Research

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Intralaryngeal thyroarytaenoid lateralisation using the Fast-Fix 360 system: a canine cadaveric study

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ABSTRACT

Introduction: Laryngeal paralysis is a condition in which failure of arytaenoid abduction results in a reduced rima glottidis cross-sectional area. The most commonly performed surgical techniques rely on unilateral abduction of the arytaenoid, requiring a lateral or ventral surgical approach to the larynx.

Aims and objectives: The aim of the study was to investigate a novel minimally invasive intralaryngeal thyroarytaenoid lateralisation technique, using the Fast-Fix 360 meniscal repair system.

Materials and methods: Larynges were harvested from large breed canine cadavers. With the aid of Kirschner wires placed between the centre of the vocal process and the centre of an imaginary line between the cranial thyroid fissure and the cricothyroid articulation, the mean insertion angle was calculated.

Results: The Fast-Fix 360 delivery needle inserted intralaryngeally (n=10), according to a simplified insertion angle (70°), resulted in thyroid penetration (>2.5 mm from margin) in all patients. The Fast-Fix was applied unilaterally at 70° with the first toggle fired on the lateral aspect of the thyroid cartilage and inside the laryngeal cavity on retraction. The suture was tightened. Preprocedural (61.06±9.21 mm2) and postprocedural (138.37±26.12 mm2) rima glottidis cross-sectional area was significantly different (P<0.0001). The mean percentage increase in rima glottidis cross-sectional area was 125.96 per cent (±16.54 per cent).

Conclusion: Intralaryngeal thyroarytaenoid laterlisation using the Fast-Fix 360 meniscal repair system ex vivo increased the rima glottidis cross-sectional area significantly.

INTRODUCTION

Laryngeal paralysis (LP) is a condition in which the nerves and/or muscles controlling the movement of the arytaenoid cartilages cease to function normally (Monnet and Tobias 2012). In the more advanced stages of LP, the condition manifests clinically as a laryngeal stridor due to a failure of the arytaenoid cartilages to abduct during inspiration. Hereditary, congenital and acquired forms of LP exist, but the clinical presentation and treatment are similar (Monnet and Tobias 2012). The most commonly performed surgical techniques rely on the abduction of the arytaenoid cartilage (s) with a non-absorbable suture material placed between the muscular process of the arytaenoid and either the cricoid or thyroid cartilages (Griffiths and others 2001, Snelling and Edwards 2003, Hammel and others 2006). These procedures require a lateral approach to the larynx, mostly combined with an intraoperative laryngeal inspection to evaluate the adequacy of arytaenoid caudolateralisation and abduction (Weinstein and Weisman 2010). Although most LP surgeries rely on a lateral surgical approach, the larynx can also be approached transorally as described for partial laryngectomy (Ross and others 1991, Trout and others 1994, Olivieri and others 2009). The reported complication rate and outcomes of these transoral techniques are variable, and might explain why they are favoured less (Peterson and others 1991, Ross and others 1991, MacPhail and Monnet 2001, Zikes and McCarthy 2012).

In the recent years, self-adjusting, self-locking suture anchor systems have been used to repair soft tissue structures like the meniscus and triangular fibrocartilage complex in human medicine (Haas and others 2005, Kotsovolos and others 2006, Cohen and others 2007, Yao 2009). An example of such a system is the Fast-Fix 360 (FF) meniscal repair system (Smith & Nephew Endoscopy, Andover, Massachusetts, USA), a combination of a delivery needle and a double toggle anchor suture component (Fig 1). The toggle anchor suture component, which is preloaded in a delivery needle, consists of two 5 mm polyether ether ketone toggle anchors connected with a 2-0

