydioxanone (<10kg) are used to close the sternum [27]. Sternotomy sites that are closed



*Fig.9. Moist laparotomy sponges have been placed on the cut sternebrae and the blades of the Finochetto rib spreader are open.*

with wire tend to be more stable but it takes longer to place compared with suture material [28]. Each suture is preplaced between two sternebrae incorporating the costal cartilage (fig.10). An assistant places traction on the suture to facilitate knot tying. The pectoral muscles are reaposed in a single layer using a continuous absorbable suture. The subcutis and skin are sutured in a routine manner.



*Fig.10. A combination of cruciate wires and 4 Metric polydioxanone have been preplaced around the sternebrae to close the median sternotomy.*

### Thoracoscopy

Thoracoscopy is easy to perform because there are few organs to manipulate and because pneumothorax is easy to induce by placing trocars. Thoracoscopy has many advantages over open thoracotomy. The magnification and intense lighting provide excellent visualisation of lesions, including those that are submacroscopic [29]. Thoracoscopy is associated with decreased postoperative pain, fewer wound complications, and a more rapid return to function compared with open thoracotomy [12, 30]. Indications include thoracic exploration, pericardial window [30-32], subtotal pericardectomy [32, 33], lung, lymph node, and mesothelial biopsy, lung lobectomy, thoracic foreign body removal, and thoracic duct occlusion.

Thoracoscopy can be performed via either a transdiaphragmatic paraxiphoid or a lateral intercostal approach. Specific port sites have been described for some standard procedures [29, 34], but sites are usually chosen on a case-by-case basis [35].

The transdiaphragmatic paraxiphoid approach enables visualisation of both hemithoraces. The animal is placed in dorsal recumbency. A skin incision is made between the last rib and the left of the xiphoid process. A haemostat is used to widen the hole and penetrate the pleura. A screw-



in cannula is inserted cranially from a subxiphoid position until it penetrates the thoracic cavity; the thoracoscope is then passed through it. Under direct visualisation, the first instrument portal can be placed intercostally into one hemithorax, the caudal mediastinum is opened using sharp dissection. The second port is placed in the opposite hemithorax. They are placed according to the location of the lesions that require exploration or treatment. If the patient is placed in lateral recumbency, an intercostal telescope portal can be established in a similar manner. Ports are placed in the intercostal spaces following the principles of triangulation with the telescope placed centrally facing the operative target and instrument ports placed cranially and bilaterally [24, 36]

#### Closure:

Before closure the cavity is flushed and suctioned. A thoracic drain is placed under thoracoscopic guidance; it should not be placed through an existing portal site because it will be difficult to achieve an airtight seal<sup>[35]</sup>. One or two interrupted sutures or an X suture in the intercostal musculature are usually necessary in the portals; the skin and subcutaneous tissue are closed routinely. If there is a significant defect in the chest wall, circumcostal sutures may be placed, however, this is rarely necessary.

## Where do you start with thoracic surgery?

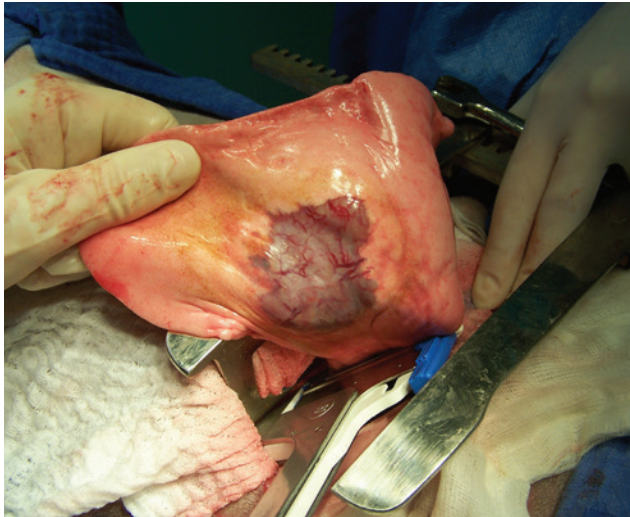
To improve familiarity with open chest surgery and intermittent positive-pressure ventilation, the surgeon should be comfortable with diaphragmatic rupture repair surgery. This provides the opportunity to anaesthetise an unstable patient, evaluate lung ventilation with direct visualisation of the lungs, monitor the animal, recreate negative pressure in the thoracic cavity, and evaluate pain in the post-operative period.

The first and most common surgery to perform is a full or partial lung lobectomy. The standard approach is via a lateral intercostal incision (see table 1) (except for blebs or bullae resection) and automatic stapling is used for ligation. Once the lateral approach has been mastered, the surgeon can attempt a median approach for exploratory thoracotomy for pyothorax and spontaneous pneumothorax. The thoracic cavity should be meticulously explored for foreign bodies and/or lung lesions. The exploration of penetrating thoracic wounds is also fairly straightforward, bearing in mind that the thoracic lesions are always underestimated before surgery. When the surgeon is comfortable with these

surgeries, they can attempt patent ductus venosus ligation or ligamentum arteriosum ligation and section. If the instrumentation is available and surgical training completed, thoracoscopy is a very rewarding technique. Biopsies and partial pericardectomy are easy to perform via a paraxiphoid transdiaphragmatic approach. More advanced surgeries such as thymoma removal, surgical treatment of chylothorax, oesophageal surgery, and chest wall tumour removal and reconstruction should be referred to a more experienced specialist.

## Lung lobectomy

Indications for lobectomies via a lateral approach include pulmonary neoplasia, consolidated lung lobe, abscesses, and lung lobe torsion. Lung lobectomy is performed by dividing the pulmonary vessels and over-sewing the lobar bronchus or using a stapling device (TA or GIA). The pulmonary artery is exposed by sharp and blunt dissection, triple ligated with two encircling and one transfixing suture, and transected. The lobe is retracted dorsally to allow access to the pulmonary vein on the ventral side of the bronchus. The vein is exposed, ligated with two encircling ligatures, and transected. The main bronchus is dissected from the remaining tissue. The bronchus is clamped and transected. Interrupted, non-absorbable, horizontal mattress sutures are placed and tied; a simple continuous suture pattern is used to over-sew the mucosa and cartilage on the distal end of the bronchus<sup>[10]</sup>. An automatic stapling device can be used to save time; the TA-55 with 3.5 mm staples will produce 2 rows of staples, 55 mm long with a 3.5 mm thickness. EndoGIA 45 mm cartridge and 3.5 mm staples will produce 4 rows of staples and cut the tissue in the middle of the rows. There is no need to oversee staple lines when performing a partial lobectomy. If point areas of leakage do occur, these can be independently occluded with either sutures or individual vascular clips<sup>[37]</sup>. Selecting the correct TA stapler and staple size to create the correct length of staple line is critical. It is important that all of the tissue to be ligated lies comfortably within the staple line. It is better to use a stapler that is too long and collect the extra staples on a sponge than to use one that is too short resulting in leakage from unstapled tissue (fig.11). The TA 55 and 60 with 3.5-mm staples are usually the staplers of choice. The absence of reported clinical complications, either short- or long-term, attests to the success of these techniques<sup>[38]</sup>. Experience in the use of the equipment is essential; this can be gained by performing liver lobectomies<sup>[39]</sup>. After removal, the remaining bronchus and vessels should

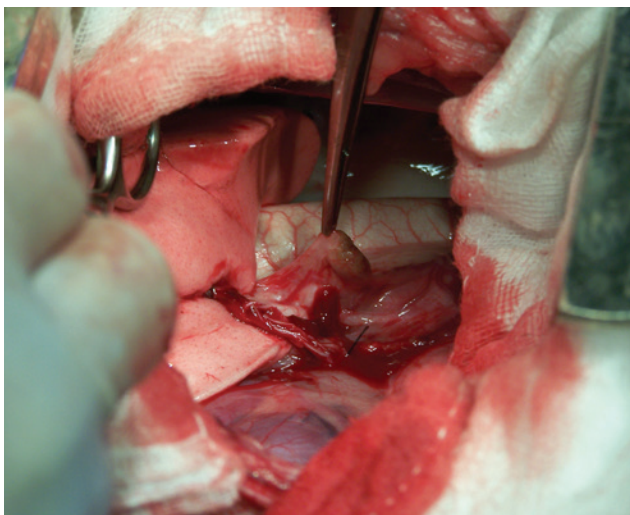


*Fig.11. A TA 60 stapling instrument was placed around the base of the lobe at the hilus away from the mass. The approximating lever has been depressed, compressing the parenchyma between the anvil and the 3.5 staple cartridge.*

be checked for leaks. To check the bronchus, the chest is flooded with saline and positive pressure breath is applied. A chest drain is placed after lung lobectomy prior to closure of the thoracotomy.

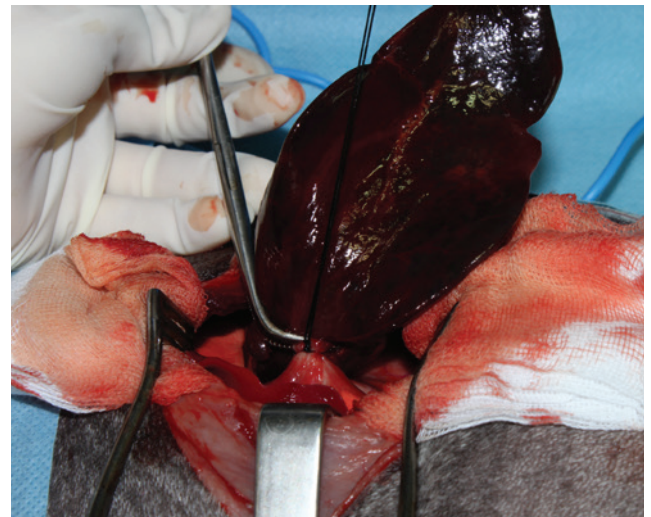
Peripheral lesions are easier to remove than those closer to the hilus as visualisation of the base of the lung lobe will be impaired. Sudden removal of more than 60% of pulmonary artery outflow is fatal in a normal dog, but usually the disease process induces a slow and progressive reduction of lung function, so that pneumonectomy of the entire left side or right side is feasible in dogs and cats [10, 40-42].

When lung neoplasia is suspected, a tracheobronchial lymph node should be exposed and biopsied for histopathology (fig.12).



*Fig.12. The suture line is checked for leakage. One of the tracheobronchial lymph nodes has been dissected and is elevated with DeBakey tissue forceps.*

Lung lobe torsion occurs when a lung lobe rotates around its longitudinal axis, resulting in twisting of the bronchus and the pulmonary vessels at the hilus. It is a rare condition that has been reported in dogs and cats; predisposed breeds include pugs and deep-chested dogs such as Afghan Hounds. In dogs, the right middle lobe has been reported as the most commonly affected; in Pugs, the left cranial lung lobe is usually involved. Untwisting the lobe and attempts to preserve the lobe are not recommended because of the risk of moving fluid into the other bronchi and drowning the patient and due to the risk of reperfusion injury and initiation of the inflammatory cascade [10, 43-46]. Clamping the pedicle and removing the lobe is sometimes easier than positioning the stapler device with the dilated congested lung lobe in place. Once it has been removed, en bloc sutures or staples can be used to seal the stump (fig.13).

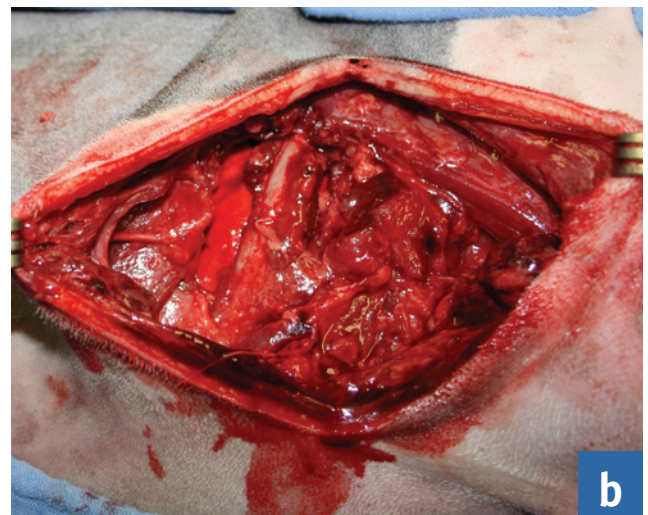


*Fig.13. Right middle lung lobe torsion in a 2-year-old Whippet. Right-angled forceps have been positioned at the base of the twisted hilus and en bloc ligation with a 3.5 Metric silk suture has been placed.*

### Partial lung lobectomy

Partial lung lobectomies are usually performed for peripheral non-neoplastic lesions of the lung parenchyma such as pulmonary blebs or bullae or lung lacerations. Primary spontaneous pneumothorax develops from the rupture of pulmonary bullae or blebs without underlying disease [47, 48]. They are usually in the periphery of the lobe. A median sternotomy is preferred because it allows evaluation of all lung lobes. Immersion of the lung lobes in saline can help to localise the affected lobe. A partial or complete lobectomy is performed. Partial lobectomy is easier with a stapling device (TA or GIA) than with manual sutures.





*Fig.14 a and b. Thoracic bite wound in an 8-year-old male Jack Russell Terrier. The right side of the chest has been clipped and two wounds are visible (a). Exploration of the thoracic bite wound shows severe muscle damage, a partially denuded rib and penetration in the thoracic cavity (b).*

### Thoracic trauma

Chest trauma is classified as penetrating or non-penetrating. Non-penetrating trauma is usually treated medically, even for flail chest. Flail chest results from the segmental fracture and/or dislocation of two or more adjacent ribs. Common injuries associated with flail chest include pulmonary contusions (most common), subcutaneous emphysema, and pneumothorax. Pulmonary contusions result in decreased pulmonary compliance, decreased ventilation, and shunting, all of which cause hypoxaemia. Surgical splinting is no longer indicated as the pain experienced during respiration results in a decreased cough reflex, inadequate ventilation, hypoxaemia, and atelectasis. The treatment of flail chest should therefore be focused on the underlying intra-thoracic injuries (pulmonary contusions), pain management, and oxygen support<sup>[49, 50]</sup>. Penetrating thoracic injuries such as bite wounds should be explored surgically; they are usually accompanied by severe damage to the internal organs or thoracic wall<sup>[51]</sup> (figs.14a and 14b). Radiology of thoracic bite wounds tends to underestimate thoracic lesions, therefore for optimal management these wounds should be explored surgically<sup>[52]</sup>. On admission, and when surgery cannot be carried out in the same practice, the chest wounds should be clipped, cleaned, and covered with a sterile occlusive bandage to prevent further air leakage during the pre-operative period, hospitalisation, or transport; then, thoracocentesis is performed to restore thoracic negative pressure<sup>[53]</sup>. Once stable, the animal is anaesthetised and the chest is widely clipped and scrubbed for surgery. The lesions encountered are usually much wider and deeper than expected<sup>[52]</sup>; the skin wounds are only “the tip of the iceberg”. Devitalised

tissue (skin, connective tissue, muscle, bone, lung parenchyma) are excised, the surgical site is copiously lavaged, and chest and sub-cutaneous drains are placed. The thorax is reconstructed by simple approximation of the remaining healthy tissue where possible. For wider defects, the chest wall can be reconstructed with a latissimus dorsi muscle or myocutaneous flap<sup>[2-5, 7-9]</sup>, deep pectoral flap<sup>[5]</sup>, or diaphragmatic advancement<sup>[1-6]</sup>. Omental pedicle flaps can also be used to reinforce the reconstruction and to drain a potentially infected site<sup>[54]</sup>. The omentum is passed through a small incision in the diaphragm or in the abdominal wall at the costo-abdominal junction. The use of prosthetic mesh is not recommended in a potentially infected surgical site<sup>[8]</sup>.

### Pyothorax

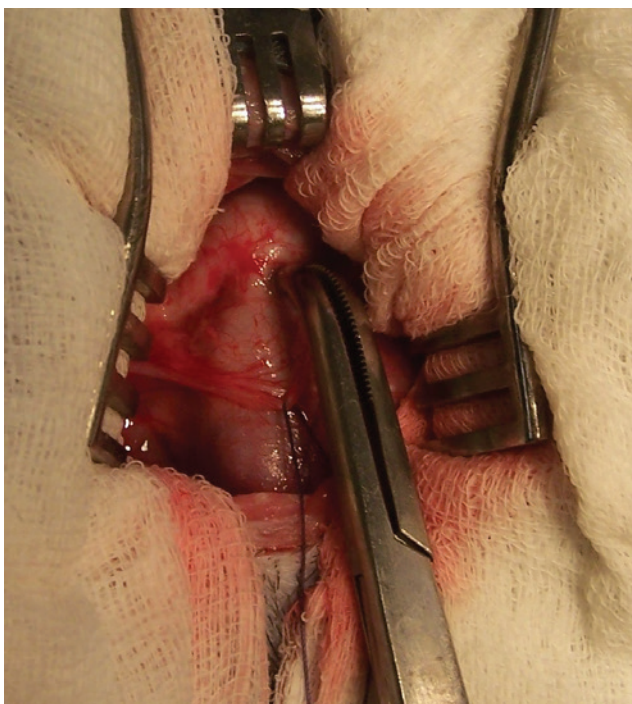
Pyothorax is a very debilitating disease and aggressive medical care is mandatory before any surgical intervention. If indicated, surgical treatment demands experience and a high level of skill. In cats, pyothorax is considered to be a medical rather than surgical disease<sup>[55,56]</sup>. Exploratory thoracotomy via a median sternotomy (or thoracoscopy) is recommended when medical management has failed, which is reported to be 5–14% of cases<sup>[57-60]</sup>. In dogs, the management of pyothorax is medical and/or surgical<sup>[61-64]</sup>. Surgical exploration via a median sternotomy (or thoracoscopy) is recommended in the presence of mediastinal or pulmonary lesions<sup>[60, 61]</sup>, failure of medical management after 4 days of treatment<sup>[60, 61]</sup>, and in the presence of *Actinomyces*<sup>[61]</sup>. The aims of exploratory thoracotomy in such cases are to identify and remove any foreign bodies, remove isolated areas of necrotic tissue including grossly abnormal lung lobes, break down fibrinous or fibrous adhesions that



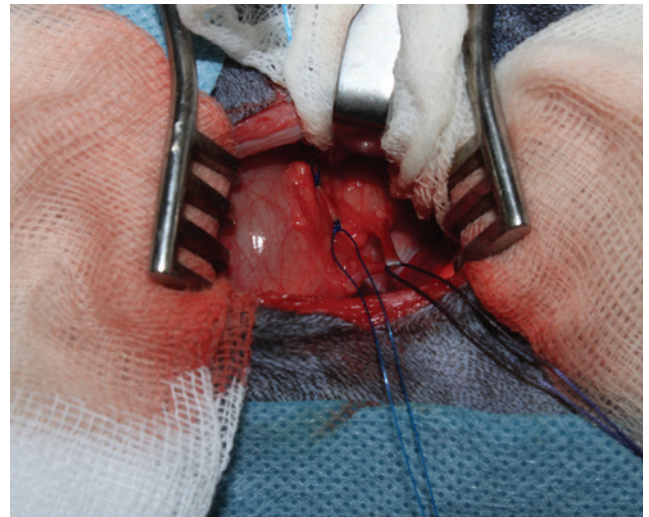
may be isolating areas of the thoracic cavity, ensure proper lavage of the entire thoracic cavity, and position bilateral thoracostomy tubes <sup>[56, 62]</sup>.

### Patent ductus arteriosus ligation and ligamentum arteriosum ligation and section

Standard surgical correction to left-to-right patent ductus arteriosus is accomplished by ligation of the ductus arteriosus. The left vagal nerve runs over the ductus arteriosus and serves as an anatomic landmark for its identification <sup>[64]</sup>; it is dissected and retracted. The ductus venosus is then isolated by careful blunt dissection using right-angled forceps without opening the pericardium <sup>[64]</sup> (fig.15), or using an intra-pericardial technique by opening the mediastinum, pleura, and pericardium ventrally and parallel to the vagal nerve <sup>[65]</sup>. Care should be taken not to rupture the ductus venosus or the pulmonary artery during dissection of the vessel. Two heavy silk (size 4 metric) ligatures are passed around the ductus using right-angled forceps. The sutures are tightened slowly. Once the surgical dissection of the ductus venosus has been mastered, it becomes a very quick and rewarding surgery. The surgical approach to the ligamentum arteriosum is the same and the dissection is easier as the ligament is tougher than the patent ductus arteriosus and longer due to it being elongated by the distended oesophagus. The ligament is dissected, double ligated, and sectioned to free the oesophagus (fig.16). Surgical treatment of persistent right aortic arch with a left ligamentum arteriosum also



*Fig.15. Caudal dissection with right-angled forceps of a patent ductus arteriosus in a 4-month-old Welsh Corgi.*



*Fig.16. Left lateral view at the 4th intercostal space of a ligamentum arteriosum in a 2.5-month-old French Bulldog presenting with a persistent right aortic arch. Two 2 Metric polypropylene sutures are placed on the ligamentum arteriosum. The dilated oesophagus is visible cranially to the ligament on the left hand side.*

includes transection of the perioesophageal fibrous bands. The long-term outcome has been reported to be good to excellent in 87% of survivors <sup>[66]</sup>.

### Thoracoscopy

If the instrumentation is available at the practice, exploratory thoracoscopy is straightforward. A paraxiphoid transdiaphragmatic approach is performed; the mediastinum is pierced with Metzenbaum scissors to expose both sides of the thorax. Exploration should be thorough and systematic. The diaphragm, mediastinum, chest wall, lung lobes, pericardium, lymph nodes, great vessels, oesophagus, and epicardium can be visualised <sup>[36]</sup>. Appropriate biopsies can then be taken. Performing a pericardial window is possible once the surgeon has become confident with thoracic triangulation. The cranial mediastinum is explored for lymph-node enlargement, and biopsies taken if necessary. Once both hemithoraces have been examined, a second instrument port is established at the fourth to sixth intercostal space on the contralateral side. Babcock forceps or aggressive grasping forceps with teeth are used to grasp and elevate a fold of pericardium, and Metzenbaum scissors are used to incise the fold for initial penetration of the pericardium. The graspers are repositioned to lift one margin of the initial pericardial incision. Any remaining excess pericardial fluid is removed to improve visibility. The pericardial incision is extended with electrocautery or a vessel sealing device to remove a segment of pericardium, taking care not to damage the phrenic nerves, heart, lungs, or great vessels <sup>[31, 33, 34]</sup>. A 4x4 cm window is recommended. This

technique dramatically improves quality of life and allows very rapid recovery and early patient discharge compared to thoracotomy <sup>[12]</sup>.

## Other surgeries

More complex surgeries or techniques that the surgeon is unfamiliar with should be referred to a specialist practice. Thymomas can be tricky to remove if they do not shell out, surgical treatment of chylothorax can be challenging and requires a combination of several techniques (pericardectomy, thoracic duct ligation, cisterna chyli ablation, and/or thoracic omentisation), chest wall tumour removal can involve massive reconstruction and post-operative care, and oesophageal rupture repair is associated with high a complication rate.

## Post-operative management

The early post-operative period after thoracic surgery is critical and patients should be carefully monitored for respiratory and cardiovascular failure. Oxygen supplementation may be required during recovery from the anaesthetic. Hypothermia should be prevented or treated by use of forced-air warming intra- and post-operatively.

Thoracic drains should be placed after thoracotomy and thoracoscopy to empty the pleural space of blood, air, pleural effusion, and lavage solution to re-establish thoracic negative pressure. The thoracic drain is maintained for at least 12 to 24 hours after surgery. The drain is suctioned every hour until three negative results have been obtained. The pleural space is then aspirated every four hours for 12 hours. If the drain remains non-productive, it is removed. Well-balanced analgesia after surgery is mandatory to minimize the negative effects of each analgesic and maximize ventilation (see protocols in the section on analgesia, above).

Most animals are eating and on oral analgesics within 48-72 hours following open thoracic surgery <sup>[11]</sup>.

## Complications

Perioperative death or euthanasia is reported in 13% to 22% of animals undergoing thoracotomy <sup>[67-69]</sup> and in 5.9% to 13% excluding euthanasia <sup>[69, 70]</sup>. Survival is lower in cats than in dogs <sup>[69]</sup>. The most common cause of death is euthanasia because of the disease; other causes of

death include haemorrhage, cardiopulmonary arrest, and postoperative pneumothorax. Non-survival at 24 hours post-operatively is associated with the more complex and longer surgeries <sup>[70]</sup>. There is an increased risk of negative outcome with oesophageal surgery <sup>[67, 69, 70]</sup>, neoplastic disease <sup>[68, 69]</sup>, and chylothorax <sup>[70]</sup>. Congenital cardiac diseases such as patent ductus arteriosus and persistent right aortic arch are associated with a positive outcome <sup>[68-70]</sup>.

Complications are reported in 0% to 78% of cases following thoracotomy <sup>[68, 69, 71]</sup>. Wound complications occur in 22% to 71% and are usually minor (e.g. seroma, oedema, swelling, wound discharge, incisional dehiscence) <sup>[67-69, 71]</sup>. Wound complications are significantly higher in dogs undergoing median sternotomy compared with lateral thoracotomy <sup>[68, 69]</sup>. Thoracic drain complications occur in 5% to 23% of cases and more frequently when the drain is maintained for a longer period of time (e.g. pyothorax, chylothorax) <sup>[68, 69]</sup>. Other complications include transient iatrogenic chylothorax, unstable sternbrae repair, thoracic limb neurological deficits <sup>[71]</sup>, and generalised atelectasia after thoracic lavage <sup>[26]</sup>. Long-term complications occur in 5% to 22% of dogs and include wound complications, haemorrhage, sternal fracture, sternal osteomyelitis, rib fracture, oesophageal stricture, pyothorax, and delayed wound healing <sup>[69, 71, 72]</sup>. Postoperative pyothorax develops in 6.5% of thoracic surgeries and this complication resulted in death in 66.7% of cases in one study <sup>[72]</sup>. Cats seem to suffer fewer complications than dogs <sup>[71]</sup>. Specific complications of thoracoscopy include iatrogenic damage to viscera (lungs and heart), vessel laceration (intercostal and internal thoracic vessels), portal site seroma formation, and tumour seeding at portal sites <sup>[35, 73, 74]</sup>. There is also a case report of accidental entrapment of an endobronchial blocker in a staple line during selective ventilation for lung lobectomy <sup>[75]</sup>.

## Conclusion

Thoracic surgery is not as complex as it is often made out to be. Selected simple surgeries can be carried out with minimal complications. The surgeon must have good basic knowledge of anatomy, surgical approaches, and open-thorax anaesthesia. Particular attention to perioperative analgesia and postoperative care is essential for a successful outcome to thoracic surgery.

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## Commissioned paper

# Current anaesthetic considerations and techniques in rabbits

## Part I: Pre-anaesthetic considerations and commonly used analgesics and anaesthetics

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### SUMMARY

Rabbit anaesthesia is perceived by many as a difficult, high-risk procedure. Many veterinarians therefore do not feel comfortable when having to sedate or anaesthetize a rabbit. Fortunately, the arrival of newer, safer anaesthetic agents, development of specialized anaesthetic equipment, and increased knowledge about veterinary anaesthesia has greatly reduced the risks of anaesthesia-related morbidity and mortality. In particular the use of endotracheal tubes or supraglottic airway devices, administration of intra-operative fluids and provision of adequate thermal support, combined with adequate and continued monitoring of the patient are important to prevent potentially fatal conditions such as hypoxia, hypovolaemia and/or hypo- or hyperthermia. Vigilant monitoring of the patient should, however, not only be limited to the anaesthetic procedure, but also extend to the pre- and post-anaesthetic period, in which a thorough evaluation of the patient may help to detect pre-existing conditions or post-anaesthetic complications that need to be dealt with in order to maximize chances of success. Various injectable and inhalant anaesthetics, premedicants and analgesics may be combined to achieve a balanced anaesthesia which minimizes the chances of adverse events. The first part of this review discusses the various aspects that need to be taken into consideration during the pre-anaesthetic evaluation as well as the most commonly used analgesics and anaesthetics in rabbit medicine.

Keywords: Rabbit; *Oryctolagus cuniculi*; Anaesthesia; Analgesia; Sedation; Premedication

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### Introduction

Pet rabbits may easily be stressed when handled. A period of prolonged, repetitive and/or forceful handling may therefore quickly lead to a deterioration of the rabbit's clinical condition, especially if it already was sick or

debilitated prior to the restraint. In addition, incorrect handling and/or vigorous kicking or struggling by the rabbit in an attempt to escape may result in serious injuries such as vertebral fractures, (sub)luxations and (permanent) damage to the spinal cord<sup>[1,2]</sup>. Correct handling is therefore essential for the wellbeing of the rabbit. To facilitate the safe performance of medical procedures such as blood collection, IV catheter placement, radiography and dental inspections, the use of sedatives and/or anaesthetic agents may be beneficial.

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Sedatives may furthermore be useful to reduce anxiety or stress related to medical conditions. For example, the use of the sedative midazolam may be beneficial in dyspnoeic rabbits as the drug will help the animal relax, thereby allowing it to breathe more easily and with less effort and increasing the efficacy of oxygen delivery into the deeper airways [3]. For diagnostic procedures, such as ultrasound, radiographs or computed tomography, a deeper type of sedation is possible by adding other sedatives such as butorphanol and combining this with inhalant drugs such as isoflurane. For more invasive procedures, such as orthopaedic or soft tissue surgeries, general anaesthesia is required with more analgesic properties. This can be achieved using (a combination of) injectable and/or inhalant drugs.

In particular anaesthesia for exotic species carries substantial risks and both peri- and postoperative complications commonly occur. Rabbits in particular prove difficult to safely sedate or anaesthetise, especially because of their relative sensitivity to the respiratory depressant effects of many anaesthetics and the required experience needed for proper intubation [4,5]. A study by Brodbelt (2008) among veterinarians across the UK revealed a significantly higher risk for peri- or post-anaesthetic death for rabbits (1.39%) compared to dogs or cats (0.17 and 0.24%, respectively), with more than one-third (36%) of patients dying during the procedure [6,7]. In addition, the study revealed that the risk of mortality is approximately ten times higher for a sick rabbit compared to a healthy individual (7.37 versus 0.73%) [6,7]. Factors which may contribute to the rabbit's overall higher susceptibility to anaesthesia-related morbidity and mortality include a) the increased susceptibility to stress from loud noises; the unfamiliar surroundings; and sight, smell or sound of predators, which may predispose to development of cardiac arrhythmias; b) the increased susceptibility to effects of pain after surgery, which may result in reduced appetite and gastric stasis; c) quick development of hypoxia due to breath holding, respiratory depression and the relative small lung capacity in combination with the increased difficulty to intubate; d) relative difficulty to gain intravenous access, particularly in smaller breeds, which limits the ability to correct fluid and/or electrolyte imbalances during anaesthesia; and e) the presence of pre-existing (subclinical) disease (e.g. dental disease, pneumonia, gastric stasis) [8,9].

To reduce the risk of anaesthesia-related morbidity and mortality, preventive measures may be taken. These include: a) performing a preoperative clinical assessment

of the health status of the patient and optimizing the patient's clinical condition prior to the procedure; b) use of an anaesthetic protocol tailored to the individual patient, with a particular emphasis on provision of sufficient analgesia; c) [endotracheal] intubation to guarantee oxygen suppletion and enable assisted breathing if needed; d) placement of an intravenous or intraosseous catheter for the administration of fluids and drugs; and e) continued monitoring of vital signs, both during the intervention and follow-up period [8]. The first part of this review will focus on the various precautions and considerations that should be taken into account during the pre-anaesthetic evaluation and induction of anaesthesia.

## Pre-Anaesthetic Considerations

Prior to performing a procedure involving anaesthesia, a thorough history and physical examination should be performed to assess the animal's overall health (Figure 1a – d). Particularly in prey species such as rabbits, it may be difficult to identify presence of (subclinical) disease as the animal often tries to hide that it is sick and may not show any signs of disease unless it is severely debilitated. Particularly diseases involving the respiratory tract, which may manifest itself by coughing, sneezing, nasal discharge (which can also be found at the medial side of the front paws), increased respiratory sounds and/or changes in breathing pattern or frequency, may pose an increased anaesthetic risk [8,10]. Other diseases or conditions that affect the animal's ability to withstand anaesthesia include diseases of the digestive tract (e.g. anorexia, dental disease, gastric stasis and/or diarrhoea) and cardiovascular system (e.g. dehydration and/or shock) as well as obesity or cachexia [8,10,11]. Based on the findings during the clinical and diagnostic work-up, patients may be classified as ASA-I to ASA-V according to their fitness prior to surgery (Table 1). Whenever possible, the patient's clinical condition should be stabilized prior to commencing anaesthesia, e.g. by providing subcutaneous, intravenous or intraosseous fluid therapy to dehydrated or hypotensive patients, oxygen to dyspnoeic patients and/or nutritional support to anorectic rabbits.

During the physical exam, care should also be taken to obtain an accurate weight, which is required to calculate the dosages of fluids and/or drugs that are used during the procedure. In the waiting period prior to the anaesthesia, and in the post-anaesthetic period, prey species such as rabbits should be hospitalized in a quiet environment, away from potential predators (e.g. dogs, cats, ferrets).



Figure 1a. The pulse in rabbits can be taken at the central ear artery (*A. auricularis*). This artery is located on the outer surface of the pinna.



Figure 1c. The conjunctival mucous membranes can be examined by everting the upper and lower eyelids.



Figure 1d. Auscultation of the lung and heart is an essential part of the preanaesthetic exam.



Figure 1b. The oral mucous membranes can be inspected by slightly raising the upper lip. Care must be taken not to occlude the nostril, as this compromises breathing and may therefore be stressful to the rabbit.

Table 1. ASA physical status classification system<sup>[12]</sup>

ASA class	Description
I	Normal, healthy patient
II	Patient with mild systemic disease, without functional limitations
III	Patient with moderate systemic disease, with functional limitations
IV	Patient with severe systemic disease that poses a constant threat to life
V	A moribund patient who is, with or without intervention, not expected to survive anaesthesia and will most likely die within 24 hrs

Provision of hiding boxes, bedding and nesting materials, or social housing may provide additional security. Since rabbits are not able to vomit, pre-anaesthetic fasting is not required. Withholding food for periods of 1-2 hours is, however, recommended to ensure that the oral cavity is empty<sup>[8,9]</sup>. Water should be provided at all times. Pre-oxygenation may be considered prior to induction of anaesthesia as this will help to improve oxygen saturation, which is particularly useful in animals with cardiac or respiratory disease and/or when using drugs that induce (temporary) apnoea, such as alphaxalone or propofol.

## Sedation and premedication

Administration of sedatives may be beneficial in patients that need to undergo procedures such as radiography,

IV catheter placement or blood collection. Sedatives may furthermore alleviate anxiety and reduce stress, thereby facilitating facemask induction and avoiding breath holding in response to the smell of inhalant anaesthetics, while at the same time also allowing reduction of the amount of administered anaesthetic drugs helping to minimize the risk of detrimental side effects to the anaesthesia and allowing smooth recovery from anaesthesia. Before administering the drugs, the calculated dosages should always be checked carefully and adjusted to the patient's clinical condition. For example, sick, debilitated rabbits may need lower doses of the same drug compared to healthy, young rabbits presenting for an elective procedure.

Midazolam, a short-acting benzodiazepine, is commonly used to facilitate diagnostic procedures (e.g. radiography,

Table 2. Commonly used drugs for premedication in rabbits<sup>[9,16]</sup>

Drug	Dose	Effects
<b>Acepromazine</b>	0.25-1 mg/kg IM	Phenothiazine derivative, tranquilizer, moderate sedation, no analgesia, hypotension, hypothermia
<b>Atropine</b>	0.1-0.5 mg/kg SC, IM	Parasympatholytic drug, reduces salivary bronchial secretions, protects the heart from vagal stimulation. Note: some rabbits possess atropinesterase which deactivates the above described activities. Glycopyrrolate is therefore preferred over atropine in rabbits
<b>Butorphanol</b>	0.1-1 mg/kg SC, IM, IV q4-6h	$\kappa$ -agonist, sedation, analgesia, dose-dependent respiratory depression
<b>Butorphanol / midazolam</b>	0.3-0.5 mg/kg (B) + 0.1-0.5 mg/kg (M) SC, IM	Commonly used combination for sedation and/or premedication in rabbits
<b>Chlorpromazine</b>	1-10 mg/kg IM, IV	Phenothiazine derivative, tranquilizer, moderate sedation, no analgesia, hypotension, hypothermia
<b>Dexmedetomidine</b>	0.20-0.35 mg/kg SC, IM, IV	$\alpha_2$ -receptor agonist, sedation, some analgesia, respiratory depression, peripheral vasoconstriction, bradycardia, cardiac arrhythmias
<b>Diazepam</b>	1-2 mg/kg IM, IV	Benzodiazepine, tranquilizer, sedation and muscle relaxation, no analgesia
<b>Glycopyrrolate</b>	0.01-0.1 mg/kg SC, IM	Parasympatholytic drug, reduces salivary and bronchial secretions, protects heart from vagal stimulation
<b>Medetomidine</b>	0.20-0.35 mg/kg SC, IM, IV	$\alpha_2$ -receptor agonist, sedation, some analgesia, respiratory depression, peripheral vasoconstriction, bradycardia, cardiac arrhythmias
<b>Midazolam</b>	1-2 mg/kg SC, IM, IV, IP	Benzodiazepine, tranquilizer, sedation and muscle relaxation, no analgesia
<b>Morphine</b>	2-5 mg/kg SC, IM	$\mu$ -agonist, sedation, analgesia, dose-dependent respiratory depression
<b>Xylazine</b>	1-5 mg/kg SC, IM	$\alpha_2$ -receptor agonist, sedation, some analgesia, respiratory depression, bradycardia, cardiac arrhythmias

IM = intramuscular; IP = intraperitoneal; IV = intravenous; SC = subcutaneous



ultrasonography) and will provide effective sedation for approximately one hour<sup>[13]</sup>. As midazolam and other benzodiazepine tranquilizers (diazepam, zolazepam) have minimal cardiorespiratory side effects, these drugs are considered relatively safe, even in critically ill patients. Midazolam may also be combined with a variety of other drugs, including ketamine, medetomidine and opioids such as buprenorphine, butorphanol and fentanyl<sup>[14-16]</sup>. A commonly used combination of sedatives that is used for premedication in rabbits includes midazolam (0.1-0.5 mg/kg SC, IM) and butorphanol (0.3-0.5 mg/kg SC, IM), which provides both muscle relaxation and analgesia (Table 2). Other tranquilizers that may be used as premedicants for anaesthesia or as a single drug for sedation to perform non-invasive procedures such as venepuncture include phenothiazine derivatives (e.g. acepromazine, chlorpromazine) and  $\alpha_2$ -adrenergic agonists (xylazine, medetomidine, dexmedetomidine; Table 2). Phenothiazine

derivatives have excellent sedative and muscle relaxing properties, but also result in marked peripheral vasodilation due to their  $\alpha$ -adrenergic blockage, which can lead to hypotension and hypothermia, particularly in smaller-sized rabbits<sup>[17]</sup>. Due to these effects, the authors do not recommend the use of these agents in smaller exotic patients. Should they be used, careful monitoring of the rabbit's body temperature is warranted.  $\alpha_2$ -adrenergic agonists, in particularly medetomidine, are commonly employed as premedicants due to their sedative, muscle relaxing and analgesic properties and may be used alone or in combination with other drugs (e.g. ketamine, propofol, midazolam) to provide surgical anaesthesia<sup>[17]</sup>. Following administration, a marked peripheral vasoconstriction and bradycardia may be noted, as well as a respiratory depression and increased risk of developing cardiac arrhythmias (particularly in higher dosages). To reverse the effects of the  $\alpha_2$ -agonist, the  $\alpha_2$ -antagonist

Table 3. Commonly used analgesics in rabbits

Drug	Dose	Effects
<b>Acetylsalicylic acid</b>	10-100 mg/kg q8-24h PO	Salicylate drug, anti-inflammatory, antipyretic, analgesic
<b>Bupivacaine</b>	1 mg/kg	Local anaesthetic for infiltrative, epidural, nerve block and intrathecal administration
<b>Buprenorphine</b>	0.01-0.05 mg/kg q6-12h SC, IM, IV, IP	Partial $\mu$ -agonist; properties with regard to $\kappa$ -receptor (agonist/antagonist) less well-defined; post-anaesthetic analgesia
<b>Butorphanol</b>	0.1-1 mg/kg SC, IM, IV q4-6h	$\kappa$ -opioid receptor agonist, sedation, analgesia, dose-dependent respiratory depression
<b>Carprofen</b>	2-4 mg/kg q12h PO	NSAID, anti-inflammatory, antipyretic, analgesic
<b>Fentanyl</b>	30-100 $\mu$ g/kg/min CRI	$\mu$ -receptor agonist, analgesia, dose-dependent respiratory depression
<b>Ketamine</b>	2-20 $\mu$ g/kg/min CRI	NMDA-receptor antagonist, mediation of sensitization of pain
<b>Ketoprofen</b>	1-3 mg/kg q12-24h SC, IM	NSAID, anti-inflammatory, antipyretic, analgesic
<b>Lidocaine</b>	2-4 mg/kg	Local anaesthetic for infiltrative, epidural, nerve block and intrathecal administration
<b>Meloxicam</b>	0.3-1.0 mg/kg q24h PO	NSAID, anti-inflammatory, antipyretic, analgesic A recent study showed doses of 1 mg/kg q24h PO did not result in detrimental effects when given for a period of 30 days.
<b>Morphine</b>	2-5 mg/kg q2-4h SC, IM	$\mu$ -receptor agonist, analgesia, dose-dependent respiratory depression
<b>Piroxicam</b>	0.2 mg/kg q8h PO	NSAID, anti-inflammatory, antipyretic, analgesic
<b>Tramadol</b>	11 mg/kg q12h PO	$\mu$ -opioid receptor agonist, mainly used in the treatment of chronic pain Note: dose did not result in adequate plasma concentrations based on human data

CRI = constant rate infusion; IM = intramuscular; IV = intravenous; IP = intraperitoneal; PO = per os; SC = subcutaneous;

atipamezole may be administered in doses varying from 1-5 times the medetomidine/dexmedetomidine dose<sup>[18]</sup>. Anticholinergic drugs, including atropine and glycopyrrolate, are not routinely used as premedicant in rabbits but may be used in patients that develop bradycardia due to vagal stimulation. In addition, they may help to reduce salivary and bronchial secretions that can occlude the airway, although it should be taken into account that the viscosity of these secretions may increase following administration of these drugs<sup>[19]</sup>. As many rabbits possess atropinesterase, which degrades atropine into inactive products<sup>[20,21]</sup>, glycopyrrolate is usually the anticholinergic drug of choice.

## Analgesia

One of the main goals of anaesthesia is to prevent the animal from sensing pain. In addition analgesics may be used to provide pain relief post operatively and/or given pre-emptively, prior to the procedure, which may result in more effective pain management and helps to lower the amount of anaesthetics required during the procedure<sup>[22]</sup>. For these reasons, pre-emptive analgesia should be considered an important part of the anaesthetic regimen for any animal undergoing a procedure that may result in pain. Analgesic drugs can be divided into different groups, each exerting their own action on the peripheral and central nervous systems. The most commonly used analgesics include local anaesthetics, non-steroidal anti-inflammatory drugs (NSAIDs) and opioid drugs (Table 3).

### Local anaesthetics

Local anaesthetics such as lidocaine and bupivacaine provide regional anaesthesia by reversibly blocking the transmission of nociceptive signals from nerve endings to the central nervous system<sup>[23,24]</sup>. They can be used topically, via direct infiltration into soft tissue containing nerve endings, intra-articularly, intravenously, or epidurally<sup>[25]</sup>. EMLA cream, a topical preparation containing 2.5% lidocaine and 2.5% prilocaine, is particularly useful for application to the ear and provides sufficient anaesthesia to prevent the rabbit from shaking its head in response to venepuncture or catheter placement in the marginal ear vein. The cream may, however, take up to 60 minutes to take effect<sup>[26]</sup>. When administering local anaesthetics, care should always be taken to prevent administration of toxic dosages, particularly in small animals, because of potential cardiovascular side effects.

## NSAIDs

NSAIDs are a class of drugs that have analgesic, antipyretic and anti-inflammatory effects. Within the veterinary field, they are the most frequently used drugs for pain relief as they are effective for both acute and chronic pain<sup>[22,23]</sup>. They exert their mode of action through inhibition of cyclooxygenase (COX), thereby reducing the production of pro-inflammatory cytokines and increasing the threshold for activation of peripheral nociceptors<sup>[27]</sup>. Over the years, many different NSAIDs have been used for analgesia in rabbits, including ketoprofen, meloxicam and carprofen. Meloxicam, a COX-2 selective inhibitor, is among the most commonly used NSAIDs of this era, primarily because of its ease of use, overall good palatability and relative safety with fewer side effects. Based on clinical experience, meloxicam appears safe for short-term administration. Long-term administration of NSAIDs, however, may lead to renal papillary necrosis, gastrointestinal ulcerations and/or toxicity<sup>[27]</sup>. As to date no studies have been performed on the efficacy and safety of long-term treatment with NSAIDs (>30 days), it is advisable to periodically collect blood and monitor plasma liver enzymes, urea and creatinine levels in patients that are in need of prolonged treatment with NSAIDs<sup>[22,23]</sup>.

## Opioids

Opioids or narcotic analgesics are psychoactive chemicals that resemble morphine and interact with opioid receptors, which can be found in the central, and peripheral nervous system and the gastrointestinal tract. Opioids produce a variety of effects dependent on the type of receptor that is stimulated. Their analgesic effects are mainly the resultant of stimulation of the  $\mu$ -receptors, which are primarily responsible for supraspinal analgesia, or stimulation of the  $\kappa$ -receptors, which are mainly responsible for spinal analgesia<sup>[22,23,28]</sup>. Opioids do not only provide a decreased perception of and reaction to pain, but also prevent sensitization that may develop from continued nociceptive stimulation<sup>[28]</sup>. They can thus be employed both in the pre-, intra- and post-anaesthetic phase. Opioids may, however, also produce less desirable side effects such as respiratory depression, constipation, sedation, euphoria or dysphoria, hallucinations, and physical dependence. These effects may be antagonized by administration of a  $\mu$ -antagonist such as naloxone<sup>[28]</sup>.

The affinity for the different receptors varies among the different opioids. Based on their affinity to the different receptors they may be classified as mixed agonist-antagonists, partial agonists, pure agonists, and pure

antagonists. For example, morphine is a full  $\mu$ -agonist, whereas butorphanol and buprenorphine, the most commonly used analgesics in rabbits, are mixed agonist/antagonist. Butorphanol is classified as a  $\mu$ -agonist, with primary affinity to the  $\kappa$ -receptor; buprenorphine, in contrast, is classified as a partial  $\mu$ -agonist with less well-defined characteristics with regard to the  $\kappa$ -receptor. As a result, both may be used for mild to moderate pain. Because of its longer half-life, buprenorphine is mostly used in the post-anaesthetic phase, whereas butorphanol also has some sedative properties and is therefore mainly used in the pre-anaesthetic phase<sup>[22,23,28-30]</sup>.

### Ketamine

Ketamine is a dissociative drug that is primarily used for the induction and maintenance of general anaesthesia. It has, however, also been shown to act as an analgesic due to its antagonist effect on the excitatory N-methyl-D-aspartate receptors in the CNS, which mediate sensitization to pain<sup>[31]</sup>. It may thus be of use on patients with chronic pain syndromes, and also appears useful to augment intra- and post-operative analgesia when administered as a constant rate infusion (CRI)<sup>[21,22,32]</sup>.

### Tramadol

Tramadol is a weak  $\mu$ -opioid receptor agonist, a serotonin releaser and a reuptake inhibitor of norepinephrine, which is metabolized by the liver into O-desmethyltramadol, a significantly more potent  $\mu$ -opioid agonist<sup>[32]</sup>. Tramadol has become increasingly popular in veterinary medicine to use as an analgesic agent for treatment of mild to severe chronic pain. Studies on the pharmacokinetics of tramadol in rabbits after both oral and intravenous administration have shown that dosages up to 11 mg/kg orally resulted in plasma levels below those that are considered analgesic in people<sup>[33]</sup>. Therapeutic plasma levels in the rabbit are, however, currently not known and although tramadol anecdotally has been used in the management of chronic pain, further studies are needed to determine the effective dose and dosing interval. Furthermore the drug appears to be extremely unpalatable when compounded, thereby necessitating the use of strong flavouring agents to increase palatability and acceptance of the drug<sup>[22,23]</sup>.

## Injectable Anaesthetics

A great variety of different injectable anaesthetics are available for use in rabbits, which can be administered via

the subcutaneous (SC), intramuscular (IM), intravenous (IV) or intraosseous (IO) route (Figure 2a – e; Table 4). A variety of factors have contributed to the overall popularity of these agents, including their ease of use, overall reasonable to good predictability and efficacy, and avoidance of the more expensive and technically-demanding inhalant anaesthesia. Compared to these inhalant anaesthetics, however, they allow less control over depth and duration of the anaesthesia, necessitating redosing and/or higher doses to accomplish anaesthesia of longer duration on the one hand, but offering little to no opportunity to shorten or reverse the anaesthesia because of the limited availability of antidotes. Because of this, use of injectable anaesthetics will more quickly lead to development of undesired physiologic side-effects (especially in animals with impaired liver or kidney function) and/or longer recovery times compared to inhalant anaesthetics. Thus, in general it is advisable to reserve the use of injectable anaesthetics for procedures that will maximally last 30-60 minutes.

### Alphaxalone-alphadolone

Alphaxalone-alphadolone is a neurosteroid anaesthetic agent that is registered for use in dogs and cats, but has also been used in rabbits<sup>[34]</sup>. It is found to produce a light to medium depth anaesthesia over a short period of time, and can be given repeatedly and/or slowly to effect to obtain the desired plane and duration of anaesthesia. A dose of 2-3 mg/kg IV appears suitable to induce anaesthesia and perform endotracheal intubation in rabbits<sup>[35]</sup>. Alphaxalone/alphadolone in general provides good muscle relaxation, but has poor analgesic properties. The use of an additional analgesic is thus required. In higher doses, the drug may cause respiratory depression, apnoea and cardiac arrest, and is therefore not recommended for use in rabbits if intubating the rabbit is not possible<sup>[36]</sup>.

### Barbiturates

Although barbiturates have been used as anaesthetic agents in laboratory rabbits, their use is relatively uncommon in pet rabbits, mainly due to their small margin of safety<sup>[37]</sup>. Pentobarbitone in particular is known to cause respiratory depression and apnoea at levels that are extremely close to the levels that are needed to induce surgical anaesthesia<sup>[38]</sup>. Of the different barbiturates, the short-acting barbiturate thiopentone (also referred to as sodium thiopental) is occasionally used during the induction phase to facilitate endotracheal intubation<sup>[8,17]</sup>.



Table 4. Commonly used drugs for induction and maintenance of anaesthesia in rabbits

Drug	Dose	Effects
<b>Alphaxalone / alphadolone</b>	12 mg/kg IV	Neurosteroid anaesthetic; light to medium anaesthesia for 8-10 min duration, muscle relaxation, no analgesia, dose-dependent respiratory depression; doses of 2-3 mg/kg may be sufficient to enable endotracheal intubation in rabbits
<b>Fentanyl-droperidol (Innovar-vet®)</b>	1 mg/kg 0.02-0.05 mg/kg (F) + 1-2.5 mg/kg (D) SC, IM (0.2-0.4 ml/kg)	Commonly used combination for neuroleptanalgesia, provides anaesthesia of 30-60 min duration; give incremental doses of 0.1 ml/kg every 30-40 min to prolong anaesthesia; may cause respiratory depression and/or bradycardia
<b>Fentanyl-fluanisone (Hypnorm®)</b>	2-4 mg/kg q12h PO 0.075-0.16 mg/kg (Fe) + 2-5 mg/kg (Fl) SC, IM (0.2-0.5 ml/kg)	Commonly used combination for neuroleptanalgesia, provides anaesthesia of 30-60 min duration; may cause respiratory depression and/or bradycardia
<b>Halothane</b>	To effect; 3-4% induction, 1-2% maintenance; MAC = 1.39%	Inhalant anaesthetic; narrower margin of safety than isoflurane or sevoflurane; cardiovascular depression
<b>Isoflurane</b>	To effect; 3-5% induction, 1.5-3% maintenance; MAC = 2.05%	Inhalant anaesthetic; dose-dependent respiratory depression, less risk of cardiovascular side-effects than halothane
<b>Ketamine</b>	20-60 mg/kg IM, SC or 10-20 mg/kg IV	Dissociative agent, muscle rigidity, dose-dependent respiratory depression, tachycardia, hypotension; provides mild to moderate anaesthesia for approx. 20 min
<b>Ketamine / medetomidine</b>	5-15 mg/kg (K) + 0.15-0.35 mg/kg (M) SC, IM	Commonly used combination for injectable anaesthesia, provides surgical plane of anaesthesia for duration of 45-60 min. To prolong anaesthesia 1/3 of the original dose may be repeated
<b>Ketamine / medetomidine / butorphanol</b>	5-10 mg/kg (K) + 0.2-0.25 mg/kg (M) + 1 mg/kg (B) SC, IM	Commonly used combination for injectable anaesthesia; provides sufficient anaesthetic depth to intubate the rabbit; continue with isoflurane or sevoflurane to effect
<b>Ketamine / xylazine</b>	20-50 mg/kg (K) + 2.5-10 mg/kg (X) SC, IM	Combination that was used commonly in the past for injectable anaesthesia, provides surgical plane of anaesthesia for duration of 45-60 min
<b>Propofol</b>	2-15 mg/kg IV, slowly to effect	Short-acting hypnotic/amnestic agent used for induction of anaesthesia (5 min) to allow endotracheal intubation; dose-dependent respiratory depression and hypotension
<b>Sevoflurane</b>	To effect; MAC=3.7%	Inhalant anaesthetic; wide margin of safety
<b>Thiopentone</b>	15-30 mg/kg IV, give slowly to effect	Short-acting barbiturate, used for induction of anaesthesia (5-10 min) to allow endotracheal intubation; dose-dependent respiratory depression and hypotension

IM = intramuscular; IV = intravenous; MAC = minimal alveolar concentration; SC = subcutaneous

### Neuroleptanalgesic combinations

Of the different neuroleptanalgesic combinations, fentanyl-droperidol (Innovar-vet®, Janssen, Pharmaceuticals Inc, Beerse, Belgium) and fentanyl-fluanisone (Hypnorm®, VetaPharma Ltd, Leeds, UK) are the two most commonly used ones in rabbits [39,40]. The combination of fentanyl-fluanisone in particular appears useful in rabbits as it provides good analgesia (up to 3 hrs after administration) and can be used as premedicant or sedative.

In combination with a muscle-relaxing benzodiazepine (midazolam, diazepam) surgical anaesthesia of moderate duration can also be achieved [41]. Respiratory depression and bradycardia may occur, which are mainly attributed to the highly potent fentanyl present in the combination [42]. To reverse the respiratory depression, doxapram (a respiratory stimulant), naloxone (an opioid antagonist) and/or mixed agonist/antagonist opioids may be used [43].



Figure 2a. By lifting the skin over the thorax a subcutaneous (SC) injection can be given. A 22-gauge needle is used as smaller needles tend to bend when inserting these through the thick skin of rabbits.



Figure 2d. An intravenous (IV) injection can be given in the saphenous vein or in the marginal ear vein. In this figure the marginal ear vein is shown.



Figure 2b. An intramuscular (IM) injection can best be given in the M. longissimus dorsi.



Figure 2e. An intraosseous (IO) catheter can be placed in the proximal femur. This will not affect movement of the leg and does not pose a risk of entering the joint. Strict hygiene must be employed when placing the catheter. Providing fluids through an IO catheter is just as effective as through an IV catheter.



Figure 2c. An intravenous (IV) injection can be given in the saphenous vein or in the marginal ear vein. In this figure the saphenous vein is shown.

### Ketamine

Ketamine is the most widely used dissociative agent in rabbit anaesthesia. Although it may be used as a sole agent for induction and/or minimally invasive procedures, it is typically used in combination with other agents (e.g. xylazine, medetomidine) for induction and maintenance as it only provides limited muscle relaxation and analgesia <sup>[44]</sup>. Using these combinations, it provides a surgical plane of anaesthesia lasting for approximately 45-60 minutes. When administered as a single drug, ketamine has a sympathomimetic effect, resulting in an increase in heart rate, cardiac output and blood pressure <sup>[45]</sup>.

## Propofol

Propofol, an alkyl phenol agent, which is licensed for use in dogs and cats can also be used in rabbits to produce a deep sedation of rapid onset and short duration. Due to its short-lived effect (~5 min), recovery after propofol sedation is usually smooth and rapid. A dose of 5–14 mg/kg IV usually provides sufficient sedation to intubate the rabbit<sup>[46]</sup>. As the drug does not accumulate in the body, repeated administration and/or continuous rate infusion is possible<sup>[47,48]</sup>. Long-term administration may, however, induce hypoxia, hypotension and/or prolonged recovery; it is therefore mainly recommended for induction and/or use during short-term, minimally invasive procedures<sup>[47]</sup>. When administered in higher doses, transient apnoea and/or respiratory arrest may occur.