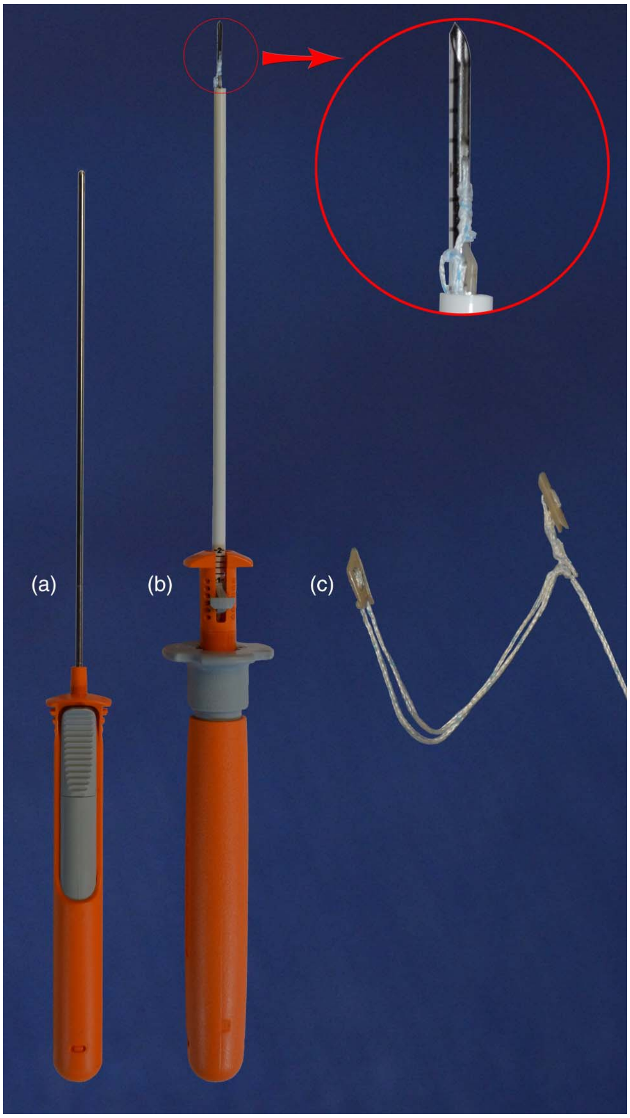

FIG 1: Fast-Fix 360 meniscal repair system. (a) Knot pusher/cutter; (b) straight delivery needle; (c) double toggle anchor suture component

ultra-high molecular weight polyethylene, braided suture material with a pretied sliding and self-locking knot (Fig 1). Tension on the free end of the suture material after deployment of both the toggle anchors will result in sliding of the knot and approximation of the toggle anchors with subsequent converging of the structures behind which they are anchored.

The aim of the study was to investigate the use of the FF for minimally invasive intralaryngeal thyroarytaenoid lateralisation and to determine the optimal insertion angle for the delivery needle of the FF. The insertion angle will then be used to conduct an intralaryngeal thyroarytaenoid lateralisation using the FF. The authors hypothesise that sequential deployment of the toggle anchor on the lateral aspect of the thyroid cartilage and, after retrieval of the needle, on the medial aspect of the arytaenoid would result in arytaenoid abduction when the suture is tightened.

MATERIALS AND METHODS

Larynges were harvested from 30 dogs (>15 kg) that were euthanased for reasons unrelated to this study. For all canine cadavers, breed, sex, body condition score, age and weight were recorded. Age, breed and neuter status were not selection criteria. The larynges were harvested within 12 hours of euthanasia, packed individually in plastic bags, identified and stored at −20° C. They were thawed in a water bath for six hours at room temperature before conducting the study. Sharp dissection of the external muscles of the larynx and pharynx was done to expose the lateral surface of the thyroid cartilage. The study consisted of three phases. In each phase, 10 larynges were used.

Phase 1: calculating the optimal insertion angle

The aim of phase 1 of the study was to determine the optimal insertion angle for the FF delivery needle by using the bisecting angle (optimal insertion angle) between two Kirschner wires placed at minimal and maximal insertion angles, inserted parallel to trachea in the dorsal plane through the arytaenoid and thyroid cartilage. The centre point of the part of the arytaenoid's vocal process visible from intralaryngeally (point X) was chosen as insertion point to allow the maximal amount of cartilage surrounding the toggle and limit the chances of pull-out of the toggle suture anchor (Fig 2). A previous pilot study indicated that 'point X' coincided with an imaginary line connecting the most caudal aspect of the cricothyroid articulation and the cranial thyroid fissure on the lateral aspect of the thyroid cartilage (Fig 2). These two landmarks were used to determine a minimal and maximal insertion angles when a starting point of 'point X' was used.

In order to assure reproducibility of the laryngeal position and to accurately measure the insertion angle, the

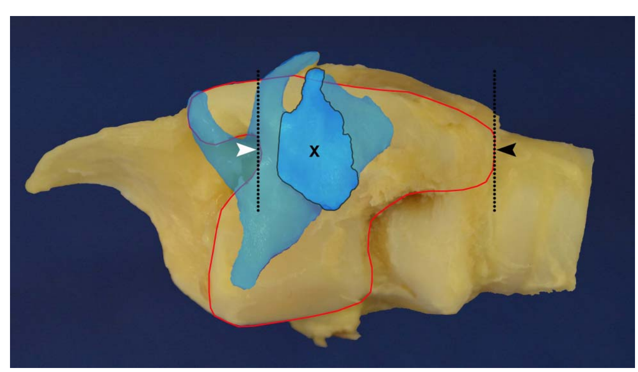

FIG 2: Lateral photographs of a canine larynx indicating the position of proposed wire entry into the centre of the part of the arytaenoid's vocal process (point X) visible from intralaryngeally (outlined in black). The arytaenoid cartilage's position is represented by the light blue colour and the thyroid cartilage is outlined with red. An imaginary line connecting the cranial thyroid fissure (white arrowhead) and the most caudal aspect of the cricothyroid articulation (black arrowhead) is in line with point X

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larynges were placed in a jig made from three pieces of plastic wall corner guards (40 mm standard corner guard; Protecura, Everberg, Belgium) and a protractor (Sencys 15 cm Protractor; Maxeda, Amsterdam, The Netherlands) (Fig 3). First, a hole was made in the ventral part of the thyroid cartilage's lamina from inside the laryngeal cavity using a 3 mm Steinmann pin on the right side. The anatomical location of this hole coincided with the medial surface and 'point X' in the parasagittal plane and the transverse plane, respectively (Fig 4a, b). This procedure was repeated on the left side. The holes, now positioned lateral to the midline on the left and right sides, served as an entry point for the bolt of a protractor (Sencys 15 cm Protractor) for measuring the insertion angles on the left and right sides, respectively. This was done to ensure that the centre of the protractor coincided with the proposed entry point of the Kirschner wire (used to determine the insertion angles) in the parasagittal and the transverse planes (Fig 4c). The larynx together with the protractor was then placed in the jig (Fig 5). The protractor was aligned with the jig to ensure that its 0°/180° marking was parallel with the front part of the jig and the ruler part of the protractor parallel to the sides of the jig. As soon as this position was attained, the ruler was fixed at the back of the jig by tightening the two bolts (Fig 5). Two 2.5 mm Steinmann

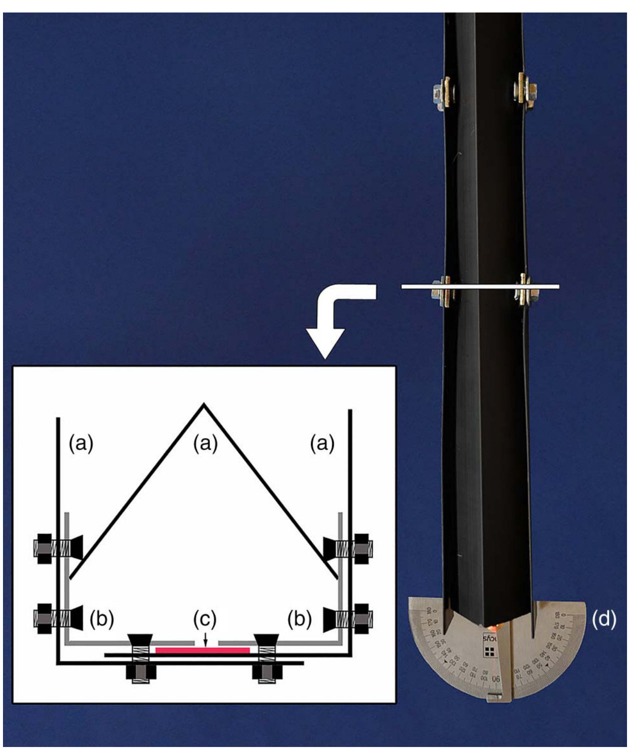

FIG 3: A jig custom made of three pieces of plastic corner protector (a) was used to securely fix the larynx. The plastic corner protectors were connected to each other using L-shaped metal flat bars (b) with predrilled holes. Bolts and nuts were used to secure the flat bar and corner protectors. The image insert indicates the location of the ruler component (c) and the protractor (d) during testing

pins were passed from one side of the jig through the trachea out the opposite side via four predrilled holes in the jig, thus, aligning the trachea parallel to the floor of the jig (Fig 5). The lid of the jig was then slid closed to fix the larynx in the sagittal plane. Finally, a laser guide (Laser Level, Lux Tools, Wermelskirchen, Germany) was used to ensure that the 90° marking on the protractor and the most lateral aspect of the corniculate process of the arytaenoid cartilage were aligned parallel to the ridge of the jig's lid.

A 1.2 mm Kirschner wire was then introduced from intralaryngeally through 'point X' (Fig 6), with the aid of a Jacobs Chuck. The wire was advanced, parallel to the table surface, through the arytaenoid cartilage in a caudolateral direction, aiming for the most caudal aspect of the cricothyroid articulation. After placement of the pin, the Jacobs Chuck was removed, and with a spirit level (8-inch magnetic torpedo level; Stanley, Connecticut, USA), it was confirmed that the wire was parallel to the table. Any deviation in the dorsal plane was corrected by repositioning the wire. The minimal insertion angle (iMin) was measured from wire 1 with the 90° marking on the protractor considered as a 0° insertion (Fig 6). A second wire was inserted extralaryngeally from the cranial thyroid fissure through 'point X' using the same techniques as described previously. Using this wire, the maximal insertion angle (iMax) was calculated with the 90° on the protractor again considered as 0° (Fig 6). The range of insertion was calculated using the following formula: (90°−iMin)+(90°−iMax). The optimal insertion angle was calculated as half the range of insertion plus iMin.