## Constant Rate Infusion

Constant rate infusion (CRI) is a technique with which opioids or ketamine are intravenously administered in a constant low dose<sup>[49]</sup>. The effects of lidocaine administration via CRI on reduction of the Minimum Alveolar Concentration (MAC) have also been studied. Unfortunately, results of this study have not been published yet<sup>[50]</sup>.

To reach effective plasma concentrations of the drugs, an initial loading dose needs to be given. After that, very low dosages can be given while still achieving a sparing effect on the inhalant anaesthetics needed. Slight changes in the dose rate can quickly result in changes in anaesthetic depth. The only potential disadvantage is that an intravenous (or intraosseous) access is needed in combination with an infusion pump to allow for a constant flow of administration. The great benefit of this multimodal approach is that side effects of each drug are so low that no clinical effect of the potential side effects is seen<sup>[49]</sup>.

## Inhalant anaesthetics

Although the use of inhalant anaesthetics requires more training and specific equipment, it generally does provide a more reliable and efficacious anaesthesia with excellent control over its depth and duration. In addition, induction and recovery are usually rapid. These features make inhalant anaesthetics particularly useful in exotic animal practice. The two most common agents currently used in practice include isoflurane and sevoflurane (Table 4). In the past, nitrous oxide (also known as laughing gas), was used as an adjunct to anaesthesia with other volatile

agents (e.g., halothane), but the arrival of newer, safer inhalant anaesthetics has limited its use in current practice. Nitrous oxide generally has good analgesic properties with minimal effects on the cardiovascular and respiratory system, and is particularly useful to reduce the amount of other inhalant anaesthetics in rabbits<sup>[8]</sup>. Long-term administration may, however, predispose to hypoxia and gastric and/or caecal dilation as the nitrous oxide may diffuse into the stomach and/or caecum<sup>[51]</sup>. Thus, it is recommended to limit its use to the induction phase of anaesthesia (in a 50/50 combination with 100% oxygen) and switch off the nitrous oxide as soon as a satisfactory plane of anaesthesia is reached.

Halothane is another volatile agent that was frequently used in the past, but has become more or less obsolete with the arrival of safer inhalant anaesthetics such as isoflurane and sevoflurane. All three allow good and rapid control over anaesthetic depth, but induction and recovery times are shorter with the latter two because of the relative low blood solubility. In addition, the latter two do not sensitize the heart to catecholamines, thereby posing less risk of development of hypotension or cardiac arrhythmias compared to halothane<sup>[52]</sup>. Isoflurane and sevoflurane are furthermore minimally metabolized in the liver, which renders them the preferable agents to use in rabbits with impaired liver and/or renal function<sup>[52]</sup>. In humans, the non-irritating properties of sevoflurane have rendered it particularly useful for facemask induction in children<sup>[53]</sup>. In rabbits, however, it was not found to prevent a breath holding response compared to isoflurane<sup>[54]</sup>. In addition, the high cost and need for special vaporizers have further prohibited its widespread use, still rendering isoflurane as the most commonly used inhalant anaesthetic in practice.

## Conclusions

Anaesthesia consists of 4 distinct but equally important periods, i.e. the pre-anaesthetic evaluation and premedication phase, induction, maintenance and recovery. Many veterinarians often tend to consider the first and latter phase to be less important, yet these contribute just as much to a successful anaesthesia as do the induction and maintenance phase. A proper patient preparation and evaluation allows veterinarians to take appropriate measures and select the most suitable anaesthetic protocol for the patient to minimize the risks of complications throughout the anaesthetic procedure. A multi-modal approach, in which a combination of anaesthetic and analgesic agents are combined, is



generally recommended as this helps to maximize the desired effects while minimizing side effects that may occur when using a single drug. Tranquilizers or sedatives are often included in such a protocol as these will help to prevent stress while also allowing a reduction in the dose of both induction and maintenance drugs. In addition, the provision of analgesics needs to be considered in any patient. Regardless of the choice of analgesics, three basic rules need to be taken into consideration: 1) analgesics preferably need to be administered prior to the painful stimulus (pre-emptive analgesia) thereby lowering the overall amount of anaesthetics required, ensuring that pain is controlled despite the anaesthesia wearing off, and preventing sensitisation of pain mechanisms; 2) preferably a combination of analgesics is used (multimodal analgesia); and 3) analgesia should be continued for as long as pain affects the quality of life of the patient.

During the induction, maintenance and recovery period, several other measures may also be taken to minimize risks involved with anaesthesia in rabbits. These aspects will be discussed in part II of this review.

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## Commissioned paper

# Current anaesthetic considerations and techniques in rabbits

## Part II: Induction, maintenance and the post-anaesthetic period

Yvonne van Zeeland<sup>1</sup> and Nico Schoemaker<sup>1</sup>

### SUMMARY

Rabbit anaesthesia is perceived by many as a difficult, high-risk procedure. Many veterinarians therefore do not feel comfortable when having to sedate or anaesthetize a rabbit. Fortunately, the arrival of newer, safer anaesthetic agents, development of specialized anaesthetic equipment, and increased knowledge about veterinary anaesthesia has greatly reduced the risks of anaesthesia-related morbidity and mortality. In particular the use of endotracheal tubes or supraglottic airway devices, administration of intra-operative fluids and provision of adequate thermal support, combined with adequate and continued monitoring of the patient are important to prevent potentially fatal conditions such as hypoxia, hypovolaemia and/or hypo- or hyperthermia. Vigilant monitoring of the patient should, however, not only be limited to the anaesthetic procedure, but also extend to the pre- and post-anaesthetic period, in which a thorough evaluation of the patient may help to detect pre-existing conditions or post-anaesthetic complications that need to be dealt with in order to maximize chances of success. Various injectable and inhalant anaesthetics, premedicants and analgesics may be combined to achieve a balanced anaesthesia which minimizes the chances of adverse events. The second part of this review discusses the various aspects that need to be taken into consideration during induction, maintenance and the post-anaesthetic period.

Keywords: Rabbit; *Oryctolagus cuniculi*; Anaesthesia; Intubation; Anaesthetic monitoring; Anaesthetic emergency

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### Introduction

As discussed in part I of this review, anaesthesia comprises of 4 distinct yet equally important phases, including the pre-anaesthetic evaluation and premedication phase, induction, maintenance and recovery. In part I, we focused

on the pre-anaesthetic considerations that need to be taken into account when anaesthetizing a rabbit, including the most commonly used analgesics and anaesthetic drugs that may be used when composing an anaesthetic protocol that is tuned to the individual patient. This second part will discuss the various aspects that need to be taken into account during induction, maintenance and recovery, including the provision of appropriate supportive care and peri- as well as post-anaesthetic monitoring of the rabbit patient.

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## Induction of general anaesthesia

Anaesthetic agents may be delivered topically (see part I 'local anaesthetics'), parenterally (see part I 'injectable anaesthetics') and/or via inhalation (see part I 'inhalant anaesthetics'). An anaesthetic protocol usually comprises of a combination of injectable and/or inhalant anaesthetics and/or premedicants (see part I 'sedation and premedication', 'injectable anaesthetics' and 'inhalant anaesthetics') and/or one or multiple analgesics (see part I 'analgesia'). To determine the optimum anaesthetic protocol, various factors need to be considered, including the clinical condition and stability of the patient, the practitioner's knowledge and experience with the various anaesthetic agents used including their side-effects, and options for monitoring and supporting the patient during the procedure<sup>[1]</sup>. Commonly used protocols include premedication with butorphanol and midazolam, followed by induction and maintenance with isoflurane or sevoflurane; induction with ketamine and medetomidine (+/- butorphanol) followed by inhalant anaesthesia<sup>[2,3]</sup>; and fentanyl/fluanisone combined with midazolam or diazepam followed by inhalant anaesthesia<sup>[4]</sup>. Total injectable anaesthesia is usually reserved for short diagnostic or surgical procedures, mainly because the rabbit's high metabolism results in short-lived effects, necessitating higher doses and/or frequent redosing thereby posing a higher risk for side-effects and/or prolonged recovery. This is less problematic when using inhalant anaesthetics, which can easily be titrated to effect and adjusted to the length of the procedure. Thus, most anaesthetic regimens in rabbits comprise of inhalant anaesthetics as their primary component. The induction is typically accomplished using a face mask (Fig. 1). In order to reduce resistance and avoid breath holding in response to the smell of anaesthetic vapours, premedicants can be administered<sup>[1,5]</sup>. Gradual introduction of the anaesthetic vapours ('low to high induction') may also help to avoid these reactions<sup>[5]</sup>.

After induction, the oral cavity should always be checked for the presence of food remnants, and cleaned with cotton swabs (Fig. 2), if necessary. Furthermore, sterile, ophthalmic ointment may be applied to the cornea to prevent desiccation and/or irritation. It is also recommended to provide oxygen to the animal during the induction and maintenance phase. Preferably, the animal is intubated using an endotracheal tube or supraglottic airway device to allow effective delivery of oxygen to the lower airways and manually- or mechanically-



*Figure 1. A regular anaesthesia cone can be used as a face mask. To reduce leakage of anaesthetic gases, the cone can be covered with latex of a glove to decrease the opening.*



*Figure 1. A regular anaesthesia cone can be used as a face mask. To reduce leakage of anaesthetic gases, the cone can be covered with latex of a glove to decrease the opening.*

assisted breathing, in case the rabbit stops breathing spontaneously (see intubation and oxygen delivery). In addition, the animal should be positioned carefully in such a way that the airway remains unobstructed at all times, and weight of the viscera is taken away from the diaphragm to allow easy breathing<sup>[5]</sup>.

## Intubation and oxygen delivery

Delivery of oxygen during the anaesthetic procedure is beneficial to any patient, independent of the anaesthetic protocol that is used. Oxygen may be delivered by facemask, through an endotracheal or nasal tube or supraglottic airway device. To be able to intubate a rabbit and place an endotracheal tube or supraglottic airway device, the rabbit should be sufficiently sedated. This can be accomplished using injectable anaesthetics that are administered either intravenously (e.g. propofol, alphaxalone) or intramuscularly (e.g. a combination

of ketamine and medetomidine and/or butorphanol), or following face mask induction with inhalant anaesthetics. The latter technique is not recommended as rabbits will start waking up as soon as the mask is removed and intubation may take some time. When using induction agents such as propofol or alfaxalone, care should furthermore be taken to avoid overdosing as this may lead to respiratory depression, apnoea and hypoxia if a patent airway cannot be accomplished quickly. In addition, the absence of breath sounds and condensation resulting from the respiratory depression may complicate blind intubation, as these parameters are often used as guidelines to evaluate if the tube is placed correctly.

### Face mask

Many veterinarians do not routinely intubate rabbits. Instead, injectable anaesthetics and/or a face mask are used for induction and/or maintenance of inhalant anaesthesia and/or oxygen delivery. Over the years, various types of facemasks have become commercially available. Preferably a tight-fitting facemask is used and placed over the mouth and nose (Fig. 1). For dental procedures, the facemask may also be placed solely over the nose. As rabbits are obligate nasal breathers, this will generally be sufficient to maintain anaesthesia when the rabbit is also premedicated. Care should, however, be taken to prevent the head being tilted into a vertical position, as this may result in the dislodgement of the epiglottis from the soft palate whereby the rabbit will start to breathe through the mouth and wake up.

Although tight-fitting facemasks allow some assisted breathing, this is generally insufficient to ensure a free airway and effective oxygen delivery to the lungs in case of respiratory arrest and/or airway obstruction. The facemask furthermore does not protect against aspiration of (regurgitated) food remnants that are present in the oral cavity or oesophagus, thereby posing a significant risk for morbidity and/or mortality. Moreover, the facemask can also have potential detrimental effects to the staff's health as a result of leakage of volatile anaesthetic gases (see Table 1 for a list of pros and cons of face mask anaesthesia).

### Endotracheal intubation

For maintenance of anaesthesia and assisted ventilation, endotracheal intubation is ideal. Although the technique is feasible in (larger-sized) rabbits, it is considered more difficult than intubating a dog or cat due to several anatomical features that hinder direct visibility of the larynx including a) the inability to open the mouth wide; b) the relative narrowness of the oral cavity and isthmus faucium; c) the relative large base of the tongue; d) the relative small size of the larynx; and e) the permanent positioning of the epiglottis on top of the soft palate. Endotracheal intubation may be accomplished either using a blind technique or by direct visualization of the larynx using a laryngoscope or endoscope. For both techniques, the rabbit is preferably placed in sternal recumbency, with the neck hyperextended in a vertical position, whereby the larynx and trachea are aligned with the oropharynx to facilitate intubation (Fig. 3)<sup>[6,7]</sup>. Local anaesthetics (e.g. xylocaine spray) may be applied prior to intubation to desensitize the larynx and prevent laryngospasm<sup>[7]</sup>. Care should furthermore be taken to ensure that the rabbit is adequately anaesthetized to prevent laryngospasm or



Figure 3. To allow tracheal intubation the nose of the rabbit needs to be directed dorsally to align the oropharynx with the larynx and trachea.

Table 1. Pros and cons of the use of a face mask to maintain anaesthesia

Advantages	Disadvantages
<ul style="list-style-type: none"> <li>• Easy to use</li> <li>• No airway irritation</li> <li>• Dental inspection is possible with the mask placed over the nose and incisors</li> </ul>	<ul style="list-style-type: none"> <li>• Leakage of anaesthetic gases (hazard for personnel)</li> <li>• Increase of dead space</li> <li>• Assisted breathing is (almost) impossible</li> <li>• No protection against aspiration</li> <li>• No protection against obstruction of the airways</li> </ul>



Table 2. Pros and cons of endotracheal intubation to maintain anaesthesia in rabbits<sup>[8,10]</sup>

Advantages	Disadvantages
<ul style="list-style-type: none"> <li>• Procedure can be performed relatively quickly with experience</li> <li>• No risk of aspiration of food</li> <li>• Ventilation is possible during breath holding</li> <li>• Free airway is guaranteed</li> <li>• Permits continuous administration of oxygen</li> <li>• Better control over depth of anaesthesia</li> <li>• Assisted breathing (incl. IPPV) is possible</li> <li>• Reduction of dead space</li> <li>• Virtually no leakage of anaesthetic gases</li> <li>• Suitable for surgery to the head (although dental inspection may be more difficult to perform)</li> </ul>	<ul style="list-style-type: none"> <li>• Technique requires experience</li> <li>• Deeper level of anaesthesia is often required</li> <li>• Risk of laryngeal spasm in insufficiently sedated animals</li> <li>• Increased risk of tracheal and/or laryngeal trauma (incl. oedema, haemorrhage, stenosis and/or strictures)</li> <li>• Risk of obstruction due to increased mucus production</li> <li>• Risk of introducing foreign bodies (especially with blind intubation)</li> <li>• Possibility of incorrect intubation (into oesophagus, bronchi)</li> <li>• Post-anaesthetic reaction to tube placement (including coughing, gagging, reduced appetite)</li> </ul>

damage to the larynx and pharynx which may subsequently result in haemorrhage, oedema and (post-anaesthetic) stenosis and strictures (Table 2).

Blind intubation, which requires some practice and experience, is generally accomplished by positioning the rabbit in the aforementioned position and advancing the tube through the diastema over the tongue into the oropharynx. At this point, it is possible to see cyclic condensation and clearing in the endotracheal tube and/or hear breath sounds, which become louder when the tube is passed into the region of the larynx. If it passes beyond the larynx into the oesophagus, breath sounds and condensation cease to appear. Once it has been ascertained that the position of the tip of the tube is in front of the larynx (i.e. maximum breathing sounds are heard), the tube can gently and slowly be advanced into the larynx. Gentle rotation (without force!) may help to guide the tip between the arytenoids. Passing of the tube into the larynx and trachea may elicit a slight wheeze or cough. Condensation, breath sounds or capnography can subsequently be used to check correct positioning prior to securing the tube in place with adhesive tape or gauze ties. In general, a 2.5 to 4.0 ID (inner diameter) uncuffed endotracheal tube can be used to intubate rabbits<sup>[5]</sup>. In case the first attempt is unsuccessful, the use of a smaller tube can be considered.

For laryngoscope- or endoscope-assisted intubation, the procedure is more or less similar<sup>[1,5,7]</sup>. An assistant may help to position the head and hold the mouth open using gauze strips, or, alternatively, a mouth gag may be used for this purpose. A laryngoscope or otoscope may subsequently be used to visualize the glottis and facilitate intubation<sup>[1,5,7]</sup>. Alternatively, the endotracheal tube may be placed over the end of a rigid endoscope. The soft palate may need to be pushed away with the tip of the endotracheal

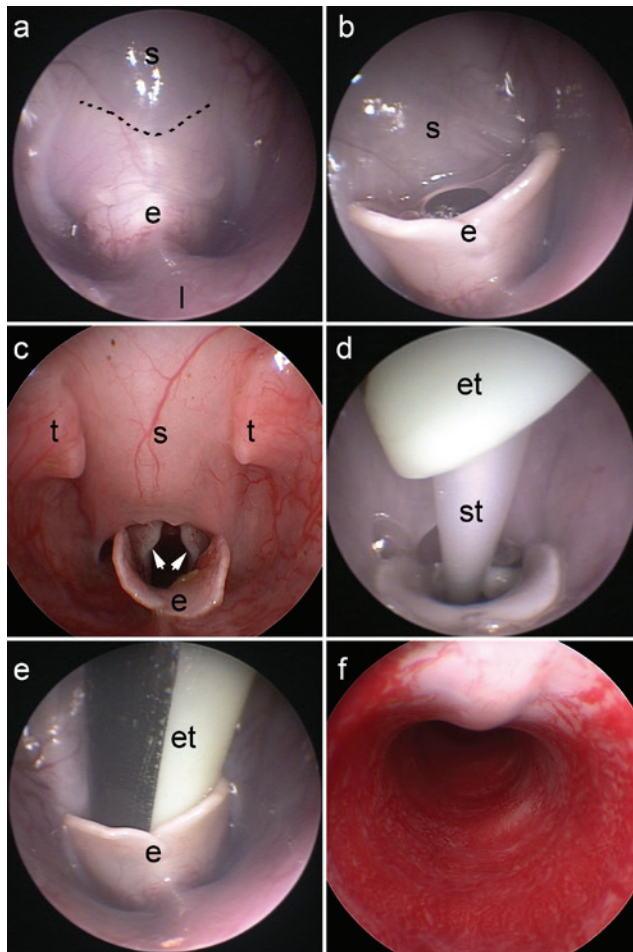
tube or endoscope before being able to visualize the entrance to the larynx and the tube can be passed carefully into the trachea (Fig.4 and 5)<sup>[11,12]</sup>.

A small gauge urinary catheter (2-5 Fr), threaded through the tube prior to inserting it into the larynx, or specially designed introducers may also be used as a guiding tool to facilitate intubation<sup>[13,14]</sup>. The main advantages of



Figure 4. By inserting an endoscope in the endotracheal tube and directing the endoscope into the trachea, visual placement of the tube into the trachea is easily accomplished.





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Figure 5. Rabbit laryngotracheoscopy and intubation.

**a.** View of the normal larynx in the nasal breathing rabbit. Note that the epiglottis (e) at the base of the tongue (l) is buttoned over the caudal edge of the soft palate (s). The cranial edge of the epiglottis can be seen through the semitransparent caudal soft palate (dotted line).

**b.** By placing gentle dorsal pressure on the anaesthetised rabbit it is easy to disengage the cranial edge of the epiglottis (e) from the soft palate (s). If the rabbit is semi-conscious then swallowing quickly re-engages the epiglottis and soft palate.

**c.** View of the larynx in an anaesthetized rabbit, after dorsal displacement on the caudal soft palate has disengaged the epiglottis. The freed epiglottis (e), arytenoid cartilages (arrows), caudal soft palate (s) and tonsils (t) are visible.

**d.** Intubation in a rabbit using side by side endoscopic guidance. An endotracheal tube (et) and stylet (st) have been introduced into the caudal buccal cavity. The stylet is first directed through the glottis under endoscopic (or laryngoscopic) view to act as a guide for the endotracheal tube.

**e.** Intubation in a rabbit using side by side endoscopic guidance. The endotracheal tube (et) is then advanced along the stylet, over the epiglottis (e) and into the trachea.

**f.** Intubation in a rabbit using over the endoscope technique. The endotracheal tube is slid up the endoscope, before the endoscope is passed through the glottis and into the anterior trachea. Once a clear view of the trachea has been obtained, as shown, then the endotracheal tube is advanced off the endoscope and into the trachea, as the endoscope is withdrawn.

visualization compared to blind intubation are the decreased risk of trauma and the ability to estimate more accurately which size tube to use, thereby enabling use of larger-sized tubes and considerably reducing the resistance during respiration.

Alternative to endotracheal intubation, nasal intubation may be attempted, in which the tube is passed into the ventral nasal meatus. Small soft nasogastric tubes or 1.0–1.5 mm endotracheal tubes are considered suitable for this purpose [5]. In order to enable successful delivery of the anaesthetics, high flow rates are required. This technique may be particularly useful in small rabbits which are difficult to intubate endotracheally. It is also possible to advance an endotracheal tube through the nasal passages and pharynx into the trachea, but this poses a risk of introducing pathogens (e.g. *Pasteurella multocida*) from the nasal cavity into the deeper airways [15].

### Supraglottic airway devices

Supraglottic airway devices, also referred to as laryngeal masks, are the latest devices used for the delivery of volatile anaesthetics. Rather than being passed through the glottis, a supraglottic airway device resides on top of the

larynx, thereby posing less risk of damage or irritation to the larynx or trachea while having similar advantages as endotracheal intubation (Fig. 6; Table 2). In addition, placement of the supraglottic device is quick and easily accomplished, and does not require a lot of skill or experience. In human medicine, supraglottic airway devices have been employed for some time, and shown to provide a good alternative for endotracheal intubation [15, 16].

In companion animal medicine, these devices have also



Figure 6. A radiograph of the head of a rabbit with a supraglottic airway device in place. The opening of the device is placed over the glottis.

been used. In rabbits, however, their use was limited primarily to laboratory animals and research settings<sup>[16-19]</sup>. Recently however, a new device (V-gel®, DocsInnovent Ltd, London, UK) was developed and tailored specifically to the rabbit's unique oropharyngeal anatomy<sup>[20]</sup>. The device, which is available in 6 sizes (Fig. 7; Table 3), has recently been tested in a clinical setting and found useful in most situations (including emergencies) except in patients requiring dental care. In >95% of cases, patent airways could be established rapidly on the first attempt and maintained successfully for the duration of the procedure in both spontaneously breathing animals and those with assisted ventilation<sup>[21]</sup>. Minor complications, including transient linguocyanosis (blue discolouration of the tongue due to restricted venous blood flow), gastric bloat and insertion difficulties due to improper anaesthetic depth or dental abnormalities, however, were encountered in a minority of cases<sup>[21]</sup>. Similar to endotracheal intubation it is important to ensure the patient is properly anaesthetized prior to inserting

*Table 3. Size of the available rabbit V-gels. For each size, the weights of the rabbit for which this device is considered suitable, is mentioned.*

Size	Body weight of the rabbit (kg)
R1	0.5 - 1.5
R2	1.0 - 2.0
R3	1.8 - 3.5
R4	2.5 - 4.0
R5	3.5 - 5.0
R6	> 4.5



*Figure 7. The largest size (R6) supraglottic airway device currently commercially available for rabbits. This device is suitable for rabbits weighing more than 4.5 kg. The smallest device is suitable for rabbits 0.5 kg and up.*

the supraglottic airway device, though lower amounts of anaesthesia seem to be required to allow proper placement without resistance<sup>[17]</sup>. A useful, commonly used, anaesthetic protocol by the authors to induce this level of anaesthesia includes the use of ketamine (5-10 mg/kg IM), medetomidine (200-250 µg/kg IM) and butorphanol (1 mg/kg IM). Once these anaesthetics have taken effect, the rabbit's mouth is opened, the tongue pulled out and the V-gel® inserted into the oropharynx with a slight twisting motion. The use of a water-based lubricant is recommended to allow for smooth placement. After ensuring proper positioning of the device (e.g. using capnography), the V-gel® is subsequently secured into place using a strap or tie (Fig. 8).



*Figure 8. After ensuring correct positioning of the supraglottic airway device, it is secured into place using cotton straps.*

## Maintenance of general anaesthesia

Once the rabbit is intubated, it can be connected to either a rebreathing circuit (if the animal weighs >2.5 kg) or a non-rebreathing circuit (for animals <2.5 kg) to allow administration of oxygen and inhalant anaesthetics. Traditionally, non-rebreathing circuits such as the Ayre's T-piece or Bain circuit are the most commonly used for rabbits and smaller exotic patients as they result in relatively low dead space volumes and low resistance. It is generally recommended to use a fresh gas flow of 2-3 times the respiratory minute volume (i.e., approximately 450 ml/kg)<sup>[23]</sup>, resulting in a gas flow of 1-3 L/min for most rabbits<sup>[24]</sup>. Once connected to the anaesthetic machine, the animal may either be allowed to breathe spontaneously, or to be mechanically- or manually ventilated. Assisted ventilation is particularly important when the animal does not breathe spontaneously, or during procedures in which the thoracic cavity is opened (e.g. explorative

thoracotomy) or paralytic drugs (e.g. atracurium) are used. When using intermittent positive pressure ventilation (IPPV), the ventilator is usually set to a tidal volume of 10-15 mL/kg, with a respiration rate of 20-40 breaths per minute and pressures of approximately 15-20 mm Hg [8,25,26].

### Intra-operative fluid therapy

Normal water consumption in rabbits is generally considered to be 100-150 mL/kg per day, which is higher than that in dogs or cats [27]. Thus, a reduced water intake in sick rabbits may rapidly result in dehydration and/or shock. Preferably, the fluid deficit is corrected prior to the anaesthetic procedure, but even in properly hydrated rabbits, fluid therapy during anaesthesia remains important as many anaesthetics result in decreased cardiac output and hypotension. In addition, fluid requirements are increased because of increased fluid loss due to breathing dry, cold air (if inhalant anaesthetics are used), haemorrhage and/or exposure of viscera to the room air. IV access may furthermore be advantageous as it allows quick and easy administration of emergency drugs and/or additional anaesthetics and/or may help to regulate body temperature, if necessary.

If possible, fluids are administered via the intravenous route, using small (22-26 G) over-the needle catheters that can be placed in the marginal ear vein (Fig. 9), the cephalic or lateral saphenous vein [28,29]. Alternatively, fluid can be administered via the intraosseous (in the proximal humerus, femur or tibia) or subcutaneous route. When providing fluids via the intravenous or intraosseous route, care should be taken not to overhydrate the rabbit, as this

may lead to severe lung oedema, dyspnoea and potentially death. In general, volumes of 10 mL/kg/h are well tolerated throughout the anaesthetic procedure. Alternatively, subcutaneous fluids may be administered in the loose skin on the dorsum in volumes of 100-150 mL/kg, divided over 2-3 treatments per day. Both crystalloids and colloids may be used for intra-operative fluid therapy. Colloids (e.g. hetastarch, dextran) are particularly useful in case rapid increase in osmotic pressure and blood volume is required and may be administered as boluses of 5 mL/kg over 5-10 min, repeated every 15 minutes, if necessary [28,29]. Alternatively, isotonic crystalloids (e.g. physiologic saline, Ringers) may be administered rapidly in doses of 10-15 mL/kg [28,29]. In case of severe blood loss, blood or haemoglobinbased oxygen carriers (e.g. Oxyglobin®, OPK Biotech LLC, Cambridge, Massachusetts, USA) may also be used.

### Thermal support

Anaesthesia usually results in loss of body temperature, particularly in animals with a high body surface area to size ratio [30]. Heat may be lost via the skin, respiratory tract (due to inhalation of cold gases) and/or surgical field (due to exposure of viscera to room air). In addition, anaesthetics suppress normal thermoregulatory mechanisms and behaviours, thereby predisposing to hypothermia and hypothermia-associated complications such as respiratory and cardiovascular suppression, prolonged recovery times and even death [31]. Hyperthermia is less common, but may also occur in densely furred rabbits if excessive heat is applied. Therefore, close monitoring of body temperature is warranted (see 'anaesthetic monitoring'). To thermoregulate the patient, a variety of passive insulators (e.g. blankets, aluminium foil, plastic or paper drapes) and active heating devices (e.g. forced-air or conductive warming systems, or radiant heating devices) can be used. In addition, minimizing the amount of presurgical antiseptic solution used to prepare the patient (with a preference to use povidone-iodine over alcohol), administration of warm fluids, heating and humidifying inspired anaesthetic gases, use of low flow techniques and/or minimizing the duration of anaesthesia may further help to prevent a drop in body temperature [30,31]. When using active heating devices (in particular electrical pads), care should be taken to avoid thermal burns.