The larynx was removed from the jig; it was repositioned and the measurements were repeated on the left side. All 10 larynges were assessed using the same protocol. The mean±sd of the optimal insertion angles was then calculated.

Phase 2: testing insertion angle reliability

The aim of phase 2 of the study was to determine the reliability of the calculated optimal insertion angle during phase 1. Ten new canine larynges were positioned in the jig as described previously. An insertion angle approaching the calculated mean optimal insertion angle (from phase 1) was then used to insert a straight FF delivery needle (not loaded with a toggle anchor suture) starting at 'point X', in a caudolateral direction, with the 90° marking on the protractor considered as 0° of insertion. The process was repeated for the contralateral side after repositioning of the larynx. On completion, the thyroid cartilage was dissected out, and its laminae were split in the ventral midline. The exit point of the needle on the lamina of the thyroid cartilage was plotted on an image of a canine thyroid cartilage based on its location measured with a calliper (Vernier precision callipers; Europac Precision, Cheshire, UK) (Fig 7). Three equally spaced zones (rostral, middle and caudal) were identified between

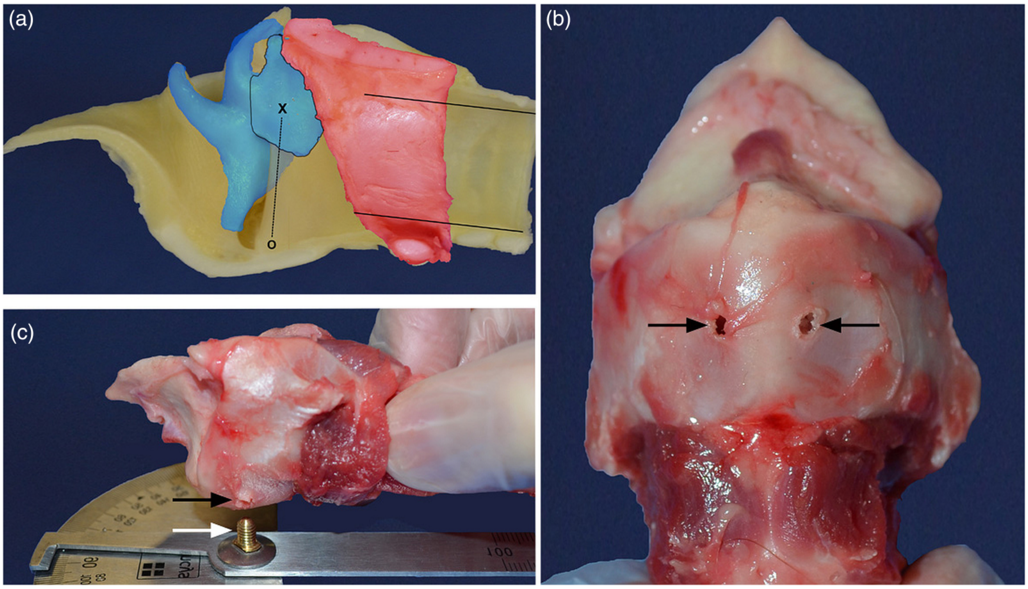

FIG 4: Photographs indicating (a) the position of proposed needle entry into the centre of the part of the arytaenoid's vocal process (point X) visible from intralaryngeally (outlined). The centre point was used as a landmark in the parasagittal plane and transverse plane to create (b) 3 mm diameter holes in the lamina of the thyroid bilaterally (black arrows; coinciding with 'o' in (a)). (c) These holes (black arrow) were used to insert the bolt of the protractor (white arrow), ensuring that the centre point of the protractor coincided with the proposed entry point of the needle

the cranial thyroid fissure (entrance point of wire 2, from phase 1) and the most caudal aspect of the cricothyroid articulation (exit point of wire 1, from phase 1). Additionally, each one of these zones were subdivided into two subzones based on whether the exit hole was up to 2.5 mm (subzone 1) or more than 2.5 mm (subzone 2) from any edge of the thyroid cartilage (Fig 7).

Phase 3: calculating the effect of FF on *rima glottidis* cross-sectional area

The aim of phase 3 of the study was to determine the effect of applying the toggle anchor system on the cross-sectional area of the *rima glottidis*. Ten new canine larynges were positioned in the jig as described previously.

Before the insertion of the needle, a preprocedural digital photograph of the larynx was taken with a calibrated dental probe positioned between the cuneiform processes of the arytaenoid cartilage (Fig 8). After insertion of the delivery needle (loaded with a toggle anchor suture) through the arytaenoid and thyroid cartilages (as described in phase 2), the first toggle anchor was fired on the lateral aspect of the thyroid cartilage by pushing the deployment slider of the delivery needle forward. The delivery needle was then retrieved and the second toggle anchor fired inside the laryngeal cavity. Retrieval of the delivery needle resulted in unravelling of the free suture end packed inside the shaft of the delivery needle. Traction, in the same direction as the delivery needle insertion, was then applied on the free end, which resulted in tightening of the slipknot and lateralisation of the arytaenoid cartilage (Fig 8). The free end was pulled till the toggle anchor on the medial aspect of the arytaenoid cartilage lay flush against the mucosal surface of the arytaenoid cartilage. The knot pusher/suture cutter was then slid over the free end of the suture material, and, with its tip positioned on the mucosal surface, the suture material was cut. A second digital photograph was taken in the same fashion as described for the preprocedural digital photograph (Fig 8).