In case of hyperthermia, treatment may be initiated by administering cold IV fluids and/or applying cold water or alcohol to the footpads or exposed skin.



*Figure 9. An IV catheter is placed in the marginal ear vein of this rabbit. IV access not only allows for continuous fluid therapy during anaesthesia, but also guarantees a direct vascular access allowing for a more rapid application of drugs during an emergency crisis.*



## Anaesthetic monitoring

Continued monitoring of the patient during anaesthesia is vital for its survival. The task of monitoring anaesthesia should preferably be assigned to a trained and experienced technician that is closely monitoring the depth of anaesthesia, cardiopulmonary parameters and body temperature. In addition, anaesthetic monitoring equipment may be used to monitor vital parameters, although it should be emphasized that no equipment can replace an observant assistant that is able to evaluate the observations in light of presurgical baselines and intraoperative events and can decide to take action whenever he or she suspects that intervention is required.

### Clinical observations and monitoring of the patient

Depth of anaesthesia is generally monitored by assessment of the various reflexes. These include the righting, palpebral, corneal, toe pinch - leg withdrawal, and pinna reflex<sup>[8]</sup>, of which the pinna and toe pinch - leg withdrawal reflex (particularly when tested in the hind legs) are considered to be the most reliable<sup>[32-34]</sup>. Whereas the toe pinch - hind leg withdrawal reflex will result in a slow withdrawal in rabbits that are under a light plane of anaesthesia, it will not elicit a reaction in rabbits that are under a surgical plane of anaesthesia. The front leg withdrawal reflex will stay present for a much longer period. The corneal reflex, in contrast, will usually be preserved until dangerously deep levels of anaesthesia are achieved. In rabbits which have received medetomidine, however, the corneal reflex may be (temporary) absent as a result of the administration of the drug itself, thereby classifying it as a less reliable parameter to evaluate the anaesthetic depth<sup>[35]</sup>.

In addition to the aforementioned reflexes, other parameters may be used as indicators for determining the anaesthetic depth, including (loss of) muscle and jaw tone; presence or absence of vocalizations and/or gross purposeful movements; and changes in the rate, depth and pattern of respiration or heart frequency [5,8]. Eye reflexes, position and movement are generally considered unreliable because they vary based on the type of anaesthesia that is used<sup>[23]</sup>.

The rate, depth and pattern of respiration can usually be assessed by direct observation of the thoracic wall or rebreathing bag. Assessment of respiratory effort may, however, be complicated when breathing is shallow. In addition, drapes may obscure the view of the patient, although the use of clear plastic drapes greatly help to overcome this issue<sup>[6]</sup>. Changes in respiratory rate

(reference: 30-60 breaths per min in an awake rabbit) may indicate excessive or too light anaesthesia and/or hypercapnia, whereas changes in the quality of respirations (e.g. increased effort made by the animal or decrease in rebreathing bag movements) may signal an obstructed airway<sup>[8,34]</sup>.

Information on the adequacy of ventilation may also be derived from direct observation of colour of the nose and mucous membranes (lips, gingiva, tongue), which may be facilitated by using clear facemasks and/or pulling the tongue out of the mouth. Cyanosis of the mucous membranes may indicate presence of hypoxia as a result of apnoea, hypopnoea or upper airway obstruction (e.g. caused by secretions or kinking of the tube due to altered neck position), although the administration of medetomidine may also result in a blue to purple discolouration<sup>[33]</sup>. In addition, the capillary refill time (CRT) and colour of the mucous membranes provide information on peripheral circulation, with pale discolouration and/or CRT of >2 sec indicating compromised circulation, e.g. due to hypovolaemia or decreased cardiac contractility.

Other cardiovascular parameters that may be monitored routinely include the heart rate, and pulse rate and quality. The heart rate may be monitored intermittently by auscultation with a stethoscope and/or palpation of the ictus cordis at the level on either side of the thoracic cavity<sup>[36]</sup>. Pulse rate and quality can be evaluated by palpating the central auricular or femoral artery. Typical heart rates in conscious rabbits lie between 240-280 beats per min (range 125-325 bpm, dependent on size and stress levels), but these may drop to 120-160 bpm after administration of e.g. medetomidine<sup>[37]</sup>.

Body temperatures are generally measured using a rectal thermometer or rectal probe. The latter may also be inserted into the oesophagus, which appears to result in less variation<sup>[5]</sup>. To avoid hyper- or hypothermia, body temperature should be checked regularly throughout the anaesthetic procedure and post-anaesthetic period, with appropriate measures taken accordingly to maintain body temperature as close to normal levels (i.e., 37-39 °C) as possible.

### Anaesthetic monitoring equipment

A variety of different anaesthetic monitoring techniques is available to monitor the cardiovascular, respiratory and thermal parameters of a patient during surgery (Fig 10). Each of these techniques will be discussed below.



Figure 10. Rabbit prepared for abdominal surgery. After induction of anaesthesia, the rabbit was intubated with a 3.5 mm endotracheal tube using endoscope-guided assistance. In addition, a 26G IV catheter was placed in the cephalic vein to enable fluid administration throughout the procedure. The rabbit was furthermore placed on a heat mattress, with temperature checked continuously throughout surgery using a rectal probe. Monitoring further included evaluation of end-tidal CO<sub>2</sub> levels and respiration rate using capnography, evaluation of heart rate and rhythm using an ECG (connected to the extremities using alligator clips) and evaluation of O<sub>2</sub> saturation using a pulse-oximeter placed on the tongue.

### Capnography

Capnography is used to measure the carbon dioxide concentrations in expired air as a function of time. Endtidal carbon dioxide tension (ETCO<sub>2</sub>) is generally used to provide a non-invasive estimate of the arterial partial pressure of carbon dioxide (PaCO<sub>2</sub>)<sup>[38]</sup>. Side stream samples generally add less resistance to the anaesthetic circuit than in-line sampling, but also provide less accurate results in small-sized patients due to their relative low respiratory minute volume.

### Electrocardiography (ECG)

Electrocardiography has been used in rabbits to monitor heart rate and rhythm. In contrast to dogs and cats, leads are usually attached just lateral to the elbows and laterally between the stifle and hock as the presence of fur on the ventral surface of the feet results in poor conduction<sup>[39]</sup>. Crocodile clips, hypodermic needles or pads may be applied to the skin to obtain a signal (Fig. 11). Electrode gel or alcohol may be used to improve contact. For anaesthetic monitoring, the ECG is most commonly viewed in lead II<sup>[32]</sup>. Due to the high heart rate of rabbits, however, not all monitors are able to obtain reliable heart frequencies. In addition, it should be emphasized that ECGs only



Figure 11. ECG electrodes can be connected to the body by means of alligator clips, blunted alligator clips, subdermal needles, needle electrodes and ECG-stickers [Previously published in Schoemaker & Zandvliet (2005) *Electrocardiograms in Selected Species. Sem Avian Exot Pet Med* 14,<sup>26-33</sup>]

demonstrate electrical activity and do not indicate adequate myocardial function and contractility.

### Doppler flow detection

A Doppler ultrasonic flow probe is commonly used as a monitoring tool in small exotic patients<sup>[32]</sup>. By placing the probe directly over a peripheral artery (i.e., central auricular, carotid or femoral artery) or the heart, it detects a change in frequency of sound reflected back by the blood flow, which is converted into an audible sound and allows continuous monitoring of the pulse (or heart) rate and rhythm<sup>[32]</sup>. In addition, the Doppler probe may be used in combination with an occlusive cuff placed just distal to the elbow (over the dorso-medially running brachial artery) or proximal to the knee (over the dorso-medially running femoral artery) in order to obtain an indirect arterial blood pressure. To obtain the best results, the cuff should preferably be placed on the forelimb and have a width to limb circumference ratio of approximately 40%<sup>[40]</sup>. Although values obtained using this technique should not be considered as absolute, repeated measurements may be compared to track trends in blood pressure over time<sup>[32]</sup>.

### Arterial blood pressure measurement

In addition to non-invasive, indirect blood pressure measurement, blood pressure may also be measured directly in rabbits through arterial cannulation of the central auricular artery<sup>[40]</sup>. In general, systolic arterial pressures of 90 mm Hg or mean arterial pressures of 60 mm Hg are recommended as a minimum<sup>[32]</sup>. Blood pressure in the central auricular artery is furthermore found to be approximately 10 mm Hg lower than in the carotid artery<sup>[41]</sup>.

Although the central ear artery is easily accessible, the cannulation technique is not commonly used in practice, as the equipment needed to perform such measurements is relatively expensive. In addition, the cannulation may damage the artery, resulting in necrosis and sloughing of the ear tip.

### Arterial blood gas analysis

Arterial blood gas analysis may be performed to assess the patient's oxygenation and acid-base status. Although both venous and arterial samples may be collected, arterial samples are generally considered to give the most reliable results<sup>[42]</sup>. Collection sites for arterial blood samples in rabbits include the femoral, metatarsal and auricular artery (Fig 12).



*Figure 12. Photograph showing the marginal ear vein (lateral) and medial auricular artery (medial) in the ear of a rabbit. The ear vein is often used for placement of IV catheters or collection of blood samples, whereas the auricular artery is used for collecting samples for blood gas analysis or direct blood pressure measurements.*

### Pulse oximetry

Pulse oximetry can be used to measure oxygen saturation and appears reliable at saturation levels >85%<sup>[43]</sup>. In addition to measuring oxygen saturation, pulse oximeters may also be useful to determine the pulse rate and rhythm. The tongue is usually the best site for placement of oximeters, but may not be accessible in all patients. In such cases, the ear, digit or tail may also be used to try and obtain a satisfactory signal<sup>[5,34]</sup>. This is, however, not always feasible when the rabbit has been anaesthetized with e.g.  $\alpha 2$ -agonists such as medetomidine, as these

drugs result in vasoconstriction and poor peripheral perfusion<sup>[5,6]</sup>. In addition, excessive compression of the auricular vasculature by the clamp holding the probe may result in a poor signal<sup>[6]</sup>.

Pulse oximeters require adequate pulsations in order to obtain accurate information. They may therefore be considered unreliable in patients with decreased blood pressure and/or vasoconstriction. In addition, it should be emphasized that pulse oximeters measure a pulse but this does not ensure an adequate blood flow<sup>[44]</sup>.

### Thermoregulatory monitoring

Measurement of core body temperature is routinely performed in almost any anaesthetic procedure, and particularly important in smaller-sized animals as they are prone to develop hypothermia. Although a standard or digital thermometer may be used to measure rectal temperature intermittently, the use of rectal or oesophageal probes is preferred as these allow continuous monitoring of the core body temperature<sup>[5,6,34]</sup>.

### Anaesthetic emergencies

Several conditions may be encountered in the anaesthetized rabbit that may be considered as an anaesthetic emergency. These conditions include apnoea or severe respiratory depression (<4 breaths per minute), upper airway obstruction, hypovolaemia, hypo- and hyperthermia, bradycardia and cardiac arrest. Using proper anaesthetic management, including careful and continued monitoring of the patient, as well as inhalant anaesthesia which allow better control over anaesthetic depth and duration, the risk that such an emergency situation may occur is decreased, though not completely eliminated. Tables 4 and 5 provide an overview of the various emergencies that may be encountered in rabbit anaesthesia (including their approach) and the different types of drugs that may be used in these emergency situations. Should cardiocerebropulmonary resuscitation be necessary, this follows the same priorities as in other animals: airway (A), breathing (B), circulation (C), and drugs (D). The "window of time" in which resuscitation can be effective, however, is shorter in rabbits compared to dogs and cats because of their relative high metabolic rates<sup>[6]</sup>. It is therefore generally recommended to calculate the dosages needed and draw up the syringes with the required volumes to enable adequate and timely response in case an emergency should be encountered.



Table 4. Protocol for various emergency situations that may be encountered during anaesthesia

Emergency situation	Actions to be taken
<b>Apnoea or respiratory arrest</b>	<ul style="list-style-type: none"> <li>• Turn off anaesthetic gas or reverse injectable anaesthetics</li> <li>• Provide 100% oxygen</li> <li>• Gently compress the chest at a rate of once per second to stimulate respiration</li> <li>• Intubate (if not already done)</li> <li>• Provide intermittent positive pressure ventilation (IPPV)</li> <li>• Administer doxapram IM/IV/IO/IT</li> </ul>
<b>Upper airway obstruction</b> (e.g. laryngospasm, laryngeal oedema, endotracheal tube blockage)	<ul style="list-style-type: none"> <li>• Use suction or gauzes to clear the oral cavity of fluids or secretions (if present)</li> <li>• Pull the tongue out of the mouth to prevent the base from blocking the airway</li> <li>• Place an endotracheal tube or supraglottic airway device to create a patent airway, if possible</li> <li>• Ensure correct positioning of the head and neck to prevent kinking of the tube</li> <li>• In case the tube is blocked: remove and replace if necessary</li> <li>• Provide 100% oxygen, reduce anaesthetic gas if recovery is feasible</li> <li>• In case of laryngeal oedema, consider the use of corticosteroids and/or perform an emergency tracheotomy</li> </ul> <p><i>Note: use of pre-emptive anticholinergics is possible to reduce production of mucous, but considered controversial as it may increase the viscosity of secretions</i></p>
<b>Hypovolaemia, shock</b>	<ul style="list-style-type: none"> <li>• Volume replacement (preferably IV or IO) with warm isotonic fluids (boluses of 10-15 mL/kg), colloids (5-10 mL/kg), or blood</li> </ul>
<b>Hypothermia (&lt;37°C)</b>	<ul style="list-style-type: none"> <li>• Minimize duration of anaesthesia and lower the amount of anaesthetics administered (if possible)</li> <li>• Warm and humidify the inspired air</li> <li>• Provide warm fluids</li> <li>• Provide supplemental heat with active warming devices</li> <li>• Increase room temperature and place rabbit in a pre-heated incubator as soon as possible</li> </ul> <p><i>Note: hypothermia may be prevented by use of passive insulators, sparing use of antiseptic solutions; minimal shaving and keeping the incision as small as possible</i></p>
<b>Hyperthermia (&gt;40.5°C)</b>	<ul style="list-style-type: none"> <li>• Turn off active heating devices</li> <li>• Administer cold fluids IV</li> <li>• Administer cold water or alcohol to the footpads or exposed skin</li> <li>• Place in a cold environment as soon as possible</li> </ul>
<b>Bradycardia, cardiac arrest</b>	<ul style="list-style-type: none"> <li>• Discontinue or reverse anaesthetics</li> <li>• Provide 100% oxygen, intubate and give IPPV</li> <li>• Administer atropine in case of bradycardia or adrenaline in case of cardiac arrest</li> <li>• Start external cardiac massage over the heart at a rate of approximately 70-90 times per minute</li> <li>• Consider the use of electric shock therapy (defibrillation) in case of ventricular fibrillation (2-10 J/kg)</li> </ul>

## Post-anaesthetic considerations

As determined in the study by Brodbelt et al., almost two-thirds of the anaesthetic-related mortalities occur in the postoperative period<sup>[45]</sup>. Close monitoring of the patient is therefore recommended, particularly in the first few hours

after the anaesthetic period<sup>[45]</sup>. During this period, heart rate, respiration and temperature should be checked at regular intervals. If hypothermia is encountered, additional thermal support may be provided. Alternatively, the rabbit may be placed in a (pre-)heated incubator until it is fully awake (Fig. 13).

Table 5. Commonly used emergency drugs in rabbits

Drug	Dose	Effects
Adrenaline	0.2 mg/kg IV, IT, IC	Sympathomimetic, for cardiac arrest (fibrillation or asystole); also start cardiac massage
Atipamezole	2.5-5x medetomidine dose or 10x dexmedetomidine dose	(Complete) reversal of the effects of $\alpha_2$ -agonists
Atropine	0.02-0.04 mg/kg IV	Parasympatholytic, treatment of (vagal-induced) bradycardia
Diazepam	1 mg/kg IM, IV, IP	Benzodiazepine, treatment of seizures
Dexamethasone	2 mg/kg IM, IV	Treatment of shock, laryngeal oedema; may not be effective and can lead to gastric ulceration and immunosuppression
Doxapram	2-5 mg/kg IV, SC	Respiratory stimulant
Flumazenil	150 mg/kg IV	Benzodiazepine antagonist
Furosemide	0.3-5 mg/kg SC, IM, IV, PO	Diuretic, treatment of pulmonary oedema
Glycopyrrolate	0.01-0.02 mg/kg SC	Parasympatholytic, treatment of bradycardia
Lidocaine	2-4 mg/kg IV, to effect	Treatment of ventricular tachycardia/tachyarrhythmia
Naloxone	0.01-0.1 mg/kg IM, IV	Opiate antagonist, narcotic reversal
Yohimbine	0.2-1 mg/kg IM, IV	Xylazine reversal

IC = intracardiac; IM = intramuscular; IP = intraperitoneal; IV = intravenous; IO = intraosseous; PO = per os; SC = subcutaneous

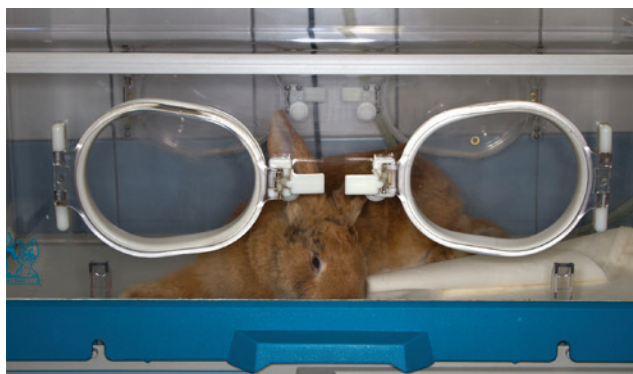


Figure 13. In the post-anaesthetic phase, the rabbit should be allowed to recover in a quiet, stress-free environment. A (pre-heated) incubator may be useful to help achieve normothermia in hypothermic animals. During the postanesthetic period, the rabbit's vital parameters should be monitored closely.

Preferably, the rabbit is allowed to recover in a quiet, comfortable location where stressors are kept to a minimum (i.e., no barking dogs, or smell of predators). As long as the animal has not regained sternal recumbency and can move around in the enclosure, periodic turning from left to right lateral recumbency is recommended to prevent hypostatic pulmonary congestion<sup>[46]</sup>. Some authors recommend leaving the IV catheter in place until recovery is complete as this enables rapid administration of fluids, glucose or medication, if necessary<sup>[33]</sup>. In addition, rabbits

may be lightly wrapped in a blanket or towel (burrito style) with the legs flexed against the body to prevent the rabbit from struggling violently and damaging its spine. As rabbits are prone to develop hypoglycaemia due to their high metabolic rate, they should be granted access to good quality food and water as soon as they are sufficiently awake. Preferably, fibrous foods such as fresh grass, hay and vegetables should be offered as these help to stimulate gut motility and encourage the rabbit to start eating. Anorectic animals may be force-fed with formulas specifically designed for critical care patients (e.g. Critical care for herbivores, Oxbow Animal Health, Murdock, Nebraska, USA; Science recovery, Supreme Pet Foods, Suffolk, UK; Emeraid, Lafeber Company, Cornell, Illinois, USA) to prevent a negative energy balance and hepatic lipidosis. If anorexia is persistent, placement of a nasogastric or oesophagostomy tube may be considered. Anaesthesia, stress related to hospitalization in an unfamiliar environment and pain may all negatively affect the rabbit's gastrointestinal motility. Close monitoring of the rabbit's appetite and faecal production is therefore warranted. Should either be reduced, supportive care should be initiated directly with force-feeding, fluids and prokinetic drugs (e.g. metoclopramide and cisapride)<sup>[33]</sup>. Ranitidine may be added to reduce acidity of the stomach

content and enhance appetite. In addition, adequate analgesia is vital to ensure that the rabbit will start eating and drinking as soon as possible. As assessment of pain in rabbits may be difficult due to the subtlety and aspecificity of signs indicating pain (e.g. anorexia, unresponsiveness, immobility, tooth grinding and/or sitting in a crouched stance), an anthropomorphic and empirical approach is often used to determine whether and what type of analgesia is needed<sup>[47]</sup>. When choosing an analgesic regimen, various factors need to be taken into consideration, including mode and duration of action and the risk of adverse side effects to the drug (see part I 'analgesics'). Of the different analgesics available, the opioids butorphanol and buprenorphine, and the NSAIDS meloxicam and carprofen, are the most commonly used. Often, a multimodal approach is employed using both opioids and NSAIDS to ensure adequate analgesia. Once the rabbit is considered stable enough to be discharged, it is vital to instruct the owners to carefully and closely monitor their rabbit to ascertain that the rabbit is eating and producing faecal pellets. Should the rabbit not have eaten or passed hard faeces within 24-48 hours after anaesthesia, they should be advised to bring the rabbit in for re-examination<sup>[5]</sup>.

## Conclusions

Rabbits are frequently sedated or anaesthetized to enable surgery and diagnostic procedures. With the increased knowledge on the pharmacokinetics and pharmacodynamics of anaesthetic agents and the arrival of newer, short-acting but potent drugs, including antagonists to reverse their effects, rabbit anaesthesia has become much more reliable, predictable and therefore safer. In particular balanced anaesthetic protocols, in which well-manageable inhalant anaesthesia is combined with injectable anaesthetics, have become commonplace in rabbit medicine and help minimize risks associated with anaesthesia. Other measures than can be taken to improve anaesthetic safety include 1) administration of oxygen throughout the procedure to prevent hypoxia; 2) assurance of a patent airway through endotracheal intubation or placement of a supraglottic airway device, which also allows assisted ventilation in case of apnoea or respiratory depression; 3) peri-operative administration of fluids to prevent hypovolaemia; 4) careful thermoregulation to prevent hypo- or hyperthermia; 5) improved ability to monitor the anaesthetic depth and vital functions throughout the procedure; and 6) the availability of drugs to counteract the effects of

anaesthetics. The increased ability to monitor and manage the patient during the anaesthetic procedure, however, does not automatically guarantee survival of the patient. A thorough pre-anaesthetic evaluation and stabilization of the patient, as well as continued monitoring and support of the rabbit after it is awake, are essential to increase the chances of success and return to normal function. In this context, provision of adequate, multimodal analgesia is of particular importance and may have a significant effect on patient's welfare and outcome of the anaesthesia.

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## Commissioned paper

# The Colourful Consultation: better for owners, pets and staff

Brian Faulkner<sup>1</sup>

## SUMMARY

Every veterinary practice must consistently deliver four outcomes if they wish to be effective and sustainable. These are clinical resolution, client satisfaction, financial resolution and team harmony and happiness. This article describes how the Colourful Consultation® model can be used to pursue these four outcomes in the consultation room.

**The Colourful Consultation – focusing on four outcomes every case, every species, every time**

Clinical  
resolution

Client  
satisfaction

Financial  
resolution

Harmony &  
Happiness

**Clinical resolution** refers to the prevention and resolution of clinical signs.

**Client satisfaction** is the emotion that occurs when a client perceives they have been advised to do what they believe to be 'the right thing for fair price'. In other words client satisfaction occurs when it feels right to the client. It is entirely possible for a client to have been given the best evidence-based technical advice that exists, but be dissatisfied because it doesn't 'fit' with their assumptions and beliefs about what is actually wrong with their pet or what should be done about it.

**Financial resolution** means that the consultation has been 'billed and banked'. I.e. the consultation has achieved a fair financial return and that the vet has considered and addressed factors which decrease the chances that the client might not settle their account.

**Team harmony 'n' happiness** means the consultation is performed in such a manner that doesn't undermine team morale or the well-being of the individual vet.

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Go to <http://www.fecava.org/ejcap>  
to see the online presentation of this paper.

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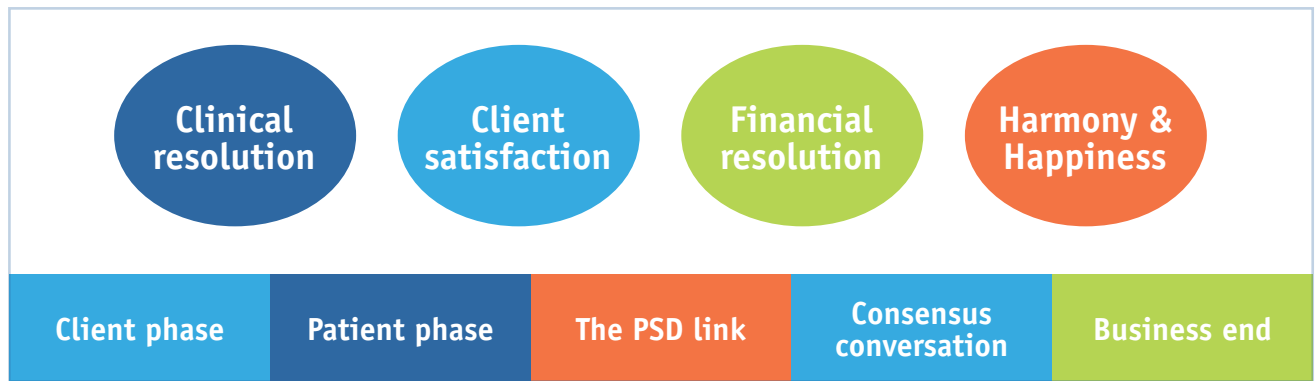


Fig 1. One consultation, four outcomes, five stages.

## Introduction

There are five types of veterinary consultations seen in first opinion practice (primary, re-check, vaccination, long-term medical and euthanasia consultations). This article will focus on how The Colourful Consultation model applies to the primary consultation.

The primary consultation occurs if it is the first time a patient is seen with a particular set of clinical signs relating to a new bout of illness; for example coughing / sneezing / vomiting / limping / scratching. This consultation usually occurs during scheduled hours but of course can occur out-of-hours and may even arise as a second opinion.

A major challenge with the primary consultation is to 'make sense' of the various presenting signs, consider the prognosis and the risks relating to the potential causes of the presenting symptoms and agree on a way forward (i.e. a resolution strategy) that feels right to both the vet and the client, all within budgetary, practical and time constraints. In other words, this consultation requires a clear conceptual and communication strategy if it is going to achieve all four of the stated outcomes (clinical, client, financial and team) at the same time.

## The Colourful Consultation model

### The client phase



The client phase aims to achieve three things:

- 1) build trust and rapport
- 2) identify relevant clinical signs during the history and
- 3) identify the client's 'presumptions' with respect to the illness.

### Trust and rapport

Every consultation must begin with attention to 'trust and rapport'. A client's trust can be weakened or even lost before the client is in the room if this part of the consultation is neglected. It is a myth that trustworthiness will be determined at the end of the consultation, i.e. the process has occurred and the client will decide if they trust the vet. Instead, people form opinions about others (and events) long before all they have enough information to assess them 'objectively'. This is human nature. Feelings of trust are based upon assumptions about someone's character (intentions and motives; - 'will you') and assumptions about someone's competence (- 'can you'). Clients usually assume competence in vets until proven otherwise whereas they tend to be more undecided about a vet's 'character' until they have met them, yet will often form conclusions very quickly. Time keeping, dress, eye contact, friendliness, attitude and facial demeanour are common variables used to 'immediately' assess one's character.

### The history: clinical and non-clinical stories

At veterinary college, the 'history' is portrayed as a technical step required to investigate the patient's clinical problem. The word history however is an extension of the word 'story' (his-story). Human beings use stories to explain, make sense of, extract meaning and make predictions about events. There are two 'stories' which emerge during the 'history'; the clinical story (about the signs the patient is or has been displaying) and the non-clinical story (about what the client thinks and believes about which is causing these findings and what they believe should be done about them). Listening for and making sense of the clinical story is the first step towards achieving clinical resolution. Listening for and making sense of the non-clinical story is the first step towards achieving client satisfaction. Note that we may not agree

with a client's 'hypotheses' about what they believe is wrong with their pet or what to do about it, but the more we know about what they are thinking, the better able we are to 'get on their side' and agree on a plausible diagnostic pathway.

### Empathy

Empathetic listening involves three skills: recognising, understanding and demonstrating the emotions. Taking the time and the patience to maintain eye-contact is essential in order to recognise emotions. Empathetic listening doesn't mean that we actually feel the same emotions but it does mean that we understand why the other person is feeling them. However, we need to demonstrate this to the client. The best way to do this face-to-face is to nod and acknowledge ('aha, I see') as the other person is talking.