After completion of the unilateral intralaryngeal thyroarytaenoid lateralisation, the larynx was removed from the jig, and the exit point on the lamina of the thyroid cartilage was plotted on an image of a thyroid cartilage as described during phase 2 (Fig 7).

The digital photographs were imported into an image processing and analysis software program (ImageJ, http://imagej.nih.gov/ij/). The image was scaled using the dental probe, and the cross-sectional area of the *rima glottidis* was then measured using the polygon selection tool to trace a line on the edge of the *rima glottidis*. The postprocedural *rima glottidis* cross-sectional area was expressed as a percentage change from the preprocedural value.

Data analysis

All data were collated into a spreadsheet program, Excel 2010 (Microsoft, Washington, USA) and imported into a commercial statistical program, SPSS Statistics V.20 (IBM, New York, USA), for analysis.

Preprocedural and postprocedural *rima glottidis* cross-sectional areas from larynges in phase 3 of the study were compared using the paired-samples *t* test. The correlation of weight and age on variables like optimal

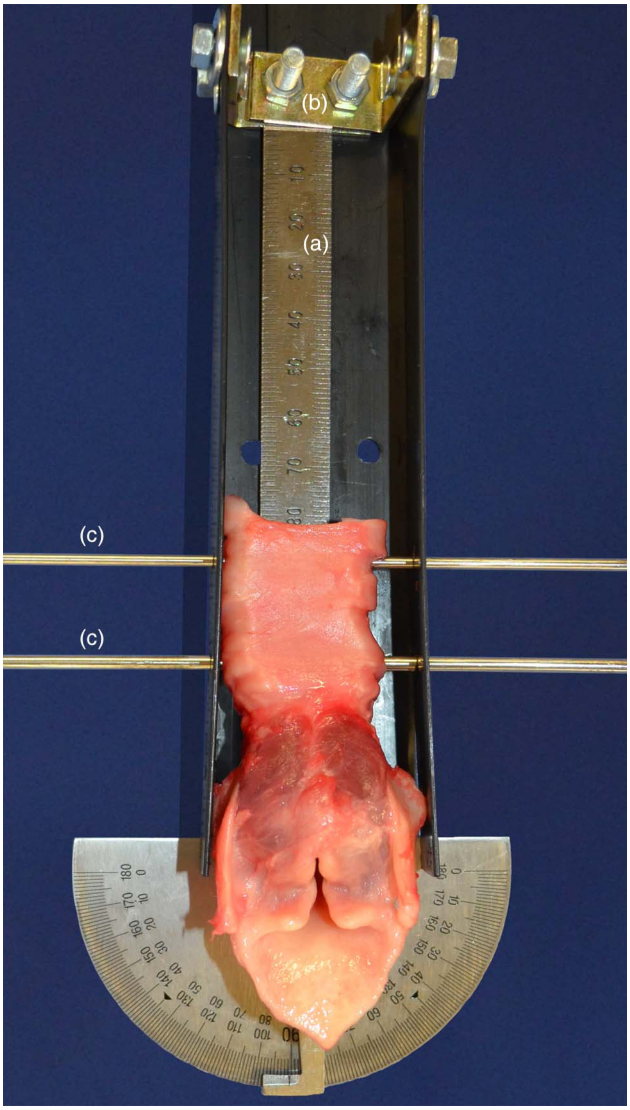

FIG 5: The larynx was positioned in the jig by placing the ruler of the protractor (a) parallel to its side and the 0°/180° marking of the protractor in line with the cranial edge of the jig. The ruler of the protractor was fixed to the jig by tightening two bolts (b). The larynx was fixed with the trachea parallel to the bottom of the jig by placing two Steinmann pins (c) through the trachea in predrilled holes in the jig

insertion angles (mean between left and right) and percentage change of the *rima glottidis* were evaluated using the Pearson's correlation coefficient. The Kruskal-Wallis test was used to compare the age and weight of the dogs during the three phases of the study. All data were expressed as mean±sd, and statistical significance was set at $P<0.05$.

RESULTS

The breed, body condition score, age and weight of the dogs used in each of the three phases of the study are summarised in Table 1. Age and weight of the dogs were not statistically different between dogs used in the three phases of the study ($P=0.30$ and $P=0.73$, respectively).

The iMin and iMax for the left and the right side are presented in Table 1. The optimal insertion angles for the left and right sides were not statistically different. From phase 1, a mean optimal insertion angle of 73.93° (±4.83°) was calculated. To make the insertion angle easier to identify in the subsequent phases of the study, a simplified insertion angle of 70° lateral to the median plane (parallel to the trachea) was chosen. This insertion angle resulted in penetration of the thyroid cartilage in all cases from phase 2 and phase 3 of the study. In phase 2 of the study, 14 out of 20 penetration sites were in the middle zone of the thyroid cartilage whereas 6 out of 20 were in the caudal zone. In phase 3, all penetrations were in the middle zone (10 out of 10). In all larynges, the thyroid cartilage was penetrated more than 2.5 mm from its margin (subzone 2) (Fig 7).

A weak negative correlation was found between iMax and weight ($r=-0.68$, $P=0.03$) and a strong positive correlation between the optimal insertion angle and the weight of the dogs in phase 1 ($r=0.82$, $P=0.004$).

There was a significant difference in the preprocedural ($61.06\ mm^2 \pm 9.21\ mm^2$) and postprocedural ($138.37\ mm^2 \pm 26.12\ mm^2$) *rima glottidis* cross-sectional area ($t(9)=-13.62$, $P<0.0001$). The mean percentage increase in surface area of the *rima glottidis* was 125.96 per cent (±16.54 per cent). Preprocedural and postprocedural surface area of the *rima glottidis* were weakly correlated to age or weight (age: $r=0.33$, $P=0.356$; $r=0.55$, $P=0.10$ and weight: $r=0.42$, $P=.23$; $r=0.58$, $P=0.08$, respectively).

DISCUSSION

LP is reported to occur mostly in large breed dogs (Burbidge 1995, MacPhail and Monnet 2001, Snelling and Edwards 2003). Although all the larynges used in this study were from large breed dogs, the results indicate that heavier dogs had an angle (iMax) formed by the centre point of the arytaenoid cartilage's vocal process (ie, visible from intralaryngeally) and the cranial thyroid fissure that is more acute. This has contributed in part to the positive correlation between the weight and the optimal insertion angle during the first phase of the study. Possible explanations for this are a more rostral location of the cranial thyroid fissure in relation to the midpoint of the arytaenoid vocal process or a decreased mediolateral distance between the two anatomical landmarks. Other factors that might result in differences in the insertion angle are anatomical variations (within and between breeds) in the relationship and the shape and anatomical relation of the arytaenoid and thyroid cartilages. To simplify the second and third part of the study, the insertion angle was set at 70°, but, considering the positive correlation with weight, it is likely that a larger insertion angle would have been more optimal for giant breed dogs. In the current study, an insertion angle of 70° necessitated caudal or ventral displacement of the cuneiform processes of the