### Succinct-and-linked

It is useful to conclude the client phase by summarising the history back to the client in a succinct form and then linking it into the clinical exam. For example, "So just to check that I've got this right; he has vomited about 6 times over the last 2 days and now he has stopped eating and is much more lethargic. Ok, there are a few things that can be, let's have a look." Demonstrating that we have listened, organised the information and that you have a clue about what is going on without actually getting dragged into a full clinical discussion at this stage.

### The patient phase



The patient phase aims to achieve three things:

- 1) identify relevant physical signs during the clinical exam;
- 2) think about the potential pathogenic processes and differential diagnoses
- 3) relate findings to the client about whether each check-point is deemed normal or abnormal.

### Articulate relevant clinical findings as we go

It is tempting to think that performing a physical exam is only about achieving 'clinical resolution'. However, since the exam occurs with the client present during consultations, it is important to keep in mind issues which effect the client's perception of whether we are doing our job 'right' if we wish to also achieve 'client satisfaction'. It is useful to commentate on what is being looked at and whether it is normal or not. This not only reinforces

the thoroughness of the exam and hence value to the client, but also educates the client about what is or isn't normal in their pet. Some clients interpret 'intense lengthy silences' as the vet is 'unsure' or 'even at a lost' about what is going on.

### Parking

There are several reasons why it is beneficial to 'park' abnormal clinical findings until the entire examination has been completed as opposed to getting bogged down in lengthy conversations about causes and / or diagnostic-therapeutic options whilst performing the physical exam. This parking enables the vet to 'rank' the urgency and importance of the various signs detected as well as complete a risk assessment of potential interventions (e.g. anaesthesia) before proposing them. Parking also avoids coming across as having a 'sales agenda' (especially with dentistry during booster vaccinations).

### The PDS link



The aim of the PDS link is to convert clinical signs into strategies and reach a decision point about how to proceed with the case. P stands for the clinical problems discovered on history and exam, D stands for the differential diagnoses of each of those clinical signs and S stands for the strategies available to deal with these clinical issues.

The PDS link is a conscious and pre-planned step towards the inevitable crossroads of the primary consultation. It is inevitable in that the client will have to decide which strategy they wish to pursue in order to resolve the case. Given this inevitability it is important to begin this stage with the end in mind and aim to build towards and arrive at this crossroads in a clear and definite manner.

### The stress of uncertainty

Many of the stresses that occur during veterinary consultations can be tracked back to one particular thought and one particular choice that is being deliberated upon in both the mind of the vet and the client: "what's causing these signs and what's the right way to proceed?"

Stress can be captured by the following equation:

$$\text{Stress} = \text{uncertainty} \times \text{urgency}$$

Uncertainty occurs when people feel that they don't have enough information whereas urgency involves a deadline. There are usually three deadlines that may be in-play during a veterinary consultation; 1) will we manage to gain control of the medical situation before a point of no-return (be that death or permanent incapacity), 2) will we manage to gain control of and resolve the situation before the client's budget is spent and 3) will we manage to gain control of the situation before the client's confidence or patience in us has run out.

In order to manage this moment of potential stress well, the vet needs to know how to frame (and thus contain) the uncertainty about what is going on in their own minds and they also need to frame (and thus contain) the uncertainty in the client's mind. This is the core objective of the PDS link and it works as follows:

### **P for Problems**

It is useful to begin by articulating to the client the 'problems' that have been discovered during history and exam in a clear and succinct manner. It is also useful to try and articulate them to the client in the order of greatest concern. 'Remembering, ranking and repeating' the historical and physical findings inspires confidence and provides a launch pad from which to discuss the options available in order to resolve them. For example we may say, *"OK, so what do we know? He has been vomiting on and off for 3 days. He hasn't eaten since yesterday morning and he started having diarrhoea this morning. On examination he seems tender when I palpate his abdomen, he has a slightly raised temperature and he is slightly dehydrated. Everything else sounds and appears normal"*.

### **D for Differentials**

No matter how much the client thinks they know what is going on with their pet, they still look towards the vet to make sense of the findings and give them a plausible explanation about what is – or could be – causing them. This is the D-step of the PDS link. It is essential to consciously consider and then succinctly articulate the differential diagnoses for each clinical sign. As far as the client is concerned the D stage needs to be a clear and succinct list of the three or four most likely causes of the findings.

For example: *"There are a few conditions that can cause these signs. The most likely causes are x, y and z and these account for 80-90% of the patients which present like this. There are other less common causes but these are the big*

*suspects which we need to rule out first"*.

### **Send a specific message**

"There are a few conditions that can cause these signs". The objective of this sentence is to acknowledge the inherent uncertainty of the situation to the client BUT in a controlled and assertive way. We should not be ashamed of not being 100% sure of our diagnosis as long as we demonstrate that we 'have a clue' about what is going on and that we have a way of dealing with this uncertainty. Saying 'there are a few conditions' in a matter of fact manner is a subtle and usually effective way of addressing the client's conviction about their own 'pet-hypothesis' without dismissing or criticising it. This will hopefully avoid an overt a 'my-diagnosis versus your-diagnosis' stand-off as well as priming the client to want to hear your suggestions.

*"The most likely causes are x, y and z and these account for 80-90% of the patients which present like this. There are other less common causes but these are the big suspects."* Stating your differentials as a factual statement whilst emphasising the probability that it is one of these 'suspects' sends a message of 'conviction and control' in the face of uncertainty. It also facilitates an entirely plausible 'get-out' if the actual diagnosis turns out not to be on your initial short list. It is important to remember that 'common conditions occur commonly' in first opinion practice. Articulating lengthy lists of rare and uncommon causes often confuses and concerns the client more than it helps (or impresses) them.

### **S is for Strategies**

Whilst we learn hundreds of different techniques at vet school, there are ultimately only three strategies available to us to 'resolve' the clinical signs presented to us during the primary consultation. These are the reactive strategy, the proactive strategy and euthanasia (Fig 2). All of these strategies are used in first opinion veterinary practice.

### **The reactive strategy**

The premise of the reactive strategy is to treat a 'presumptive diagnosis' and react according to how the patient responds. In first-opinion consultations, this strategy is used approximately 80% of the time. It is therefore important to understand the risks and the rewards of using it and how it relates to using re-check consultations in particular. The main risk of the reactive strategy relates to 'picking the wrong diagnosis' as our presumed diagnosis which allows the actual cause to



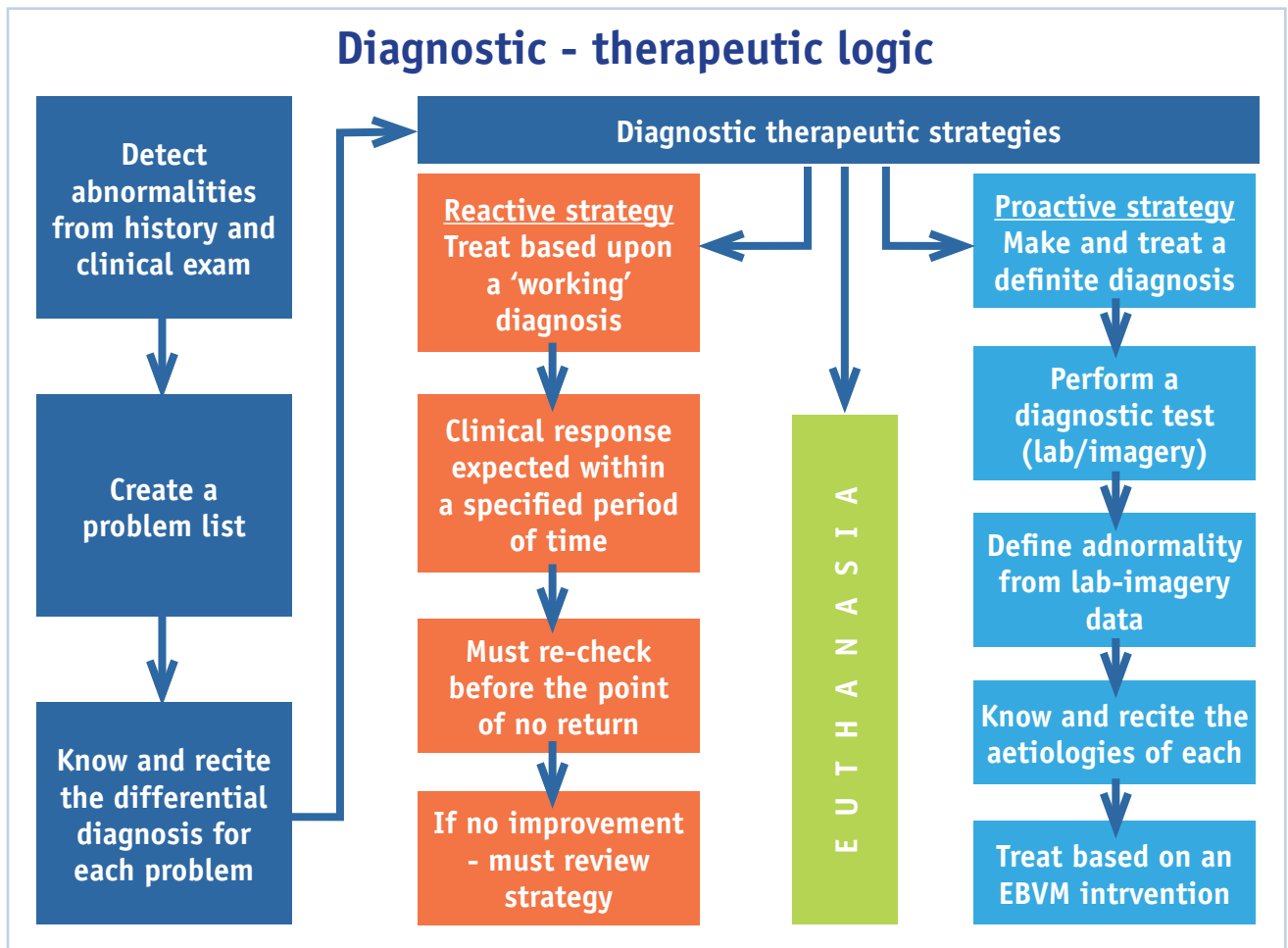


Fig 2. Hundreds of techniques, only three strategies.

progress or if our treatment is even perceived to have harmed the patient. This not only affects clinical resolution objective but also client satisfaction, with the impact on how willingly they pay their bill as well as our own sense of stress and harmony. The reactive strategy should only be used when the patient's signs are not expected to deteriorate rapidly beyond the 'point of no return' or when failing to be more proactive (or euthanasia) would result in unacceptable suffering. Sound clinical judgement in this regard is based upon considering and checking for MNI (must not ignore) signs such as:

- Dyspnoea
- Circulatory compromise, severe dehydration, haemorrhage and shock
- Uncontrollable pain
- Reduced mentation and lack of voluntary control and collapse
- Inability to defecate and urinate
- Ocular emergencies (increased intraocular pressure and corneal penetration)

### The proactive strategy

The ideal objective of the proactive strategy is to make

and treat a 100% conclusive diagnosis using evidence-based diagnostics and treat using the 'gold-standard' evidence based intervention. However, this is often not always possible for both technical and practical reasons. It is useful to think of proactive diagnostics in terms of 'buying information'. By buying information we decrease the probability that we treat (or euthanase) based upon the wrong condition. Note that there is a difference between 'selling diagnostic tests' and 'buying information'. Recommending a raft of diagnostic tests just because they are available without a clear plan about what information is being 'bought' in relation to a differentials diagnosis list is speculative, unfocused and often wasteful.

### The euthanasia strategy

Technically euthanasia is always available as an option to resolve any clinical situation. There is a spectrum of attitudes with respect to how early and how often vets recommend euthanasia. Likewise, there is a spectrum of attitudes with respect to how open or reluctant clients are to embrace euthanasia as a resolution strategy. It is therefore important to have a gentle probe phase which 'tests' the client's response to potential euthanasia. For

example, "We can do this. We can do that. But, you know, whatever we do, we need to keep his quality of life in the forefront of our mind".

### The right strategy?

It is important to note that the PDS link is a 'neutral' phase of the consultation. The aim isn't to influence or persuade the client; the aim is to succinctly explain what we believe may be causing the findings as well as what we believe the client's options are in order to resolve them (via a reactive, proactive or euthanasia strategy). Which strategy is considered the 'right' way to proceed will involve a conversation with the client about the risks-costs-benefits of each. This is the next stage of the consultation known as the 'consensus conversation'.

## The Consensus Conversation



The aim of this phase of the consultation is to reach a consensus with the client about which strategy will be used to try and resolve the clinical signs. This decision about which strategy to pursue is in fact pivotal to how those involved will evaluate how effective a consultation was over the short, medium and long term.

The Consensus Conversation aims to achieve four things:

1. Inform the client about 4 P's relating to each strategy and assess their response
2. Make and respond to an assertive recommendation
3. Achieve informed consent
4. Write up the clinical notes

Clients often want and to know four things (the four P's) of each strategy in order to make an informed decision about how they wish to proceed with the case (Fig. 3).

### Pain (and distress)

Clients will make decisions about what 'feels right' to them based upon their assumptions of the 'pain-caused' versus the 'pain-relieved' by each strategy. Some clients assume that proactive strategies (which may involve anaesthetics, surgery or invasive diagnostics) will cause their pet excessive pain and distress. Some clients may have a natural reluctance to 'put them through it'. It is important to be proactive about anticipating a client's legitimate concerns about subjecting their pet to potential pain and distress. Clients are more likely to manage their concerns if they know what steps can and will be taken to alleviate or minimise any distress involved.

### Prognosis and risk

Clients also make decisions about what 'feels right' to them based upon their assumptions about whether they consider



Fig. 3 Making the pivotal decision: 4 P's

the diagnostic or therapeutic intervention 'worth it' in terms of the potential payback and risks to both quality and quantity of life. In order for diagnostic information to be deemed worth it, clients often wish to understand how this information relates to either-or type choices; "if the test results say this we can then do this, whereas if they say that then we can do that".

### Price

Whilst most clients have ultimately limited resources we should never exclude a strategic option on the basis of price. Some clients may be embarrassed to ask about costs and it is always advisable to give an estimate for all proactive options.

### Practicality

Clients will also make decisions about what 'feels right' to them based upon their assumptions about whether they themselves will be able to cope with the inconvenience or physical issues relating to their pet's treatment and recovery. Sometimes clients reach conclusions about the need for tableting, confinement, lead walks, re-dressings etc. which may be less (or more) onerous than they assume.

### Tell me what you're thinking?

It is important to make and maintain eye contact with clients when discussing major decisions, none more so than the pivotal decision of the consultation. Clients typically exhibit one of four responses whilst they listen and enquire about their options. These are: 1) "Yes, I like the sound of that" 2) "I'm not too sure about that" 3) The "blank" response and 4) "What do you recommend?" Many vets assume that when clients exhibit the blank response that they are doubting them. Most vets get the blank-response about thirty to forty per cent of the time. Rather than keep talking and hoping for a response, it is useful to say in a gentle but inquisitive tone, "Tell me what you're thinking?"

### Call to action

Some vets feel uncomfortable about making a recommendation in the concern that they may be perceived as selling to or unethically influencing the client. This in part results from misunderstanding the term 'assertiveness'. Assertive communication occurs when both parties feel they have had a chance to express their needs, wants and opinions but in a way that doesn't violate the needs, wants and opinions of the other. Phrasing a recommendation

by incorporating an awareness of both the vet's and the client's emotions can be effective. For example, instead of saying "I recommend an x-ray. This will cost €100", this can be re-worded as "I would love to take an x-ray... but I appreciate I'm asking you to pay for that. An x-ray costs €100." Then stop talking and look at the client for their response. This twenty word 'call to action' is often more effective (and efficient) than a long waffling discussion.

### Writing up the clinical notes

Although most vets write up their notes after the client has left the room, it is beneficial to write the notes up with the client present. Verbalising clinical notes to the client as they are being written up and checking for consensus before the notes are saved increases the chances that genuine consensus has been achieved.

The notes should reflect the structure of the Colourful Consultation; history, exam (pertinent findings as well as pertinent normalities), top 3-4 differential diagnoses, options, consensus about options including estimated costs, any working diagnosis, follow-up and plan B. Dictation can take the form of "that's what we said, wasn't it?" or "Are we happy with that?" whilst typing. It is worth making a particular effort to write up notes with clients who have a history of deliberately or accidentally distorting or misinterpreting comments after the event. The acronym 'NACE' (Notes Articulated. Consensus Expressed) may be used to sign off notes when consulting with this type of client.

## The Business End



The final stage of the Colourful Consultation is known as the Business End. There are four objectives within this phase:

1. Action the plan agreed to during the Consensus Conversation
2. Ensure that the account is properly 'billed'
3. Direct the client towards payment and think about when will I see you again?

### Action the agreed plan: Treat, sample or admit

Most plans of action will take the form of treating, sampling or admitting the patient. 'Treating' can also mean euthanasia. This stage of the consultation can be very variable in length and may range anywhere from a quick injection to a time-consuming laboratory test. Admissions



can more or less efficient depending on whether the client and the patient can be handed-over to a colleague. Steps that we be taken to improve the efficiency of the treat-sample-admit phase include: having common diagnostic materials (ophthalmoscope, otoscope, bacteriology swabs, microscope slides for fine needle aspirates, blood tubes for sampling, fluorescein and Schirmer tear tests) within the consultation room as well as muzzles and cordless electric clippers.

### **'Book, bill and bank' the client's account**

Unpaid bills, bad debts and disputes about charges and value for money are frustrating and harmful to any business. Many of the bad debts within veterinary practice originate within the consultation room. There are a range of behaviours that increase the chances that a client is more or less motivated to hand over their cash or card. Proactively discussing costs and charges during the Consensus Conversation is essential. Many vets only tend to do this though when large sums are involved. However unpaid bills and disputes about prices and value for money frequently occur around relative small amounts incurred during outpatient consultations. Disputes about the fairness of re-check consultation charges is a common example. Two simple behaviours which increase the probability that clients will pay their bills after a consultation are 'the €75 rule' and 'Navigating the Bermuda Triangle'.

#### **The €75 rule**

The €75 rule states *"if a bill comes to more than €75, tell the client before they leave the room"*. (€75 has been chosen as the amount that most clients will pay without commenting. For some practices this may be €100, whilst for others it's €50.) Failing to do so will lead to exclamations of "How much?!" at reception thus setting off a cascade of time consuming, emotionally uncomfortable distractions, the potential of an unpaid account or even a lost client. The €75-rule patter may go something like this; *"So just to let you know that with the consultation and the four weeks of treatment the bill today comes to €100. I only mention it because that's a little bit more than the average consultation bill, and that's because the anti-inflammatories costs €50 just by themselves. I just want to check that's OK with you."* If not, we can either give them less anti-inflammatories, cheaper anti-inflammatories, even no anti-inflammatories, but either way most clients appreciate the consideration shown and the forewarning before they go out to the desk, get shocked or embarrassed about not being able to pay.

### **Navigating the Bermuda Triangle**

The Bermuda Triangle is the space between the consultation room door and the reception desk. All too often agreements and expectations that have been made in the consultation room disappear 'without trace' the moment the client walks out of the consultation room. Clients can be distracted by that cute puppy or someone they know.

The aim of Navigating the Bermuda Triangle is to be proactive about leading the client towards the payment point as well as ensuring that any follow up appointments or operations are booked instead of forgotten. This is particularly important after re-check consultations when clients often don't expect to have to pay anything. In order to avoid the prospect of this happening it is well worthwhile chatting with the client as you escort them 'across the Bermuda Triangle' and hand them over to a receptionist and ask them to book a follow-up appointment if relevant. If no follow up is expected, instead of allowing the client to walk out of the consultation room and head for the exit, it is useful to casually, but deliberately, walk out with them to the desk. If the receptionist is occupied on the telephone or with another client I will lead them to reception, say my goodbyes and advise them that 'my receptionist will be with you in a moment' which is code for 'there is a bill to pay'.

### **When will I see you again?**

Every business requires enough repeat 'customers' in order to be sustainable. Once again we can be proactive or reactive in our orientation to follow up business.

The reactive mindset merely 'hopes' that clients will come back again when they require veterinary services.

The more proactive mindset in contrast thinks 'when will I see you again?' In an ideal world every dog, cat and rabbit will be seen at least once year for their annual vaccination. Therefore when a patient is 'signed off' after a short-term illness, it is advisable to check the vaccination re-call status and make sure that there is a scheduled follow-up for annual booster. In fact it is most useful to check before taking in a re-check whether they are vaccinated up to date. If a patient is not up to date with its vaccinations the best time to bring this up is at the final re-check. The fact that the patient is not vaccinated can be broached by saying that you look forward to seeing him again at his annual check-up and asking when that is. Clients are often

more amenable to considering paying for a vaccinating when they realise that this can be given in lieu of paying for a re-check fee.

A subsequent article in EJCAP [25(1), Spring 2015] will focus on how the author's Colourful Receptionist® model acts as a syllabus to coach and train the proactive pursuit of these four outcomes in members of staff who work at the 'front of house'.



## Reprint paper\*

# Prophylactic gastropexy in dogs: a review of currently available surgical techniques

Sieglinde D. David and Bart Van Goethem<sup>1</sup>

## SUMMARY

Prophylactic gastropexy is highly recommended in dogs predisposed to gastric dilatation and volvulus (GDV). Of the traditional coeliotomy (midline laparotomy) techniques, circumcostal and belt-loop gastropexy result in the strongest adhesions and lowest chance of developing GDV. These techniques however can be associated with major complications such as iatrogenic pneumothorax, rib fracture and peritonitis. Incisional gastropexy results in a mechanically weaker adhesion but still results in a significantly lower incidence of GDV. Because this technique has few complications it is seen as the technique of choice. Morbidity is an important issue regarding elective surgeries. Using minimally invasive techniques can reduce this morbidity. The major advantages of laparoscopic gastropexy regarding tissue trauma and patient comfort and wellbeing outweigh the technical demands and longer time needed to develop new surgical skills.

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Go to <http://www.fecava.org/ejcap>  
to see the online presentation of this paper.

## Introduction

Although the exact aetiology of Gastric Dilatation and Volvulus (GDV) remains unknown, numerous predisposing factors have been identified. Most dogs affected by GDV are large and giant breeds, with Great Danes, German Shepherds, Standard Poodles, Basset Hounds, Chow Chows and large mixed breeds at the highest risk (Glickman et al., 1994; Brockman et al., 1995; Evans et al., 2010). The life-time risk for a large or giant breed dog developing GDV is 24% and 21% respectively and their risk of dying of GDV is 7% (Glickman et al., 2000a). GDV occurs more frequently in middle-aged and older dogs, males are more often affected

than females and there appears to be a familial predisposition to the disease (Glickman et al., 2000b). Other predisposing factors include body conformation (large thoracic depth-to-width ratio), behaviour (rapid and gulping eating style), eating from a raised food dish, stress (grooming, dog shows, boarding), food particles less than 3 cm in size, once daily feeding, underlying inflammatory bowel disease and increased hepatogastric ligament length (Schellenberg et al., 1994; Hall et al., 1995; Braun et al., 1996; Bredal, 1998; Elwood, 1998; Theyse et al., 1998; Glickman et al., 2000a; Glickman et al., 2000a). Although in the past, it was assumed that splenic torsion or splenectomy increased the risk of GDV (Millis et al. 1995), this was not confirmed by Goldhammer et al. (2010) in a large retrospective study. GDV is characterized by dilatation and a variable degree of volvulus of the stomach. Gastric gas and fluid accumulation leads to circulatory and respiratory dysfunction. Death is inevitable unless prompt and accurate treatment is started. In spite of appropriate medical and surgical intervention, case fatality rates as high as 15% to 33% have been reported (Brockman, 1995; Glickman et al., 1998). The initial therapy includes hypovolaemic shock treatment

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and gastric decompression either by passing a stomach tube or by percutaneous puncture of the stomach with a large bore needle or trochar.

When torsion is present, surgical intervention should follow initial medical treatment as soon as the patient's cardiorespiratory status allows general anaesthesia (Glickman et al., 1998).

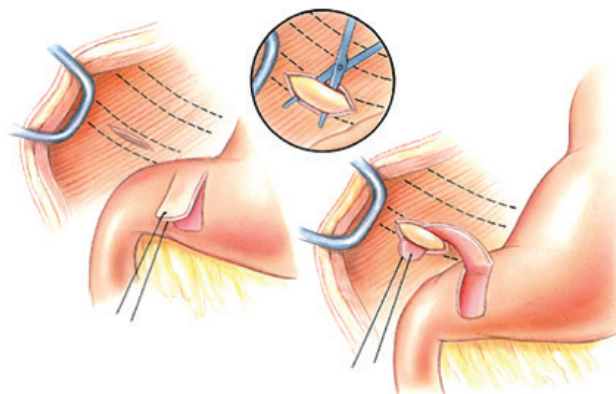
If a gastropexy is performed after repositioning of the stomach, a permanent adhesion is formed between the stomach and the right abdominal wall and the recurrence rate decreases from 54.5% to 4.3% (Glickman et al., 1998). The median survival time for dogs after emergency surgery for GDV increases from 188 days to 547 days when gastropexy is performed (Glickman et al., 1998).

Considering the high incidence of GDV and because not all of the predisposing factors can be eliminated, elective surgery is justified. In Rottweilers and Great Danes, a prophylactic gastropexy resulted in a 2 to 30-fold reduction in mortality due to GDV, respectively (Ward et al. 2003). Prophylactic gastropexy can be performed by conventional (midline) coeliotomy or by more recently introduced laparoscopic-assisted or laparoscopic techniques. The aim of this article is to offer a review of the currently available techniques and assess the advantages and disadvantages of minimally invasive methods.

## Conventional coeliotomy techniques

### Circumcostal gastropexy

This technique relies on a gastric seromuscular tissue flap, which is passed through a tunnel created behind the last full rib and sutured back to the stomach (Figure 1).



*Figure 1. Circumcostal gastropexy. The transverse abdominal muscle is incised over the costochondral junction of the last rib. A tunnel around the rib is created using blunt dissection. Creation of a seromuscular flap in the pyloric antrum which is passed through the tunnel.*

Source: Fossum T.W. (2007). *Small animal surgery. 3th Edition, Missouri, USA, Mosby Elsevier, p. 409-433.*

A 3 to 5-cm-incision is made through the ventrolateral peritoneum and transverse abdominal muscle over the costochondral junction of the last most complete rib (11th or 12th). Care is required to avoid diaphragmatic muscle damage and iatrogenic pneumothorax. A tunnel around the rib is created using blunt dissection. Subsequently, two parallel 4-cm-incisions are made 3 cm apart through the serosal and muscular layers in the pyloric antrum region of the stomach. The area between the two incisions is undermined by blunt dissection and the tip of the flap is created by connecting the cranial ends of each incision with an arching incision. The flap is elevated, passed craniodorsally through the tunnel under the rib and is sutured to the original gastric margin. A double hinged flap technique has also been described in which the elevated strip of seromuscularis of the stomach is cut along its midline instead of at its tip and the two flaps are eventually sutured to each other (Broome and Walsh, 2003; Fossum, 2007).

Modifications of the technique consist of transecting the cartilaginous portion of the 10th or 11th rib, passing the proximal end through a seromuscular tunnel in the pyloric antrum and then suturing the ends of the transected rib together (Pope and Jones, 1999). Advantages include rapidity and the ability for it to be performed without surgical assistance. Another modification has been described that minimizes the gastric wall dissection necessary for flap creation by using the loose attachment between the gastric serosa/muscularis and submucosa/mucosa. The seromuscular layer of the stomach is first grasped with an atraumatic tissue forceps and pulled through the tunnel making a 3 cm wrap of gastric wall around the rib before making 3 or 4 incisions into the serosa and muscularis on both sides of the gastric wrap which are subsequently apposed in a simple continuous pattern (Degna et al., 2001). Potential complications including peritonitis resulting from perforation of the stomach (Woolfson and Kostolich, 1986), pneumothorax (Leib et al., 1985) and iatrogenic rib fracture (Rasmussen, 2003) have been attributed to inexperience with the technique. The gastric myoelectric activity or gastric emptying is not affected by this technique (Hall et al., 1992; Hall et al., 1997).

Circumcostal gastropexy results in a very strong connection. Tensile tests performed at day 21 after surgery revealed a breaking strength of 109 N (Fox et al., 1985). After circumcostal gastropexy no confirmed recurrences of GDV have been published. Leib and others (1985) found 1 of 30 dogs (3%) that developed a gastric dilatation after circumcostal gastropexy for surgical correction of GDV (Leib et al., 1985). Woolfson and Kostolich (1986) described 2

of 31 dogs (6%) that died or were euthanized because of severe acute gastric dilatation (stomach position was not determined). In both studies it was not determined if the stomach was also torsed.