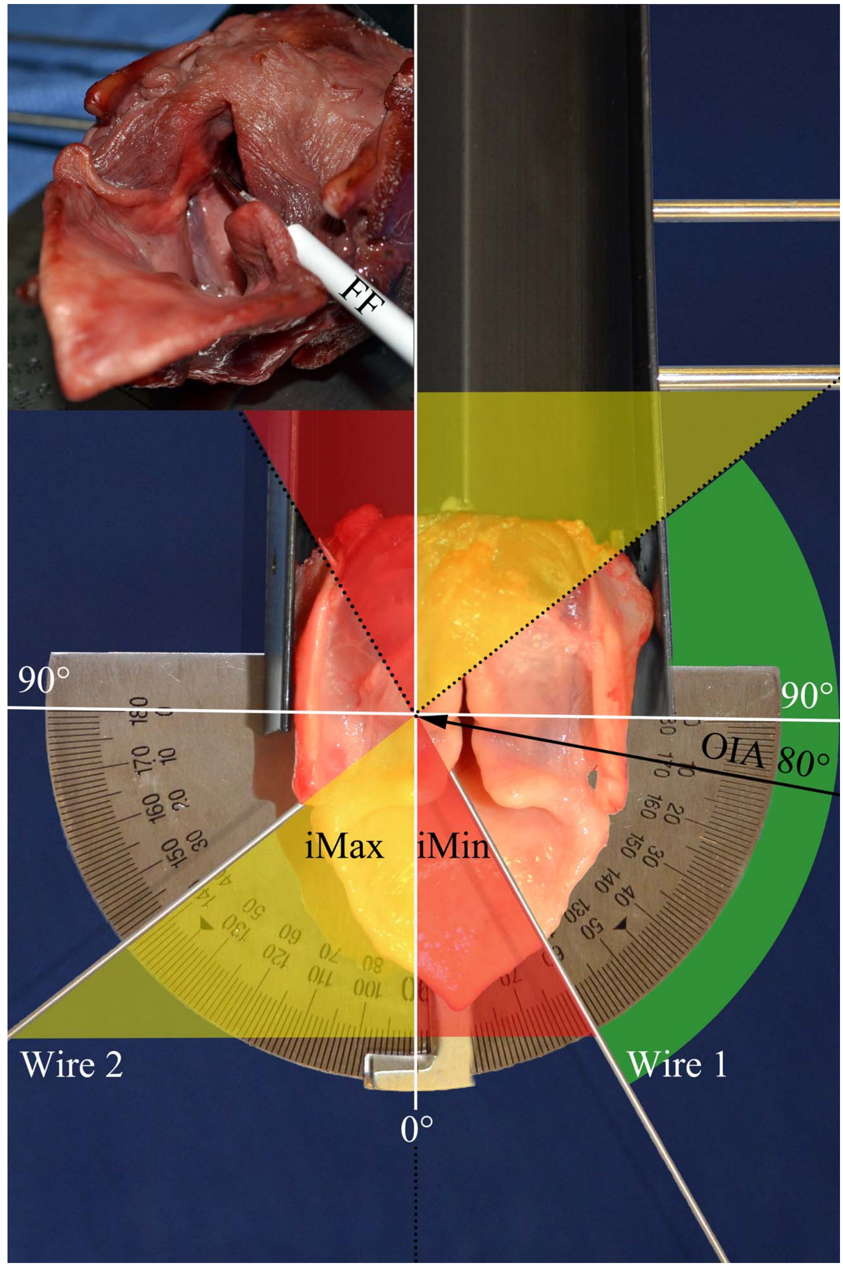

FIG 6: Photograph depicting the insertion angle of wire 1 (iMin) and wire 2 (iMax). The range of insertion was calculated using the following formula: (90°−iMin)+(90°−iMax). The optimal insertion angle was considered as half the range of insertion (green zone) plus iMin. The black arrow indicates the optimal insertion angle for this dog (optimal insertion angle 80°). The entry point for the device (FF), is indicated on the picture inset and coincides with point X in Fig 2. FF, Fast-Fix 360; iMax, maximal insertion angle; iMin, minimal insertion angle

contralateral arytaenoid cartilage with the shaft of the delivery needle during needle insertion. Increasing the insertion angle might result in delivery needle encroachment on the more rigid corniculate process of the contralateral arytaenoid, and might create technical difficulties. In addition, the caudal position of the larynx in situ with interference of the mandible, tongue, lips and teeth might prove technically challenging. Transcutaneous pharyngeal penetration of the needle as a minimally invasive approach might assist in achieving the proposed insertion angle of 70°. The manufacturer of the meniscal repair system used in this study also sells a device with the tip of the delivery needle bent at a 22° angle that might assist in delivery needle placement where technical difficulties are encountered. Further studies are necessary to evaluate this.

An insertion angle of 70° resulted in penetration of the thyroid cartilage in all the larynges tested, without fracture or fissuring of the cartilage. No attempt was made to study the extent of laryngeal cartilage calcification, and thus, care should be taken in interpreting absence of cartilage fracture as no risk for fracture. All dogs in the study had the toggle anchor penetrating more than 2.5 mm from the edge of the thyroid cartilage. The distance was equal to half of the length of the toggle anchor and a penetration of 2.5 mm from the edge of the thyroid cartilage, thus, will result in full contact of the toggle anchor with the surface of the thyroid cartilage. It is unknown how far from the margin of the thyroid cartilage the penetration should be to prevent pull-out of the anchor toggle. Although this was not specifically evaluated, it is likely that this critical distance is even less than

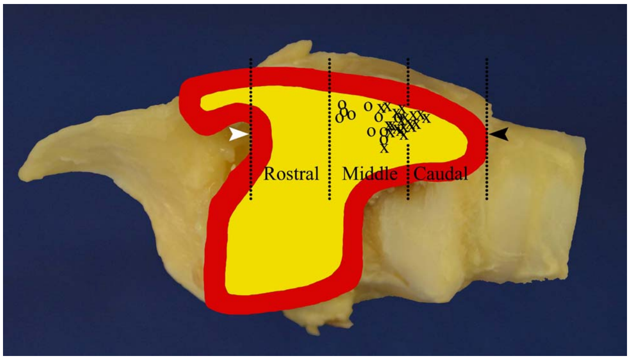

FIG 7: Three equally spaced zones (rostral, middle and caudal) were identified between the cranial thyroid fissure (white arrowhead) and the most caudal aspect of the cricothyroid articulation (black arrowhead). Additionally, each one of these zones was subdivided into two subzones based on whether the exit hole was up to 2.5 mm (subzone 1, indicated in red) or more than 2.5 mm (subzone 2, indicated in yellow) from any edge of the thyroid cartilage. 'x' and 'o' indicate needle penetration during phase 2 and 3 of the study, respectively

the 2.5 mm as the direction of the pull of the suture is rostroventral in relation to the dorsal margin of the thyroid cartilage lamina. In human cadaveric studies on menisci, a mean load to failure of 125 N was recorded. In these specimens, half of the constructs failed due to suture breakage and half via suture pull through (Kocabey and others 2006). Although it cannot be compared directly with the strength of the suture system in laryngeal cartilage, it is unlikely that the suture in this location will ever be exposed to forces that are high enough to result in suture breakage. Cyclic forces exerted on the implant during normal respiration and swallowing can also lead to failure, but additional studies are needed to investigate this.