### Belt-loop gastropexy

Belt-loop gastropexy differs from single-pedicle circumcostal gastropexy since the seromuscular flap is passed through a soft tissue tunnel in the abdominal wall instead of around the last rib (Figure 2).

Two parallel dorsoventral incisions of 3 to 4 cm are made through the transverse abdominal muscle. The incisions are 2 cm apart, and two to three finger widths caudal to the last rib and approximately one third the distance from ventral to dorsal midline. Blunt dissection between the

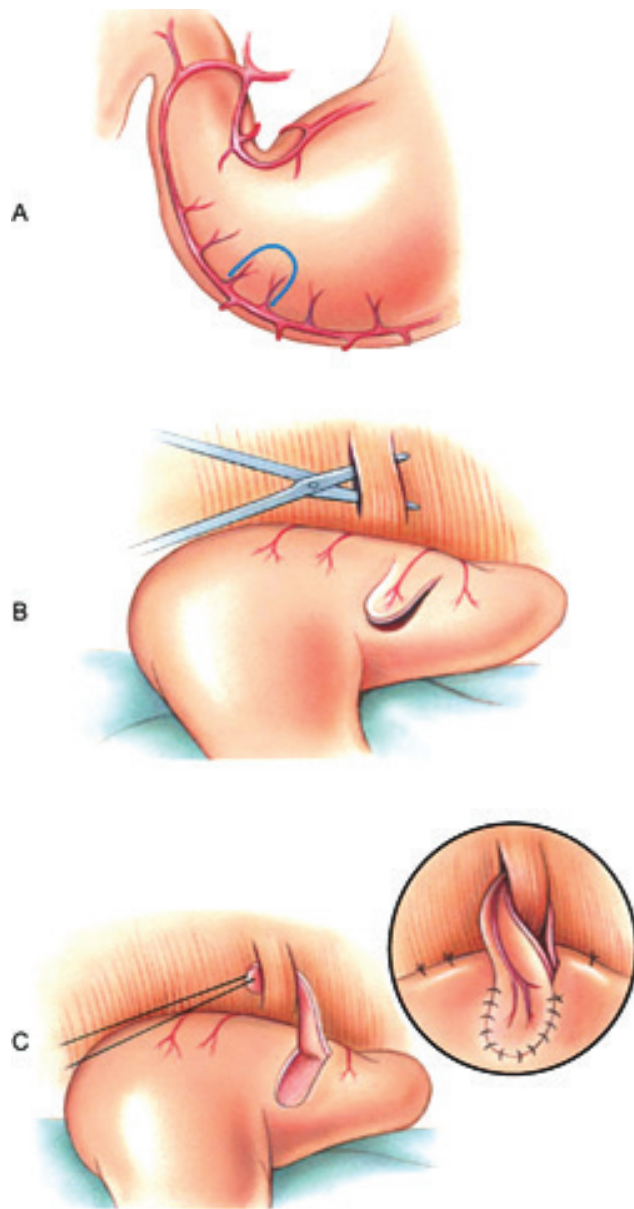


Figure 2. Belt-loop gastropexy. The gastric seromuscular flap is passed through a soft tissue tunnel in the abdominal wall. Source: Fossum T.W. (2007). *Small animal surgery*. 3th Edition, Missouri, USA, Mosby Elsevier, p. 409-433.

two incisions creates the belt-loop tunnel. Subsequently, a gastric flap is created as if to perform a circumcostal gastropexy. The tip of the flap is then pulled through the tunnel in a caudal to cranial direction and the flap is secured to its original location (Whitney et al., 1989). This technique does not interfere with normal peristaltic contractions (Whitney et al., 1989). Complications directly related to the procedure are rare. Iatrogenic pneumothorax, due to the abdominal wall incisions entering the thoracic cavity, has been observed (Rasmussen, 2003).

Modification of the technique consists of apposing tissue with skin staples instead of hand suturing (Coolman et al., 1999). The stapled gastropexy was found to be as strong as the sutured gastropexy but decreased surgery time by 50%. Belandria et al. (1999) also described a belt-loop gastropexy technique using an automatic stapling device intended for gastrointestinal anastomosis.

Maximum tensile strength 50 days after surgery is reported to be 109 N (Wilson et al., 1996).

None of three retrospective studies (cumulative patient number 19+20+21) with follow-up ranging from 3-33 months could detect any occurrence of GDV (Schulman et al., 1986; Whitney et al., 1989; Belandria et al. 1999).

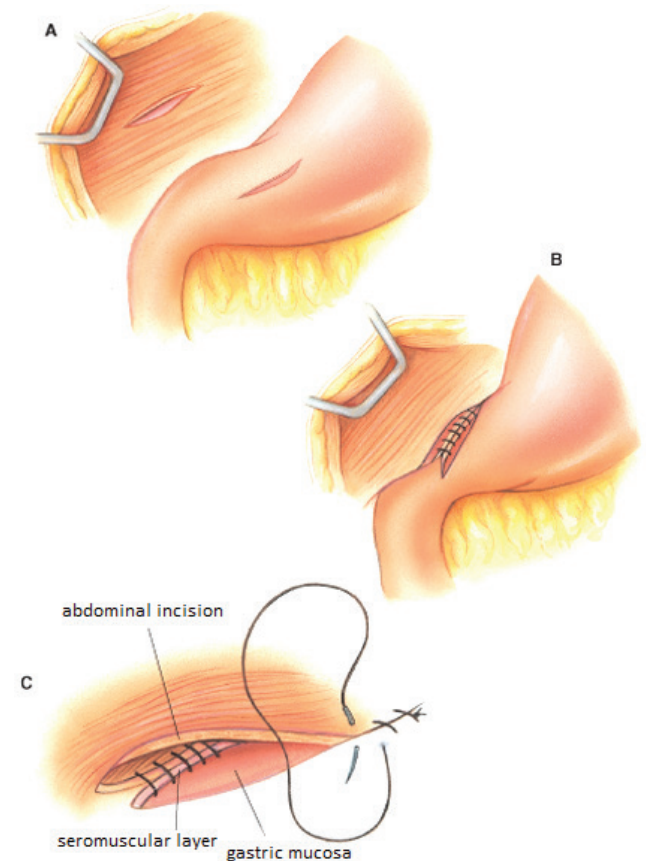


Figure 3. Incisional gastropexy. The edges of an abdominal wall incision are sutured to the edges of a gastric incision. Source: Fossum T.W. (2007). *Small animal surgery*. 3th Edition, Missouri, USA, Mosby Elsevier, p. 409-433.

### Incisional gastropexy

The strength of this gastropexy relies on the healing/fusion of the edges of a gastric seromuscular incision to the edges of a transverse abdominal muscle incision (Figure 3).

This technically easy procedure consists of a 5 to 6 cm incision in the right ventrolateral abdominal wall through the transverse abdominal muscle, perpendicular to the long axis of the patient. A similar incision is made in the seromuscular layer of the gastric wall of the pyloric antrum, midway between the greater and lesser curvatures. Both edges of the incision are sutured to the opposing edges of the incision in the abdominal wall in a simple continuous pattern beginning with the most cranial incision edges of the body wall and gastric incisions (MacCoy et al., 1982). Complications of accidental gastric mucosa penetration and iatrogenic pneumothorax are rare when the procedure is preformed by an experienced surgeon.

Mean tensile load to failure is between 60 and 85 N depending on the time after surgery at which the breaking strength was determined (Fox et al., 1985; Hardie et al., 1996; Waschak et al., 1997).

Reported incidence of GDV after incisional gastropexy is between 0% (0 of 44) and 4% (3 of 74) (MacCoy et al., 1982; Glickman et al., 1998).

### Tube gastropexy

When a gastrostomy tube is placed in the pylorus (right ventral wall) instead of in the fundus (left ventral wall),

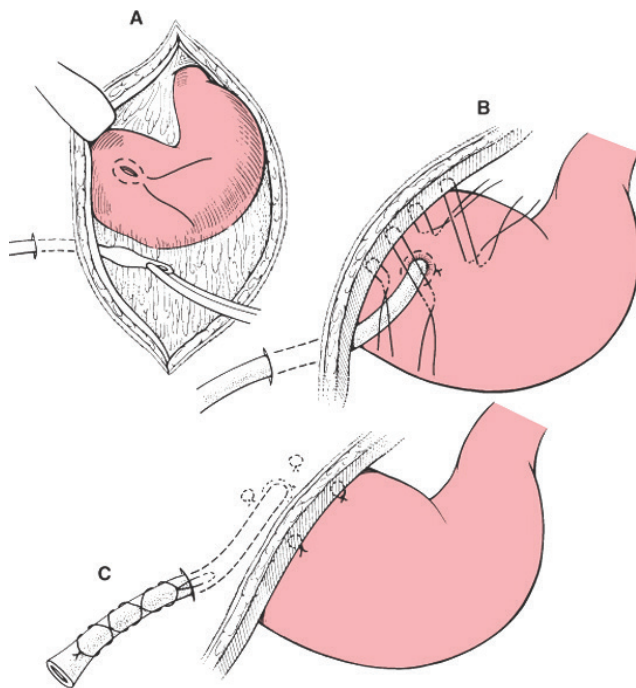


Figure 4. Tube gastropexy. Placement of a tube during laparotomy with 4 extra sutures between stomach and abdominal wall. Source: Fossum T.W. (2007). *Small animal surgery*. 3th Edition, Missouri, USA, Mosby Elsevier, p. 409-433.

the resulting adhesions will prevent the stomach from rotating. The tube gastropexy via (flank) laparotomy was originally described as a quick and relatively simple technique to allow gastric decompression and the administration of medications after GDV surgery. The percutaneous tube gastropexy can also be performed as an elective technique (Figure 4).

A Foley catheter is passed through a stab incision in the right abdominal wall and through the stomach wall into the gastric lumen. The catheter's cuff is then inflated and the stomach is pulled tightly against the abdominal wall by traction on the catheter. The tube should be kept in place for at least 7 to 10 days in order to achieve a permanent adhesion. The tube can also be placed during a laparotomy. Three or four sutures can then be placed between the pyloric antrum and the body wall to ensure a good adhesion (Fossum, 2007).

The risk of gastric content leakage is minimal but when the procedure is performed improperly it may result in peritonitis (Broome en Walsh, 2003; Fossum, 2007). The morbidity rates associated with this technique may be high because of altered gastric myoelectric activity (Stampley et al., 1992; Hosgood, 1994).

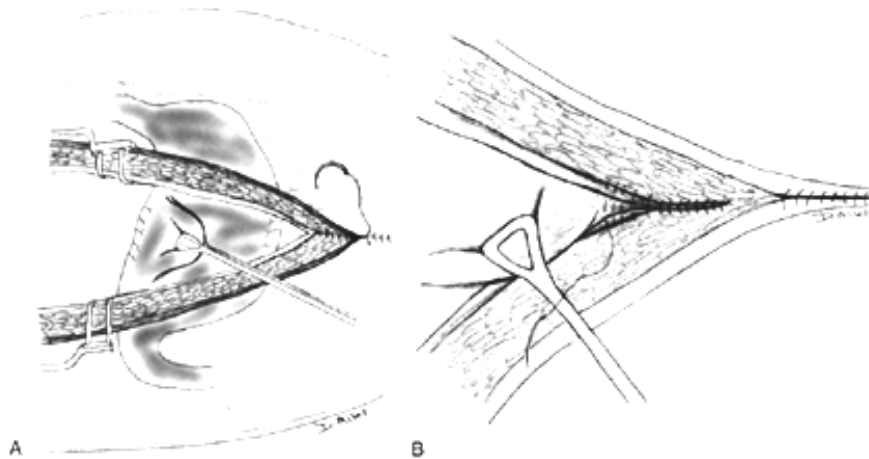
An experimental study evaluating percutaneous gastropexy found that only 4 of 7 dogs effectively developed adhesions between the stomach and abdominal wall at 58 days after placement. The tensile strength of this gastropexy was only one third (22 N) of that of the control group (7 dogs) where an incisional gastropexy (60 N) was performed (Waschak et al., 1997). A tube gastropexy performed by laparotomy instead of percutaneous PEG tube placement, had breaking strengths around 63 N (Johnson et al., 1984). The incidence of GDV with this technique is reported to be 5-11% (Johnson et al., 1984; Fox, 1985).

### Incorporating gastropexy

This simple and rapid method of gastropexy involves incorporating a portion of the pyloric antrum in the linea alba suture line during abdominal closure. A length of 5 cm of gastric wall is captured by passing the suture needle through the seromuscular layer of the stomach in between two linea alba incision margin bites. This technique does therefore not include a gastric incision (Meyer-Lindenberg et al., 1993) (Figure 5).

Since additional surgeries might encounter problems during midline abdominal approach, leading to inadvertent gastric opening, this technique is only advised when the patient is unstable and rapid closure is necessary (Rasmussen, 2003; Fossum, 2007).





*Figure 5. Incorporating gastropexy. Incorporation of the pyloric antrum in the linea alba suture.*

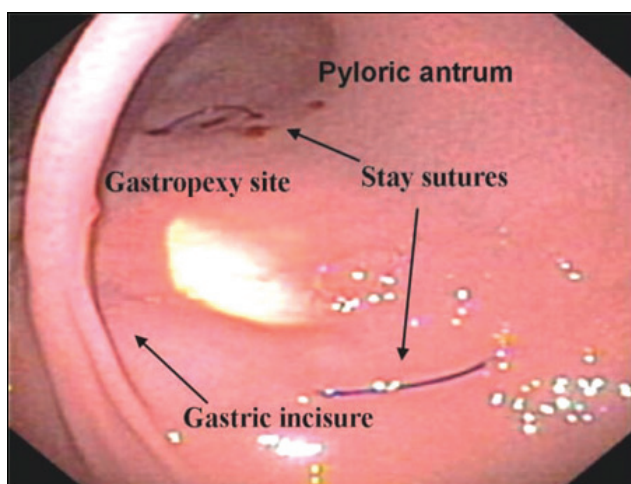
*Source: Rasmussen, LM. (2003) Stomach. In: Textbook of Small Animal Surgery. Ed. Slatter. D., 3th edition, Philadelphia, USA, Saunders, p 592-640.*

A low incidence of GDV of 6% was reported in a large retrospective study (4/63 dogs) (Meyer-Lindenberg et al., 1993). There are no studies available that evaluate the tensile strength of the incorporating gastropexy.

## Minimally invasive techniques

### Endoscopic-assisted gastropexy

Because the right position of the pyloric antrum can be determined by insufflation and visualization of the stomach with an endoscope the gastropexy can be performed through a mini-laparotomy in the flank (Figure 6). This technique involves insufflation of the stomach and concurrent use of endoscopy to provide surgeons with adequate visibility during percutaneous placement of stay sutures into the region of the pyloric antrum. The stay



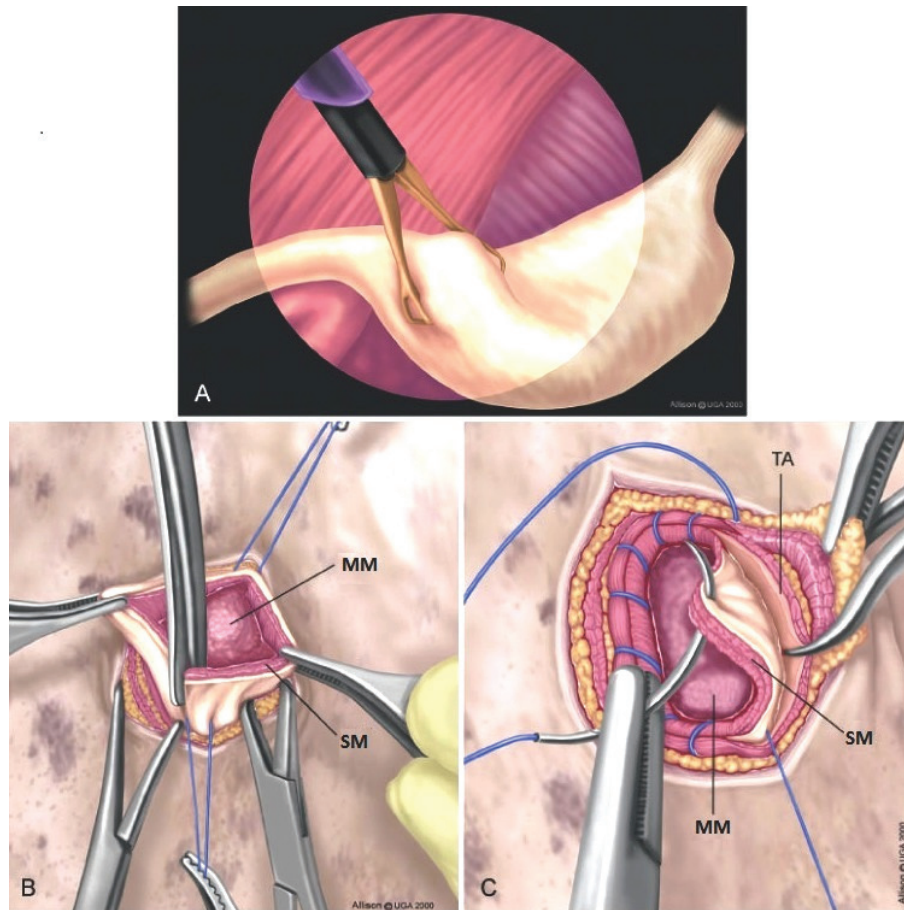
*Figure 6. Endoscopic assisted gastropexy. Use of a gastroscope to guide the placement of percutaneous stay sutures. The stay sutures are then pulled taut to place the stomach directly against the body wall.*

*Source: Dujowich M., Reimer S.B. (2008). Evaluation of an endoscopically assisted gastropexy technique in dogs, American Journal of Veterinary Research 69, 537-514.*

sutures then are pulled taut in an effort to place the stomach directly against the body wall. An incision between the stay sutures is made through the skin, subcutaneous tissues and layers of the abdominal musculature and subsequently a longitudinal incision of approximately 4 cm is made through the serosal and muscular layers of the pyloric antrum. The seromuscular layer is sutured to the transverse abdominal muscle by use of 2 separate continuous patterns. The external abdominal oblique muscle is closed in a simple continuous pattern and subcutaneous tissue and skin are closed in a routine manner (Dujowich et al., 2010). Mean duration of the procedure was determined at 22 min. No major surgical or anaesthetic complications were reported. Only mild gastrointestinal complications such as vomiting and diarrhoea occurred shortly after surgery and resolved without any medical intervention. A possible difficulty during the procedure is to achieve an appropriate position of the stomach during insufflation. The stomach must make contact with the abdominal wall caudal to the 13th rib to enable gastropexy. This may contribute to the duration of the procedure as a result of the need to reposition the patient. No occurrence of GDV was reported in 23 dogs during a mean follow up period of 1.4 months after surgery. Dujowich et al. (2010) however did not evaluate the ultimate load necessary to cause failure at the adhesion site but assumed a similar failure load of 106.5 +/- 45.6 N as reported for laparoscopic-assisted gastropexy.

### Laparoscopic-assisted gastropexy (with mini-laparotomy)

The pylorus is identified and pulled against the right ventral wall with laparoscopic techniques and the gastropexy is then performed through a mini-laparotomy (Figure 7). After insufflation of the abdomen with carbon dioxide, a laparoscope is placed through a 5 or 10 mm cannula in-



*Figure 7. Laparoscopic assisted gastropexy with mini-laparotomy. A, The pyloric antrum is grasped with a laparoscopic Babcock forceps and pulled against the abdominal wall. B, The canula opening is extended to a mini laparotomy and an incision is made in the seromuscular layer of the stomach. C, The seromuscular layer of the stomach is sutured to the transverse abdominal muscle. Source: Rawlings C.A., Foutz T.L., Mahaffey M.B., Howerth E.W., Bement S., Canalis C. (2001). A rapid and strong laparoscopic-assisted gastropexy in dogs. American Journal of Veterinary Research 62, 871-875.*

serted in the ventral midline 2 to 3 cm caudal to the umbilicus. A second 10 mm cannula is placed lateral to the right margin of the rectus abdominis and 3 cm caudal to the last rib. A laparoscopic Babcock forceps is passed through the second cannula to grasp the pyloric antrum. The Babcock forceps and pyloric antrum are exteriorized by removing the right side cannula and extending the incision to 4 cm in a direction parallel to the last rib. Subsequently an incision of 4 cm is made through the serosa and muscular layer of the pyloric antrum and this is sutured to the transverse abdominal muscle. The oblique abdominal muscles, subcutaneous tissue and skin are closed routinely (Rawlings et al., 2001; Rawlings et al., 2002; Rawlings, 2002).

The 8 dogs from the original study of Rawlings et al. (2001) developed only minimal postoperative complications and none of them had gastrointestinal problems within 1 month of surgery. Another study however reported the following possible complications: skin fold at the side of the gastropexy immediately after the surgery (47%), seroma formation at the site of gastropexy (6%) and iatrogenic perforation of the splenic capsule during trocar placement (12%) (Urbanová et al., 2011). In case of iatrogenic splenic trauma, the bleeding can often be stopped by gentle compression with an atraumatic instrument but in some cases more severe haemorrhage can occur and this may

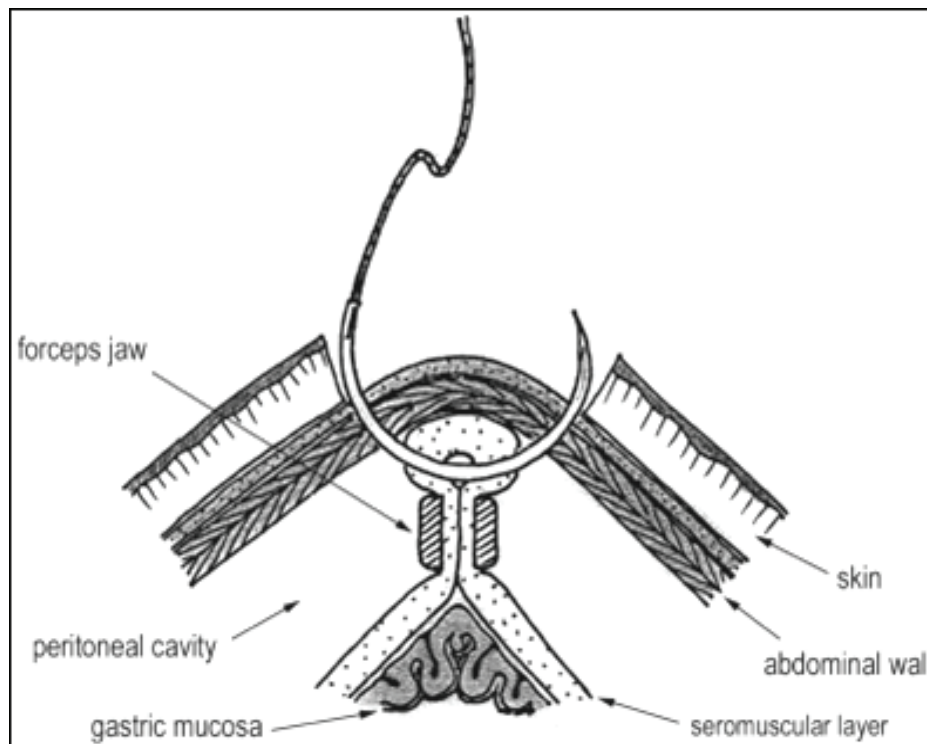
necessitate conversion to a conventional (midline) coeliotomy. Another possible difficulty during a laparoscopic procedure is the entrapment of the stomach by omentum. This can be solved by grasping the omentum with an atraumatic forceps. The performance of a laparoscopic (assisted) procedure can also be technically a lot more challenging in obese animals because of large amounts of adipose tissue in the abdominal cavity (Urbanová et al., 2011).

A study using positive contrast gastrography 25 days after surgery revealed normal stomach position and gastric emptying. The mean ultimate load of the adhesion in tension is reported to be 106.5 +/- 45.6 N (Rawlings et al., 2001). Another study using this technique in 23 dogs reported no occurrence of GDV within 1 year after gastropexy (Rawlings et al., 2002).

### **Laparoscopic-assisted gastropexy (without mini-laparotomy)**

The gastric wall is pulled against the abdominal wall using laparoscopic techniques and is then fixed with percutaneous sutures (Figure 8).

Pneumoperitoneum is performed and the camera-cannula is placed caudal to the umbilicus and two additional instrument portals are introduced in the midline 6-7 cm cranial and caudal to the umbilicus. The pyloric antrum is grasped



**Figure 8.** Laparoscopic assisted gastropexy without mini-laparotomy. A. The peritoneum is cut at the proposed gastropexy site using a coagulation hook probe and the pyloric antrum is grasped and pulled to the abdominal wall. B. Four sutures are placed through the intact abdominal wall musculature and seromuscular layer of the stomach.

Source: Mathon D.H., Dossin O., Paliarne S., Cremoux M., Rodriguez H., Meynaud-Collard P., Steiner J.M., Suchodolski J.W., Lefebvre H.P., Autefage A. (2009). A Laparoscopic-sutured gastropexy technique in dogs: mechanical and functional evaluation. *Veterinary Surgery* 38, 967-974.

and lifted towards the right ventral abdominal wall. The appropriate peritoneal area is located 3 cm caudal to the 13th rib and 3–4 cm lateral to the right rectus abdominis muscle. The peritoneum and gastric serosa are cut at the gastropexy site using a coagulation hook probe. Subsequently a skin incision is made along the gastropexy site while transilluminating the area from inside the abdomen. Four sutures are then placed through the intact abdominal wall and seromuscular layer of the stomach. The sutures are all tied extracorporeally with the knots buried in the subcutaneous tissue. After deflation of the abdomen, the skin and subcutaneous tissue superficial to the extracorporeal sutures are closed in a simple continuous pattern and the cannula openings are closed routinely. Mean duration of surgery is estimated at 40 min. Potential mucosal penetration by the suture material is a possible complication with this technique (Mathon et al., 2009).

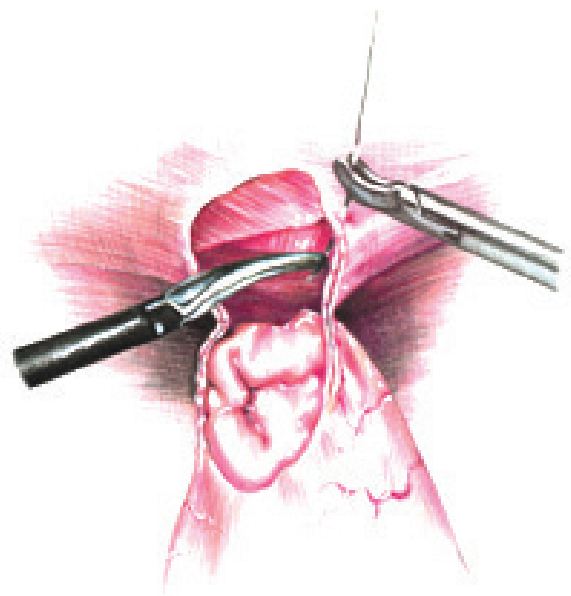
Radiographic evaluation 10 weeks postoperatively revealed only minor changes in gastric emptying (Mathon et al., 2009).

Mean tensile force to disrupt adhesions 10 weeks after surgery is determined to be 51.1 +/- 16.4 N. (Mathon et al., 2009).

### Laparoscopic gastropexy (intracorporeal suturing)

Mayhew and Brown (2009) described a completely laparoscopic gastropexy technique based on intracorporeal suturing (Figure 9).

In this technique the 3 portals are all placed in the ventral midline. The caudal instrument cannula is in an infraumbilical position, the cranial instrument cannula is 3–4 cm caudal to the xyphoid process and the camera cannula is midway between the other 2 portals and directly medial



**Figure 9.** Laparoscopic gastropexy with intracorporeal suturing. Suture material is passed through a cannula or percutaneously and is used to suture the incision in the transverse abdominal muscle to the incision in the pyloric antrum using two laparoscopic needle holders.

Source: Sanchez-Margallo F.M., Diaz-Güemes I., Usón-Gargallo J. (2007). Intracorporeal suture reinforcement during laparoscopic gastropexy in dogs. *Veterinary Record* 160, 806-807.



to the proposed site of gastropexy. A laparoscopic Metzenbaum scissors is used instead of electrocoagulation to make the incisions in the abdominal and gastric wall. An approximately 30 cm length of suture is then passed through a cannula or percutaneously and is used to suture the incision in the transversus abdominis muscle to the antral incision using 2 laparoscopic needle holders. Mayhew and Brown (2009) suggested that it is easier to suture the 2nd side of the gastropexy if the orientation of the incisions is parallel to the ventral midline rather than perpendicular to the dog's ventral midline. Median gastropexy time of this procedure is reported to be about 48 min (Mayhew and Brown, 2009).

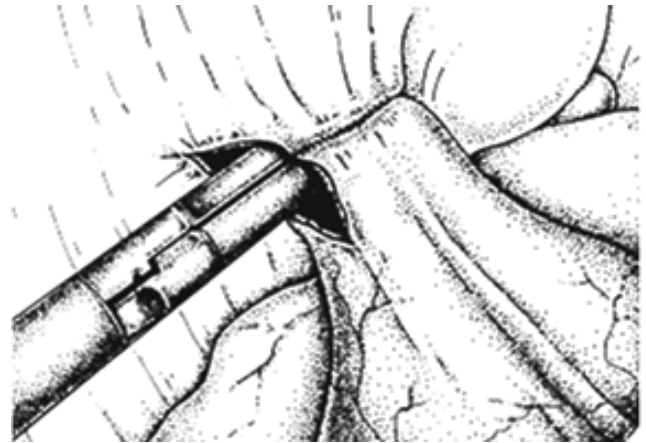
Mayhew and Brown (2009) also described a modified intracorporeal sutured laparoscopic gastropexy using a suture-assist device (Endostitch, Autosuture, United States Surgical Corporation, Norwalk, Connecticut). This device consists of a double sharp tipped straight needle and has a suture attached to the middle of the needle. This needle can be switched between the jaw tips of the device by closing the handles and flipping toggle levers. This allows the suture to be passed through tissues when the tissue is interposed between the jaw tips. Similarly, passing the needle from tip to tip allows knots to be tied. The rest of the procedure is similar to the hand-sutured technique. The median gastropexy time of this technique is reported to be 56 min. No major complications were reported during the procedure or postoperatively. Intracorporeal suturing is technically challenging and demands the right instrumentation. A difficulty occurring with a total laparoscopic technique is the adequate length of suture material (approximately 30 cm) that must be introduced into the peritoneal cavity to complete the suture line. However, it is not recommended to introduce excessive amounts of suture material, which makes intracorporeal suture handling laborious and increases the chances of inappropriate knot formation (Mayhew and Brown, 2009).

Mayhew and Brown (2009) have proved that dogs undergoing total laparoscopic gastropexy are significantly more active in the postoperative period than dogs that had a laparoscopic assisted gastropexy.

The maximum tensile strength and risk of developing GDV with an intracorporeally sutured gastropexy technique has not yet been determined.

### Laparoscopic gastropexy (intracorporeal stapling)

The gastropexy is performed completely laparoscopically and both incisions are connected using a stapler (Figure 10).



*Figure 10. laparoscopic gastropexy with intracorporeal stapling. The stomach is attached to the right abdominal wall using a endo GI stapler firing 6 rows of staples and cutting between the middle two rows.*

*Source: Hardie R.J., Flanders J.A., Schmidt P., Credille K.M., Pedrick T.P., Short C.E. (1996). Biomechanical and histological evaluation of a laparoscopic stapled gastropexy technique in dogs. Veterinary Surgery 25, 127-133.*

During this procedure, a 2 by 5 cm submucosal tunnel is made in the ventral aspect of the pyloric antrum with a Metzenbaum scissors. A similar tunnel is made in the adjacent right lateral abdominal wall between the transverse and internal abdominal oblique muscles at the proposed gastropexy site. A laparoscopic stapler (endo GIA stapler, United States Surgical Corporation, Norwalk, Connecticut) is used to staple the stomach to the right abdominal wall by placing six rows of tissue staples and cutting between the middle two rows. A laparoscopic hernia stapler is then used to close the tunnel opening with three to six staples placed individually while apposing the tissues with a grasping instrument. The mean surgical time for this procedure was determined at 130 min. (Hardie et al., 1996). Reported complications are stomach perforation (2/14 dogs), splenic puncture (2/14 dogs) and subcutaneous emphysema (4/14 dogs). The mean tensile load to failure at 7 days was 44.86 N and at 30 days 72.39 N (Hardie et al., 1996).

Sanchez-Margallo et al. (2007) described a procedure involving laparoscopic gastropexy with combined stapling and intracorporeal suturing. A seromuscular tunnel is created in the pyloric antrum and a tunnel of the same size was created in the right abdominal wall by making an incision between the abdominal muscles just caudal to the last thoracic rib. The two tunnels are apposed and attached to each other using a stapler device. The imperforate stoma resulting from the anastomosis of the two tunnels is closed with an intracorporeal simple interrupted suture

pattern. Mean duration of this technique is about 73 min. No particular intraoperative difficulties or postoperative complications are reported with this technique.

## Discussion

Gastropexy is proven to be very effective in preventing GDV (Glickman et al., 1998; Ward, 2003). The ideal gastropexy is quick and simple to perform, permanently attaches the stomach to the abdominal wall in an anatomic position to prevent volvulus, does not alter gastric function and has minimal intra-operative and postoperative complications (Rawlings et al., 2001). The gastric muscle must be in contact with the abdominal musculature to create a permanent attachment because an intact gastric serosa does not form permanent adhesions to an intact peritoneal surface. Therefore, the mesothelium of the gastric serosa and peritoneum either has to be removed, cauterized or incised (Fossum, 2007). An adequate gastropexy should be at least 3 cm in length (Dujowich et al., 2010) and the optimal time for performing preventive gastropexy is said to be 6-8 months of age (Monnet, 2003). It can be performed at the time of an abdominal exploration or an ovariohysterectomy (Monnet, 2003).

In the past, a lot of different techniques have been described to perform a permanent gastropexy. The first developed techniques are all performed through an open midline coeliotomy. The three most recommended of these methods are incisional, circumcostal and belt-loop gastropexy. Circumcostal and belt-loop gastropexy reduce the risk to develop GDV to 0-6% (Woolfson and Kostolich, 1986; Leib et al., 1985, Whitney et al., 1989, Schulman et al. 1986) and they both result in a very strong adhesion of the pyloric antrum to the abdominal wall (109N) (Fox et al., 1985; Wilson et al., 1996). These techniques however are technically more challenging and possible complications include iatrogenic pneumothorax, ribfracture and peritonitis (Woolfson and Kostolich, 1986; Leib et al., 1985; Rasmussen, 1997, Rasmussen, 2003). Nevertheless these complications are rare when the procedure is performed by an experienced surgeon. Although resulting in an inferior tensile strength (60-85N) (Fox et al., 1985; Hardie et al., 1996; Waschak et al., 1997) the incisional technique is preferred by a lot of surgeons because of the reduction in incidence of GDV (0-4%) and low morbidity associated with the procedure (MacCoy et al., 1982; Glickman et al., 1998). Because of potential inadvertent gastric incision during a second coeliotomy, an incorporating gastropexy should only be used in cases where abrupt discontinuation of an-

aesthesia is required. Tube gastropexy should not be used because of the high incidence of GDV (5-11%) (Johnson et al. 1984; Fox et al., 1985) and the altered gastric myoelectric activity (Stapley et al., 1992, Hosgood, 1994), which is probably caused by the incision of all gastric layers when this technique is used.

The traditional techniques require a (midline) coeliotomy with the attendant risks of morbidity and mortality. In an effort to decrease these risks, several investigators have developed minimally invasive techniques for gastropexy. Some of these techniques are endoscopically or laparoscopically assisted whilst others are completely laparoscopic. The advantage of these techniques are smaller surgical wounds accompanied by less pain, a better cosmetic result, lower risk of blood loss, shorter hospitalisation time and a faster recovery (Dujowich et al., 2010; Urbanová et al., 2011). The endoscopy-assisted gastropexy appears to be an excellent alternative to create a permanent adhesion of the stomach to the abdominal wall (Dujowich et al., 2010). This technique requires only 1 incision compared to 2 incisions for the laparoscopic-assisted gastropexy. Another advantage over the other less invasive techniques is that the required instrumentation might already be more widely available in veterinary practices than the equipment for laparoscopic techniques.

Although laparoscopic and endoscopically assisted techniques are less invasive than the "open" approach, these techniques still require a full thickness incision through the skin and abdominal muscles, which can be painful and result in incisional complications (e.g. seroma and fistula formation) (Mayhew and Brown, 2009).

The total laparoscopic techniques might be technically more difficult to perform but they are associated with a decrease in incisional complications and a significant decrease in time required to regain normal activity post-operatively (Mayhew and Brown, 2009). Another great advantage of the laparoscopic approach is the possibility to evaluate most abdominal cavity organs without the necessity of enlarging the incision as in classical coeliotomy and concurrently, the possibility to take biopsies in case of pathological findings (Urbanová et al., 2011). The major drawback of all laparoscopic procedures is the need for expensive instruments and the duration of the procedure. The use of laparoscopic staplers or a suture-assist device (Endostitch™) surprisingly does not decrease the surgical time (Mayhew and Brown, 2009; Hardie et al., 1996) and therefore intracorporeal hand suturing should be preferred over the use of expensive endomechanical devices. Although laparoscopic procedures may take longer, practice

and increased surgical efficiency lead to a significant decrease in surgery time (Dujowich, 2010). The mean maximum tensile strength of gastropexy adhesions acquired with minimal invasive techniques (51-72N) is lower than those of the coeliotomy techniques (Hardie et al., 1996; Mayhew and Brown, 2009; Mathon et al., 2009). However, care should be taken when interpreting these results. In the different studies examining the strength of the gastropexy, these tests were performed at different times after surgery and different suture material (absorbable vs. non-absorbable) was used, which may influence the results. In addition, the strength of an adhesion required to prevent gastric volvulus is not known and breaking strength has not been correlated with clinical efficiency (i.e. a reduction in incidence rate of volvulus) (Rawlings et al., 2001).

Overall, minimal invasive techniques can be considered as a good alternative to open coeliotomy gastropexies. Despite the greater effort needed to acquire these skills and the longer surgical times, studies have proven the efficiency of these techniques regarding incidence rates, postoperative complications and patient comfort. Therefore the use of training simulators and further specialized training is recommended to enhance a surgeon's skills and reduce the time needed for a prophylactic laparoscopic gastropexy so this technique can become the new gold standard.

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# One Health Conference

## *Abstracts of the presentations*

Antimicrobial resistance (AMR), anthroponotic and zoonotic health issues are of great importance to human health and veterinary practice. On 13 October 2014, a One Health Conference was organised by the Bella Moss Foundation in London. The programme included presentations and panel discussions addressing critical aspects of antimicrobial resistance and infection control, with particular emphasis on anthroponotic and zoonotic considerations, thus meeting the imperative of the One Health theme. The conference featured presentations by influential and respected authorities – both of the veterinary and medical fields - with key roles in both the development and direction, and in research relevant to the topic areas, and highlighted areas where current approaches need to be developed and reinforced. By publishing the conference proceedings and conclusions in this issue of EJCAP, FECAVA supports the Bella Moss Foundation in disseminating and raising awareness of the One Health approach relating to responsible antimicrobial use and disease control.

EJCAP (2014), Winter 24(4); p67-p88 Go to <http://www.fecava.org/ejcap> to see the online presentation of these papers, including highlights and interview with the authors.

### **Session 1: Antimicrobial resistance and responsible antimicrobial use**

**Chair: Prof Peter Borriello, Chief Executive,  
Veterinary Medicines Directorate**

- Antimicrobial resistance and responsible antimicrobial use: a global challenge  
**Prof Anthony Kessel**, *Director, Public Health England*
- Animal and human interaction, and travel, as effectors of antimicrobial resistance  
**Prof Neil Woodford**, *Head, Antimicrobial Resistance and Healthcare Associated Infections Reference Unit, Public Health England*
- Hospitals, practices, agriculture and aquaculture: is responsible antimicrobial use working?  
**Prof Malcolm Bennett**, *Prof of Veterinary Pathology, University of Liverpool*
- Panel discussion: Making responsible antimicrobial use policy work.  
*Chair* **Prof Bob Michell**, *Formerly Vice-Chairman, Comparative Clinical Science Foundation.*

### **Session 2: Zoonosis and infection control**

**Chair: Prof Jodi Lindsay, Prof of Microbial  
Pathogenesis, St George's, University of London**

- Zoonosis and infection control: bringing together human and veterinary medicine  
**Prof Michael Day**, *Prof of Veterinary Pathology, University of Bristol Veterinary School*
- Emerging zoonotic diseases: new threats for old?  
**Prof David Heymann**, *Prof of Infectious Disease Epidemiology, London School of Hygiene and Tropical Medicine*
- Are infection control policies fit for purpose?  
**Prof Dirk Pfeiffer**, *Prof of Veterinary Epidemiology, Royal Veterinary College, London, and Prof Tony Barnett, London School of Hygiene and Tropical Medicine*
- Panel discussion: Making infection control work.  
*Chair* **Prof Bob Michell**, *Formerly Vice-Chairman, Comparative Clinical Science Foundation.*



## AMR: top priority for FECAVA

FECAVA is a long-standing advocate of the responsible use of antibiotics. Its working group on hygiene and the use of antimicrobials in veterinary practice (founded in 2007) produced several posters for veterinary practitioners (see Fig. 1). In 2013, FECAVA organised a symposium on the topic, which was reported in detail in the EJCAP 2013 winter issue. FECAVA is also member of EPRUMA, the European platform on the responsible use of medicines in animals, and together with the Federation of Veterinarians of Europe, it has produced a leaflet for pet owners on the responsible use of antimicrobials.

Due to their involvement in contingency planning against the Ebola virus threat, some authors were unable to provide us with a full abstract in time for publication.

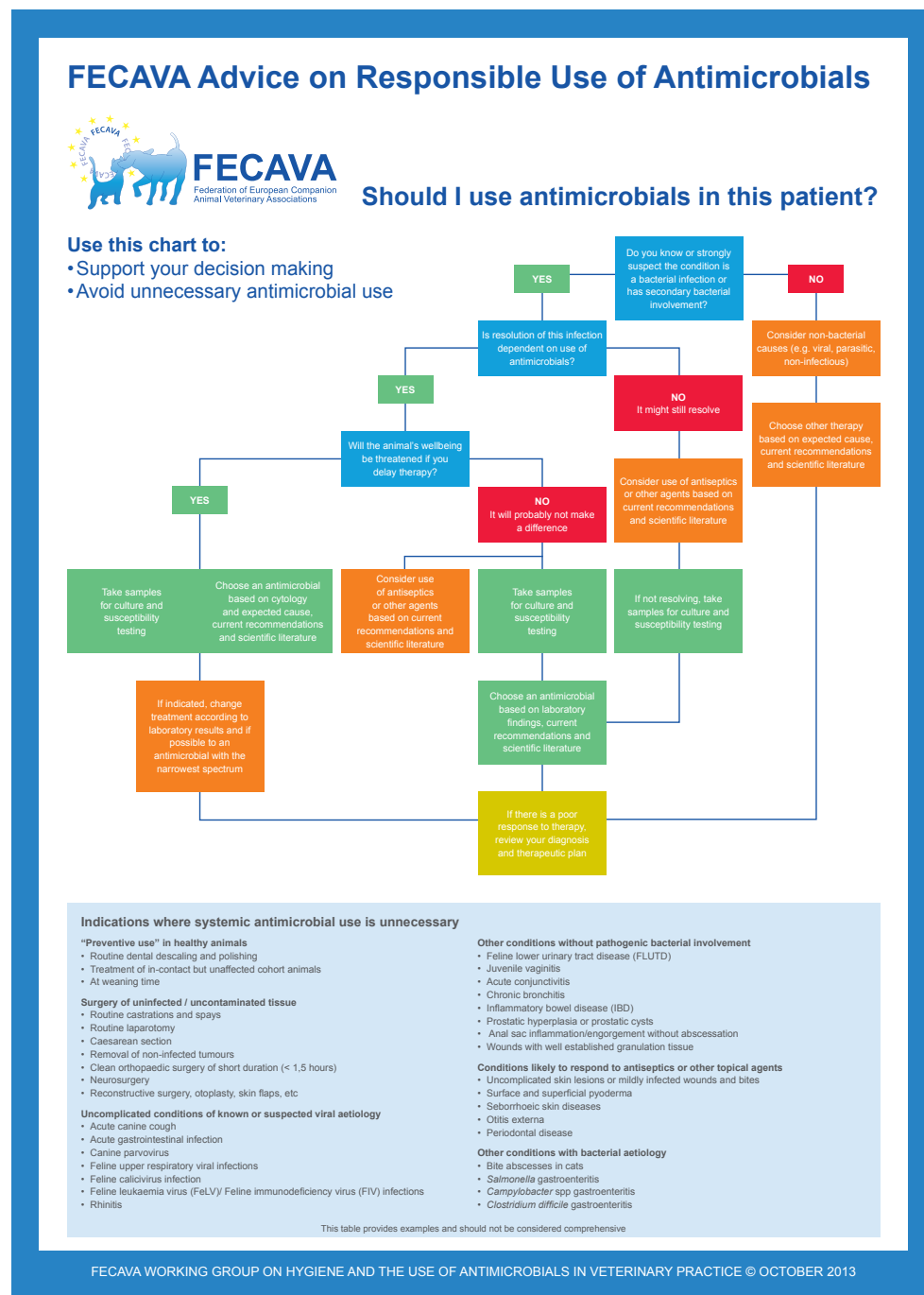


Fig. 1. One of several posters produced by FECAVA to help combat antimicrobial resistance



# Antimicrobial resistance and responsible antimicrobial use: a global challenge

*Anthony Kessel<sup>1</sup>*

Abstract of the presentation given at the One Health Conference held in London on 13 October 2014, organised by the Bella Moss Foundation together with the Royal Society of Medicine.

EJCAP (2014), Winter 24(4); p69.

Go to <http://www.fecava.org/ejcap> to see the online presentation of this paper (including an interview with the author)

## Abstract

Antimicrobial resistance (AMR) is a global health challenge of huge significance. The costs and adverse health consequences of AMR are now well established, but the path to addressing this testing issue is daunting. In this talk I first provide the historical backdrop and outline the global nature of AMR, before focusing on action to tackle AMR in this country. The connections between animal and human health are explored in terms of the philosophical separation of man from nature and the particular problems this poses for the One Health approach.

<sup>1</sup> Professor Anthony Kessel, Director of Public Health Strategy, Public Health England, London, UK



# Animal and human interaction and travel as effectors of antimicrobial resistance

Neil Woodford<sup>1</sup>

Abstract of the presentation given at the One Health Conference held in London on 13 October 2014, organised by the Bella Moss Foundation together with the Royal Society of Medicine.

EJCAP (2014), Winter 24(4); p70-71.

Go to <http://www.fecava.org/ejcap> to see the online presentation of this paper.

## Abstract

Antibiotic resistance is now recognised and publicised widely as a global issue that threatens humanity, specifically our ability to treat and prevent bacterial diseases. The problem is hugely complex with multiple factors contributing to rising rates of resistance in many bacterial species. The epidemiology of resistance varies with each 'bug/drug' combination, but can involve any or all of: emergence through mutation; spread of transferable resistance genes between bacterial strains, species and genera; spread of resistant organisms; movement of infected or colonized 'patients' (which may be humans or animals); diverse environmental reservoirs; and contaminated foodstuffs. Resistance is fundamentally a natural phenomenon; it is a bacterial response to the adverse growth conditions exerted by exposure to antibiotics. Any use of antibiotics contributes selective pressure and encourages spread of resistant strains. Antibiotics are used not only in human medicine, but also in the veterinary sector for treatment and/or prevention of disease in companion and food-producing animals and in agriculture for crop production. Furthermore, there is highly varied use of antibiotics across the globe, not just in the quantities used but in how they are used, which ranges from highly-regulated prescription-only use to extensive over-the-counter availability and growth promotional use in animals (a practice banned in the EU). These different practices contribute to marked regional differences in the

prevalence of resistant bacteria. Geographic resistance 'hot spots' pose a risk to low prevalence areas through travel since bacteria do not respect geopolitical boundaries. Humans are major vectors for the international spread of resistance and many resistant bacteria are disseminated via this route, including *Mycobacterium tuberculosis*, methicillin-resistant *Staphylococcus aureus*, penicillin-resistant *Streptococcus pneumoniae*, drug-resistant *Neisseria gonorrhoeae* and multi-resistant Enterobacteriaceae with extended-spectrum beta-lactamases (ESBLs) or, most recently, carbapenemases.

The extent to which non-human reservoirs of resistant bacteria (in animals, food and the environment) pose a public health risk is often hotly debated. The link is clear for zoonotic bacteria such as *Campylobacter*, non-typhoidal *Salmonella* and *E. coli* O157, but it is far more contentious for commensal organisms spread via the faecal-oral route, such as enterococci and non-toxigenic *E. coli*. These may cause infection, or may simply colonise human hosts asymptomatically; in a third scenario they may pass transiently through the human gut, but act during their transit as sources of resistance genes, which may be transferred to resident gut flora. Here, detailed analyses of bacterial strains and their resistance elements are required to define the extent of overlap between the types found in non-human sources and those responsible for the burden of human disease. National and global action plans to combat resistance consistently seek (i) to reduce or (ideally) eliminate inappropriate use of antibiotics in every sector,

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(ii) to link better data on antibiotic usage with resistance data, and (iii) to reduce the numbers of infected/colonized individuals or levels of environmental contamination. More comprehensive surveillance schemes are essential across all sectors and capacity to deliver must be supported in developing countries. Surveillance must be underpinned by good microbiology to identify the key public health risks. By so doing, our limited resources can be directed towards the most appropriate interventions.

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# Hospitals, practices, agriculture and aquaculture: is responsible antimicrobial use working?

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## Abstract

The title of this talk covers a huge area and asks a question as yet impossible to answer: so rather than taking the title head-on, the presentation will focus on a few issues associated with the veterinary use of antimicrobials and resistance in animals and the environment, and discuss some of the questions arising from these in terms of stewardship and policy.

In the UK (and similarly in many 'developed' countries - but by no means globally), antibiotics are used in non-human animals only under licence, with particular restrictions on their use in food animals to ensure that antibiotics do not enter the human food chain.

The use of antibiotics as growth promoters has been banned in Europe since 2006 - although this move was arguably based more on taking a precautionary approach than hard evidence. Furthermore, most of the antibiotics used in non-human animals are older drugs, rather than the newer antibiotics used in human animals.

In companion (pet) animal medicine the drivers for antibiotic use are probably similar to those in human medicine: health and welfare but with extra pressures (emotional and financial) from clients (in this case the owners of the patients) who want 'something'. In farm animals, the main driver is arguably production - a combination of welfare and economics - and the decision of whether or not to use antibiotics is very much one of costs and benefits. Such calculations can be quite complex as they involve not just the cost of treatment and loss

of production through disease, but losses in production through the very use of antibiotics (e.g. milk from treated animals having to be discarded), and, combined with some anomalies in licensing, can result in perverse incentives to do other than the 'right' thing.

All of this has led some policy makers to suggest tighter restrictions on the use of antibiotics in non-human animals - the underlying argument being that use in animals will select for resistance genes and resistant bacteria that will, in turn, be transmitted to humans. However, while there is evidence for the transfer of resistance from non-human to human animals (and in the other direction), there is little evidence that such transmission underlies the problems faced in human medicine and is a significant burden on public health: indeed, with a few exceptions, antibiotic resistance is not generally regarded as a clinical problem in veterinary medicine, so what, it might be argued, is there to be transmitted to people?

Looking at resistance in the environment - including in wildlife - allows some of these issues of evolution, ecology and cross-host-species transmission to be thought about without the distractions of a policy blame game. It turns out that many wildlife species, in many parts of the world, carry antibiotic-resistant bacteria, without there being clear mechanisms of selection for that resistance, while evolutionary and 'fossil' studies suggest antibiotic resistance genes have always been around - or at least for tens of thousands of years.

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So transmission is complex and selection for resistance is complex: and this means that control of resistance is also likely to be complicated. Evidence-based stewardship of antibiotics - based on recognizing their enormous value to human society and seeking antibiotic sustainability - is doubtless the way forward, but requires a greater understanding of human behaviour and the drivers of antibiotic use, not just at home but internationally: it is still the case that globally more people die of treatable infections (i.e. lack of access to antibiotics) than of resistant infections. And we need to understand a lot more about not just resistance in humans, livestock and our pets but our environment more generally.

In other words, here is a problem that requires a truly interdisciplinary, global and One Health solution.





# One Health: Bringing Together Human and Veterinary Medicine

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## ABSTRACT

In the past decade there has been renewed interest in the concept of the 'One Health' approach to addressing significant global problems in human and animal healthcare. There is no universally accepted definition of One Health, but the concept is underpinned by the principle of multidisciplinary teamwork involving human medical and veterinary professionals working collaboratively with a wide spectrum of scientific, sociological, economic and political experts.

This paper reviews the recent history of One Health and exemplifies the concept by examining the work of the One Health Committee of the World Small Animal Veterinary Association (WSAVA). The mission statement of this group is 'to ensure the prominence of the small companion animal-human interface in the global One Health agenda'. The committee focuses on three elements of One Health related to small companion animals: (1) the human-companion animal bond, (2) comparative and translational medicine, and (3) zoonotic infectious disease. In the context of the latter, the committee has called for surveillance of companion animal zoonoses and promoted programmes for control of the two most significant of these: canine rabies and leishmaniosis. The committee is also a partner in the EU-funded CALLISTO project, which will make recommendations on the surveillance and control of companion animal zoonoses in Europe.

Key words: One Health, World Small Animal Veterinary Association, dog, cat

## What is One Health?

There is no universally accepted definition of 'One Health' and attempts to formulate one have occupied many hours of expert discussion. The definition favoured by this author is that One Health encapsulates the reunification

of the medical and veterinary professions with the establishment of collaborative ventures in clinical care, surveillance and control of cross-species disease, education, and research into disease pathogenesis, diagnosis, therapy and vaccination. In fact, One Health is an evolving concept which has moved from initial

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consideration of medical and veterinary healthcare to incorporate the area of 'environmental health' which impacts on both of the former areas. The idea of the 'One Health Triad' linking human, animal and environmental health is now commonly promulgated.

## Is One Health a New Idea?

The answer to this question is clearly 'no'. The comparative (human and animal) approach to the study of disease dates to the ancient civilizations, and throughout the millennia key scientific advances have been underpinned by investigations focusing on equivalent problems in man and animals<sup>[1]</sup>. The formalized One Health approach in more recent history is often attributed to the founder of the first veterinary school (established in 1761 in Lyon, France), Claude Bourgelat, who wrote: 'We have realised the intimacy of the relation which exists between the human and the animal machines; this relation is such that either medicine will mutually enlighten and perfect the other when we discard a derisory, harmful prejudice'. The greats of 19th century biological research, Louis Pasteur, Robert Koch and Rudolf Virchow all applied the comparative approach. Pasteur's early successes with the development of vaccines were all related to animal diseases and Virchow is attributed with the statement: 'Between animal and human medicine there is no dividing line - nor should there be. The object is different but the experience obtained constitutes the basis of all medicine'. The founder of the Journal of Comparative Pathology and Therapeutics (1888), Sir John M'Fadyean, was a dually trained veterinarian and human medical physician who espoused the One Health approach<sup>[2]</sup>; although historians now suggest that this era of the strengthening of veterinary research was the time that human and animal medicine became dissociated from each other.

The modern father of One Health is generally regarded as the veterinary epidemiologist Calvin Schwabe (1927–2006) who wrote about the concept in his book *Veterinary Medicine and Human Health*<sup>[3]</sup>. In the past decade there have been numerous One Health milestones. An initial focus was achieved by the British Medical Association and British Veterinary Association with the 2005 co-publication of special One Health issues of the British Medical Journal and the Veterinary Record. This was followed by similar discussions between the American Medical Association and the American

Veterinary Medical Association (AVMA) and a One Health focus from the Federation of Veterinarians in Europe. In 2008, a joint meeting on One Health was held between the International Organisation for Animal Health (Office International des Épizooties [OIE]), the World Health Organisation (WHO), the Food and Agriculture Organisation (FAO), UNICEF and the World Bank and the outcome of this meeting was formalized in publication of a tripartite concept note from OIE, WHO and FAO in 2010<sup>[4]</sup>. In the USA, the AVMA One Health Initiative Task Force was formalised into the US One Health Commission which works in parallel with the web-based One Health Initiative. The UK Comparative Clinical Science Foundation has now held several meetings related to comparative and translational clinical research.

The discipline of One Health is now serviced by textbooks such as that edited by Rabinowitz and Conti (2010)<sup>[5]</sup> and the 2012 publication of the popular science text *Zoobiquity* (Natterson-Horowitz and Bowers)<sup>[6]</sup>, which reviews the spectrum of scientific advances made with a One Health approach. There have now been two international One Health conferences, with a third planned for March 2015 in the Netherlands, with regional events such as that organised by One Health for Central and Eastern Africa (OHCEA). The importance of instilling a One Health approach to the next generation of human and veterinary clinicians and researchers is readily shown by the recent introduction of numerous postgraduate programmes in One Health in North American and European universities, the establishment of One Health student forums and the adoption of a One Health theme by many veterinary schools.

**Are Companion Animals Well-represented in One Health?**  
Much of the early focus on One Health related to diseases that might be transmitted to man from farmed livestock species with global attention given to pandemics of avian and porcine influenza, SARS coronavirus and others. As environmental health became part of the One Health platform, interest mounted in wildlife disease and the potential for emergence and re-emergence of infectious diseases from wildlife reservoirs. In all of this, a major group of domestic animals, which most closely share the human environment, were not considered. The breadth of companion animal species is remarkably wide and crosses phyla from insects to mammals. A useful definition of a companion animal comes from the EU-funded 'Companion Animals Multisectorial, Interprofessional

and Interdisciplinary Strategic Think Tank on Zoonoses' (CALLISTO) project<sup>[7]</sup>: 'Companion animals are any domesticated, domestic-bred or wild-caught animals, permanently living in a community and kept by people for company, enjoyment, work (e.g. support for blind or deaf people, police or military dogs) or psychological support – including, but not limited to dogs, cats, horses, rabbits, ferrets, guinea pigs, reptiles, birds and ornamental fish'.

The species most commonly considered as small companion animals are the domestic dog and cat. The numbers of these animals can only be estimated with some 83 million pet dogs and 95 million pet cats kept in 62 percent of American households<sup>[8]</sup> and some 8–10 million pet dogs and similar number of pet cats kept in over one quarter of UK households<sup>[9]</sup>. Estimates of these species in developing countries are even more challenging to make, but one example might be the estimation of around 2.5 million free-roaming dogs in India. The dog in particular has an important role in the lives of rural villagers in many developing countries.

## The WSAVA One Health Committee

The World Small Animal Veterinary Association (WSAVA) comprises of the national small animal veterinary associations of some 80 member countries, together with around 20 specialist affiliate groups, collectively

representing approximately 140,000 small animal veterinarians around the globe. In 2010, the WSAVA established a One Health Committee, which has as a mission statement:

*'To ensure the prominence of the small companion animal-human interface in the global One Health agenda'* <sup>[10]</sup>.

The committee consists of a group of internationally recognized experts representing a breadth of scientific disciplines and nationalities and including delegates from the OIE, the US Centers for Disease Control and Prevention (CDC) and the US National Institutes for Health (NIH) (Table 1). The committee addresses One Health issues related to the three specific areas of small companion animal health and welfare that are elaborated below. Over the past 4 years, the WSAVA One Health Committee has produced a series of scientific papers and conference abstracts, established webpages<sup>[11]</sup> and a facebook page<sup>[12]</sup> and spoken widely to the veterinary and human medical communities. The committee has established the WSAVA Global One Health award, presented annually to an organisation or individual who has made major international contribution to One Health from a small animal perspective (Table 2) and each year presents a separate award to an open poster or oral communication given at the WSAVA Congress that best encapsulates the One Health ideal. The committee is also a partner in the EU-funded CALLISTO project described above<sup>[7]</sup>.

Table 1. Members of the WSAVA One Health Committee

Committee Member	Affiliation	Country
Michael J. Day [Chairman]	University of Bristol	UK
Sarah Cleaveland	University of Glasgow	UK
Chand Khanna	National Institutes of Health	USA
Mike Lappin	Colorado State University	USA
Carol Rubin	US Centers for Disease Control and Prevention	USA
Umesh Karkare	Private Veterinary Practice	India
Gregg Takashima	Private Veterinary Practice	USA
Alex Thiermann	OIE	France
Will Eward	Duke Medical Centre	USA
Ed Breitschwerdt	North Carolina State University	USA
Thijs Kuiken	Erasmus Medical Centre	The Netherlands
Colin Burrows	WSAVA Board Liaison	USA



Table 2. Recipients of the WSAVA Global One Health Award

Year	Recipient	Affiliation
2011	Dr Bernard Vallat (representing the OIE)	International Organisation for Animal Health (OIE), Paris
2012	Professor Ab Osterhaus	Erasmus Medical Centre, The Netherlands
2013	Professor Lonnie King	Ohio State University, USA
2014	Professor Lucille Blumberg	National Institute for Communicable Diseases, South Africa

## The Human–Small Companion Animal Bond

The cornerstone of the work of the One Health Committee lies with the human–small companion animal bond and with the recognition that the relationship between people and working or pet domesticated companion animals is a key element of societal stability. There is now a large literature that proves the human medical benefits of keeping pets and catalogues the associated savings in the human healthcare economy linked to these benefits<sup>[13]</sup>. The use of pets (particularly dogs) in hospitals, schools and other institutions in programmes such as ‘pet-assisted therapy’ or ‘reading to dogs’ is of growing international importance. The benefits of keeping pets are lifelong and extend from positive influences on child development, to exercise programmes to counteract adult obesity, to providing companionship for the lone elderly population<sup>[14]</sup>. The One Health Committee supports and promotes all such programmes and also recognizes the significance of domestic dogs and cats in the village communities of the developing world where there are equally strong bonds between people and their animals.

## Comparative and Translational Clinical Research

The One Health Committee strongly supports the investigation of spontaneously arising disease in the dog and cat as a model for the equivalent human disorders. Dogs in particular, develop a range of inflammatory, degenerative, neoplastic, allergic and autoimmune diseases that are close clinical mimics for the human diseases and, unlike widely-used rodent models of disease, occur naturally in a species that closely shares the human environment. The dog is also a valuable model for studies of human ageing, due to its relatively long lifespan (i.e. relative to a mouse) and the natural

occurrence of cognitive and physical disorders of ageing. The major advances in canine genomics since publication of the canine genome in 2005<sup>[15]</sup> have seen numerous breakthroughs in understanding the genetic basis of morphology and disease in the dog. It is not by coincidence that several members of the One Health committee work at the forefront of comparative clinical research, in particular the comparative oncology laboratories of Dr Chand Khanna at NIH (Bethesda, Maryland) and Dr Will Eward at Duke University Medical Center (Raleigh, North Carolina).

## Zoonotic Infectious Disease

Much of the focus of the One Health Committee has been on the zoonotic infectious diseases that might be transmitted from small companion animals to man, or rarely, a ‘reverse zoonosis’ that might follow the opposite route of transmission. The committee produced a ‘white paper’ published in *Emerging Infectious Diseases*<sup>[16]</sup>, which highlighted the wide range of small companion animal zoonosis and called for establishment of more robust global surveillance for known and emerging pathogens that might involve the dog and cat. The risks for human health of small animal zoonoses are compounded by the large numbers of these pet animal species and their very close association with man, and increasingly by the international mobility of pet animals that may carry disease or vectors into non-endemic regions or countries<sup>[17]</sup>. The spread of arthropod-borne infectious diseases (e.g. leishmaniosis) from the Mediterranean to northern European countries and the reports of autochthonous cases arising in non-travelled pets highlight these risks. A recent study has suggested that the dog shares the largest number of pathogens with man as the dog was one of the first animals to be domesticated<sup>[18]</sup>. Numerous experimental studies show the susceptibility of dogs and cats to newly emergent human pathogens (e.g. SARS coronavirus, avian and porcine

influenza) and document the emergence of new strains of influenza virus in these animals<sup>[19,20]</sup>.

The single most significant small companion animal zoonosis is canine rabies infection, which is conservatively estimated to kill 55,000 – 70,000 people each year<sup>[21]</sup>. Most of these deaths occur in Asia and Africa with an estimated 25,000 deaths annually in India alone. The victims are most often the children (who are more likely to be bitten by affected dogs) of the rural poor (who have inadequate access to preventive or therapeutic healthcare). It is tragic that these deaths continue to occur due to a disease which is entirely preventable by vaccinating dogs.

The One Health committee has focused much attention on the global fight to eliminate canine rabies. In November 2013, the committee jointly hosted a 2.5 day symposium on small companion animal zoonoses with the OIE at OIE Headquarters in Paris. The outcome from this meeting was a joint OIE–WSAVA One Health Committee statement, which described seven key steps towards successful control of canine rabies, and set a target date of 2030 for global elimination of this disease<sup>[22]</sup>. The committee has

engaged with the Global Alliance for Rabies Control and other non-governmental organizations that work in the field on rabies control programmes.

In particular the committee has worked with the Afya Serengeti Project in Tanzania<sup>[23]</sup> and the Mission Rabies Project in India<sup>[24]</sup>. A WSAVA One Health Committee member, Professor Sarah Cleaveland, heads the Afya Serengeti Project which runs mass vaccination campaigns in the rural villages surrounding the Serengeti National Park and has provided robust scientific evidence that vaccination of 70% of a population of dogs is sufficient to control this disease<sup>[25]</sup>. In 2013, the committee (with the support of MSD Animal Health) provided 30,000 dog collars and matching wrist bands to the project. The wrist bands successfully incentivized villagers (particularly the children) to bring dogs for vaccination and the collars provided an effective means of conducting a census of vaccination levels achieved within each village during the campaign (Figure 1). The committee, working with the WSAVA Foundation, has also supported the incredibly successful Mission Rabies Project (principally funded by the UK Dogs Trust), which in under a year vaccinated



*Figure 1. The Afya Serengeti Project (2013 mass vaccination campaign). This vaccinated dog wears a blue WSAVA collar to indicate that it has been vaccinated and the boy wears a matching blue wrist band.*

over 100,000 dogs in parallel with providing education to schoolchildren and tuition to veterinarians in neutering surgical techniques. The WSAVA Foundation now conducts an annual 'Fun(d) Run' during WSAVA Congress – the proceeds from which have to date been used to support Mission Rabies. In 2014, the WSAVA Foundation launched an ambitious new programme in Africa: the African Small Companion Animal Network (AFSCAN)<sup>[26]</sup>, which amongst other targets will promote rabies control programmes in the continent.

## Future Challenges

The WSAVA One Health Committee has been remarkably successful in achieving awareness of and action for these One Health issues related to small companion animals. One major achievement was the signing of a memorandum of understanding with OIE, bringing for the first time, issues related to small companion animals to the international forum of Chief Veterinary Officers. The committee has also done much to raise awareness within the veterinary profession, but one of the greatest remaining challenges is to broker true engagement with the One Health philosophy by our human medical colleagues. An excellent example of the desired approach was the recent collaboration established between the ministries of human and animal health in the Philippines, in which large-scale funding was provided from the human healthcare budget to enable veterinary officials to undertake canine mass vaccination in order to achieve the national target of elimination of canine rabies by 2016. It is only through such collaborations that real and practical advances will be made that have true impact on the lives of human and animal populations.

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# Emerging Zoonotic diseases: New threats for old?

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## Abstract

The majority of emerging infectious diseases have their source in animals, and emergence occurs at the human/animal interface, when infections in animals breach the species barrier to infect humans, the population in which they are often first identified. The response is frequently characterised by a series of emergency activities to contain and manage the infection in human populations and at the same time to identify the source of the infection in nature. If infection is found to have a source in animals and if animals cause a continuous threat of human infection, culling is often recommended, with severe economic impact.

It may be more cost-effective to shift the current paradigm of rapid response to prevention of emergence at the source by understanding and mitigating the factors, or determinants, that influence animal infection. Better understanding of these factors learned from surveillance; epidemiological investigation of past and present emergence events; and modelling and study of the cost effectiveness of interventions that could result in their mitigation could provide evidence necessary to better address potential barriers to prevention. These barriers are driven by the basic difference between the goals and approach in the animal and human health sectors: profit versus saving lives.

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# Are Infection Control Policies Fit for Purpose?

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## ABSTRACT

Fitness for purpose is a complex idea. Infectious diseases are social, cultural and economic events as well as biological, epidemiological and molecular events. The frequent assumption that people do not act on behaviour messages because they do not understand them is often incorrect. Scientifically rational messages may be inappropriate to the rational rationales of people who are at risk or whose animals are at risk. Implementation of infectious disease control policies which are “fit for purpose” will have to be based on knowledge that is generated through real interdisciplinary research between natural, medical and veterinary scientists and social scientists in the broadest sense.

## Framing the problem

Human health and animal health have always been closely intertwined. Little reflection is required to realise that the division between these realms is cultural and historical, resting in the abrupt division enshrined in some cultures, including those of the European post-enlightenment world. In Cartesian philosophy, particularly in its nineteenth century interpretation, animals were understood as akin to machines, in contrast to human beings who are uniquely rational and distinct in this, as well as in having souls. This point relates to the more general development of natural sciences and natural philosophy wherein human and natural realms were separate until the intellectual struggles (not finished in some places) attendant upon the Darwinian revolution. Modern natural history tells a different story: primates (including humans) and pathogens (notably malaria) have co-evolved <sup>[1]</sup> as entities within a

complex eco-social system. This view is the basis of One Health and depends on another intellectual revolution which is still in progress.

## Molecular and global interconnectedness

Antimicrobial resistance (AMR) is not unique to a nature dominated by humans, it is a natural process consistent with the concept of evolution. But human actions in the last 30 years in relation to animal and human health management have dramatically increased the frequency of occurrence while there being less or even lack of development of replacement antimicrobials. The proportion of AMR to commonly used drugs for *E. coli*, *K. pneumoniae* and *S. aureus* exceeded 50% in many settings. There are serious limitations in effective treatment options for some common community-acquired infections in several countries; few, if any, treatment

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options for some common severe and health-care associated infections in many places, and insensitivity to carbapenems, usually the last line treatment, by *K. pneumonia* is reported in all WHO regions<sup>[2]</sup>. Use of antimicrobials in companion and production animals, dietary indirect ingestion of residues, antimicrobial residues in slurry ponds attached to large scale commercial animal production units, all these increase the global exposure and transmission of resistance in the form of plasmids, complete DNA fragments, and the resultant opportunities for combination and re-combination which with complex integrated international food systems can and does result all too often in events such as that reported from Saskatoon in Canada in 2014 where researchers found carbapenem resistant bacteria in squid imported from South Korea which had been purchased in January 2014. The speed and distance of this global spread is an example of what we now know to be possible; the great potential for more rapid and frequent transfer.

Thus – to make the point yet again – the world is an integrated time-space continuum within which there are not only whole biological organisms of widely differing complexity (from virus to human) which travel, but also their molecular components. But interconnectedness describes more than the biological world. It also refers to the economic, political and social world. In particular it describes the way that – since at least the early middle ages (probably long before) expanding production and exchange has drawn diverse and far-flung communities and societies into ever closer if sometimes indirect association<sup>[3-5]</sup>. Apart from the classical approach to examining the problem of AMR solely within its biological context, we must also consider the importance of economic factors such as investment, circulation of capital and realisation of profit in terms of their influence on human actions promoting emergence of AMR. Anybody who has ever lost a house purchase because their intended purchaser cannot realise the cash locked up in their house, will know about liquidity and illiquidity. A central problem of production is that you need cash to invest in raw materials, pay labour and purchase land or plant. If you don't have cash you must borrow. In either case, once you sink your money into productive assets, you must sell the product if you are to realise your capital (hopefully at a profit) and thus be able to start the cycle of production and profit making once again. This process can be described as the circulation of capital. The more rapidly you can complete

the process successfully, i.e. selling your products, the more opportunities you have to realise a profit. In the case of animal production, a constraint is the length of the production cycle of the animal from birth to slaughter and retail. The shorter this period, the more times profit can be reaped from the circuit of capital. So the velocity of circulation is important and antimicrobials may be used as growth promoters and/or to control disease so as to ensure maximum rate of animal growth, and therefore a reduction in the length of the production cycle. This indicates the relationship between money capital, investment, production, sale and realisation of profit for reinvestment. Given the demand for meat in rapidly growing economies, as for example in east and south east Asia, increased numbers of large scale integrated animal production units have come into existence. With “quantitative easing”, the amount of loaned capital available for investment has also increased. Thus it is that in the One Health World, increased demand for and production of animal protein in rapidly developing countries has resulted in increased use of antimicrobials. All of the preceding complex processes, from the circulation of capital to the circulation of plasmids and DNA fragments in the subsoil and in slurry ponds, are part of what is referred to as “anthropogenic activity”<sup>[6]</sup>. It is therefore essential to recognise that the concept of a One Health world does not allow for a Cartesian division between nature and human action, as humans are and indeed have always been part of “nature”.

## **Infection control programmes as anthropogenic activities complementing and extending our immune systems**

Much as some other animals, humans construct social structures, tools, culture – only, as far as we know, they do these things on a larger scale than do other animals. Tools are developed to enhance the functionality of evolved bodies; similarly, public health institutions, surveillance systems, laboratory testing, theories of infection, PCR. Conceptually, all these may be thought of as designed to complement and extend the ability of the human immune system to deal with pathogen threats. Infection control programmes are a result of “anthropogenic activity”. As with so much of human behaviour, they are “political”, having to do with the use of power, authority, ideas and resources to achieve ends. Infection control can be done as top down or



in a participatory manner, or a combination of these. This means that we have to take account of much else beside the technicalities of reducing transmission rates in considering whether or not infection control is “fit for purpose”. This is the point at which natural science, public health, veterinary and human medicine come into contact with the social sciences. The latter situate the problem of fitness for purpose in a frame which poses the following types of questions: (a) if the purpose of control of infectious pathogens is to minimise adverse effects on humans and animals, there may be social, economic and cultural choices to make as the cost of doing some things for some groups may affect the benefits for others, which is the basic benefit cost/externalities question; (b) the potential impact of infection can be expressed in economic, “welfare”, or other terms, a simple example being how much would you spend to save one chicken in a poultry unit, or one dearly loved pet Labrador. Or your mother? These are complex ethical, financial, welfare and philosophical issues. They are related to different philosophical and economic views about welfare and how we see the world, ideas which may be broadly divided into Cartesian, Kantian, Utilitarian approaches. And within this framework, how we respond to infection in differing situations, animal, plant, human, different groups of humans (old or young, rich or poor &c) raises issues of regulation, consent and differing rationalities and purposes of differing social, cultural and political groups. Fitness for purpose therefore is an extremely complex matter. There is a difference between “rational” approaches, which tends to mean based in “science” and approaches which are able to take account of and/or engage with the different “rationales” of sub cultures, social groups, men or women, small scale livestock farmers, commercial animal protein producers: each having a different rationale as groups or individuals.

## Generating Evidence for Infection Control Policy development

The Cartesian approach to evidence and action builds on a view which is familiar to scientists, it is the standard model of “science” that we learn at school (if we are well taught) and it goes roughly: observation, problem, theory, hypothesis generation, experimental design, data collection, analysis of results, and finally probabilistic statement of conclusions, leading to wider testing of those conclusions. At any stage, conclusions may inform policy and action, and the particular stage may reflect

happenings in the realm of politics rather than the realm of science. This approach serves us well – up to a point. The ability of the research community to deliver scientific excellence tends to focus on investigation of distinct aspects of selected elements of a system. However, it often uses a reductionist approach which while producing high quality science, as judged within a particular scientific community (in itself a social process whereby “truth” is assessed), may not take account of the interactions between the various elements and resultant emerging properties of the complex systems within which infection occurs. Indeed it may even misrepresent true underlying anthropogenic influences which are confounded by measured epidemiological variables. In other words, “science” may so disaggregate the problem that the complex processes, anthropogenic or “natural”, may not be brought to the fore and thus lead to the development of infection control policies that are ineffective or of limited effectiveness.

## What is evidence?

And further, the ways that evidence generated by ‘science’ is deployed in behaviour change education may be based on a wrong assumption: notably that people just need to be provided with ‘correct’ information to make them change their behaviour<sup>[7]</sup>. But it is not as simple as that: people act rationally most of the time, but that rationality is likely to be different from ‘objective’ rationality desired by scientists. They act in terms of the meaning of the situation for them – a point widely understood by each of us in our pragmatic daily problem solving and noted formally by the German sociologist Max Weber (1864-1920)<sup>[8]</sup>. It is often absence of a proper understanding of the roots of human social, cultural and economic behaviour which stands in the way of changing what, to the rational scientific mind, may be obstinately established and maintained risky behaviours likely to propagate infection. In other words, effective control policies require an integrated understanding of the biological and social roots of the infection process. This represents a real interdisciplinary challenge since different disciplines as between the social and natural sciences have different criteria of “proof” and “disproof”/ forms of evidence and may be dealing with different levels and aspects of “reality” – the natural sciences at the level of plasmids, gene recombination, molecular structures and forces, the social sciences with economic structures, social institutions and human beings, agents

who constantly construct and reconstruct the world as they experience it and reflect on their experience.

## Conclusions

The One Health perspective on dealing with threats to animal and human health emphasizes that the classical science model is not able to integrate anthropogenic aspects of effective infection control in any simple manner. Intelligent human agents with their own goals get in the way of what scientists say it would be rational to do to achieve effective infection control – and in any case politicians may not accept that advice for short term and expedient political reasons. This should make us think anew about how we understand “science” and “evidence”. Effective infection control has to: recognise the subtle and limited/constructive nature of “truth”; be prepared to listen to and identify other kinds of voices and rationales; struggle with the problem of “evidence”, “anecdote”, “evidence-like statements”, “guesses/hunches” and much else which goes on in the real world of infectious diseases as social, cultural and economic processes as well as molecular, microbiological and epidemiological processes.

Apart from requiring effective implementation of true interdisciplinary research, it is as important to develop mechanisms to communicate these diverse ideas, particularly the probabilistic nature of scientific findings, to the public(s) with their different rationalities, and to politicians who in turn have to communicate ideas about infection and risk within their particular milieu of political expediency and ideological belief.

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# Comparative Medicine: an outstanding but still underappreciated resource for clinical progress

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Closing remarks of the One Health Conference held in London on 13 October 2014, organised by the Bella Moss Foundation together with the Royal Society of Medicine.

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Go to <http://www.fecava.org/ejcap> to see the online presentation of this paper (including an interview with the author)

The growing interest in a shared approach to problems where medical and veterinary interests overlap was clearly shown in the response to this meeting; the range of backgrounds among the participants and the quality of their participation. The focus was on infection control and, particularly, the appropriate use of antibiotics, in the face of the diminishing flow of new types and the accelerating resistance to the existing range. Sadly, the recent dire warnings from the Chief Medical Officer differ little from those given in 1998 & 1999 by the House of Lords' Select Committee on Science & Technology and the Advisory Committee on the Microbiological Safety of Food. Everyone agrees on the need for 'wise and prudent use'; the question is whether we can be confident of the evidence underlying how that should be achieved. For example, emphasis on completing the prescribed course is widely familiar - but is it correct?

## Optimising prescribing

Unfortunately, however dire or authoritative the warnings, our political system is not amenable to problems which demand attention far beyond the electoral cycle, e.g. climate change or antimicrobial resistance. The fact is, despite the warnings, National Health Service (NHS) patients are consuming more antibiotics than ever, often inappropriately prescribed. One way of optimising prescribing would be to introduce mechanisms which

gave dispensing pharmacists encouragement and power to query and to intervene. They represent a highly knowledgeable and underused resource in primary care, unlike hospitals where they are used far more effectively, especially because clinicians tend to be knowledgeable about the drugs used in their own specialty but patients increasingly present with multiple problems and multiple medications, with obvious risks of adverse drug interactions.

## 'Hospital acquired infections'

We should also temper our instinct to imagine that urgent problems are new and require new solutions, that the wheel needs reinvention. In the 1970s, long before MRSA was in the everyday vocabulary, 'hospital acquired infections' were a notorious problem and excellent books were written about minimising this risk - long out of print and not easy to retrieve via the internet.

Key principles included:

1. Try not to move patients through a succession of wards; move doctors between wards [and ensure they obey hygiene protocols].
2. Do not exceed optimum bed occupancy; higher levels rapidly increase infection.

But managers, concerned with the 'bottom line' will have a default resistance to both; the first is inefficient, the second is unprofitable.

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## Inappropriate dosing

It is obvious to vets that drug dose needs to reflect the size of the patient, but not to doctors: prima ballerinas and Sumo wrestlers are likely to receive 'the adult dose' and a growing number of NHS patients are approaching the Sumo range of bodyweight. They are likely to be underdosed, while the ballerinas are at greater risk of side effects. Apart from being poor practice, this is a waste of money. Appallingly, the greatest risk of inappropriate dosing for body weight is in children in primary care; in a recent study, none younger than 1 year was correctly dosed, most receiving a 100% overdose, while among those aged 6-12 or 12 -18, 40% or 70% respectively were underdosed (Saxena et al., 2014). Granted that the criteria for correct dosage were based on the BNF for children, universally accessible to both doctors and pharmacists, this looks like negligence as the norm.

## Funding required

Granted that exposure to antimicrobials, whether used appropriately or not, favours the emergence of resistant strains, 'research to define the shortest effective course for common infections is urgently needed' (Spellberg, 2013). But who will fund it? It is certainly not in the interests of the shareholders of pharmaceutical companies and research on antimicrobial resistance has long failed to appeal to major research funding bodies (Michell, 2000). More fundamentally, we ideally need rapid and simple tests to indicate that further continuation of the course is no longer necessary.

I make no apology for ending by pointing out that zoonoses - and antimicrobial resistance is arguably an example since it is a clinical problem exchangeable between humans and animals - are but one aspect of comparative medicine.

## The animal model

Domestic animals, especially dogs and cats, offer spontaneous models of human diseases, which are frequently more authentic than contrived models in laboratory rodents. Excellent examples are plentiful especially in nephrology, oncology, cardiovascular and enteric disease (Michell, 2005). They include the remarkable within-species, between-breed differences

in longevity and blood pressure in dogs, notably high but harmless normal pressures in several large athletic breeds ['sighthounds']. Dogs and cats are more likely to have their renal function measured accurately [using the stable marker iohexol; Bexfield et al., 2008] than NHS patients [still largely assessed by derivatives of plasma creatinine]. Yet adverse reactions in elderly NHS patients are an important problem and frequently reflect failure to adjust drug-dosage for the 'natural' subclinical age-related decline in renal function. How natural is it; what might retard it; questions worth studying within the faster ageing canine lifespan.

## A potential win-win scenario

Collaboration on such spontaneous models is 'win-win': better models for developing remedies for human patients and earlier access to innovative remedies for veterinary patients (Michell, 1999).

The WHO identified the greatest life-saving advance of the 20th century as the treatment of acute diarrhoea - not by antibiotics but by oral rehydration [though it was originally advocated in 1831!]. Yet one of the most avoidable abuses of antibiotics is the continuing willingness of doctors to supply them as frontline precautionary treatment for 'travellers' diarrhoea', despite the evidence that with very few exceptions they are inappropriate and sometimes counterproductive. Of course the widespread and welcome use of oral rehydration in refugee camps and post-disaster settlements, highly vulnerable to cholera, assumes that the solutions are optimally formulated, the best available.

It is therefore outrageous that an oral rehydration solution [ORS] formulated for neonatal diarrhoea in calves, a good model for acute cholera-type diarrhoea, performs far better than the solution advocated by WHO and conscientiously supplied by the tireless workers of MSF (Michell, 2005). Unlike the WHO ORS, the veterinary ORS was very effective at restoring plasma volume, plasma Na & K, correcting acidosis, and restoring renal function; uniquely it also facilitated recovery of enteric villi because it contains glutamine on which they are specifically dependent (Michell, 2010). Sadly, tragically, in 2007 in Geneva, offered a free supply of this ORS and outline protocols for assessment of safety and efficacy, the WHO declined.



## True One Health: an open mind

Veterinary graduates, seeing a disease in different species, imbibe an instinctive interest in comparative medicine. But as others noted during the meeting, some medics still 'don't get it'; they harbour the belief that humans are uniquely created, that evidence from animals somehow will not apply to man. This belief is biologically inept. Comparative medicine has moved on from the study of animal diseases which merely resemble human diseases to the realisation that frequently the receptors, the mediators, the underlying genes, are demonstrably identical: it is truly the study of the same disease in different species, including humans, learning from both the similarities and the differences.

Yet there have long been outstanding examples of medics with a more enlightened view - despite slender support from leading funding agencies. Nearly 30 years ago, at a symposium on comparative aspects of renal disease, held in London and published by Blackwell, one of Britain's most outstanding research clinicians and a former President of the International Society of Nephrology, Professor Stewart Cameron of Guys Hospital, said the following:

'Too little attention has been paid to comparison of human and spontaneous animal disease either by veterinarians or physicians, and it is to be hoped that greater exchange of information can be organized in future' (Cameron, 1988).

Had he said it today, and despite welcome progress since, it would remain hard to say it any better.

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