In phase 3 of the study, the toggle anchor systems all penetrated the middle zone of the lamina of the thyroid cartilage. In contrast, 30 per cent of penetrations were situated caudal to that middle zone when the reliability of the insertion angle was tested in phase 2 of the study. During phase 2, one single unloaded delivery needle was used to perform all tests. Multiple cartilage penetration most likely blunted the needle, resulting in a pushing rather than a cutting action, displacing the larynx during needle insertion and leading to more caudal penetration on the thyroid cartilage. Obviously, in phase 3, a new needle was used with each application.

The FF is supplied with a knot pusher/cutter that facilitates tightening of the knot and additionally cutting of the free end of the suture material. In a pilot study preceding the current study, it was found that, when using the knot pusher for tightening the slipknot, the tip of the knot pusher/cutter penetrated the arytaenoid cartilage due to the fact that the slipknot is positioned closest to the first deployed toggle anchor (in the present study setting, lateral to the thyroid cartilage). This resulted in damage to the arytaenoid cartilage and even fracture in one case. For this reason, the knot pusher/cutter was not used to tighten the slipknot. Although not recorded, subjectively, there was a moderate amount of tissue drag created by the multifilament suture material when tightening the slipknot. In the process of tightening, the thyroid cartilage was pulled medially towards the arytaenoid. The free end of the suture was pulled till the anchor toggle made firm contact with the mucosa on the surface of the arytaenoid cartilage. Recoil of the thyroid cartilage once the tension was released, resulted in additional, although minimal, lateralisation of the arytaenoid cartilage. To adjust the tension based on patient needs, it might be necessary to intermittently release the tension during tightening of the free strand to assess its effect of lateralisation. A limitation of the current study was that tension placed on the suture strands was not standardised between the tested larynges. A tensioning device could have been used, but due to the effect of the tissue drag by the multifilament suture material, it might still not

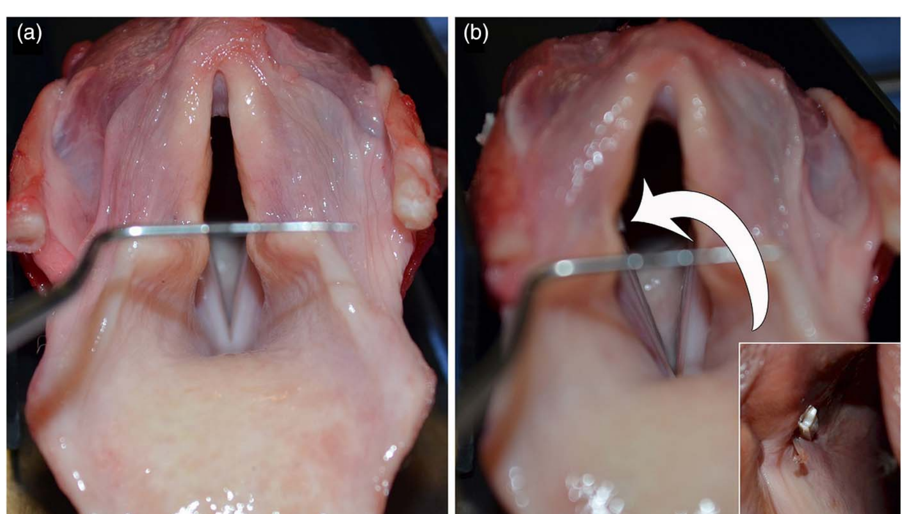

FIG 8: (a) Preprocedural and (b) postprocedural digital photographs taken for comparison of the cross-sectional area of the *rima glottidis*. The inset indicates the position of the intralaryngeal toggle anchor on the medial aspect of the arytaenoid cartilage

TABLE 1: Summary of the dog and measurement data during the three phases of the study

Phase 1											**Mean**	**sd**
Sex	F	M	F	F	FN	FN	M	M	M	F		
Age (months)	15.00	10.00	52.00	158.00	170.00	53.00	48.00	125.00	69.00	12.00	71.20	59.48
Weight (kg)	27.10	29.60	22.40	16.50	20.20	26.20	58.30	35.80	33.70	29.10	29.89	11.59
BCS (1–5)	3.00	3.00	3.00	2.50	4.00	3.00	3.00	3.50	3.50	3.00		
Breed	Belgian shepherd dog	Rottweiler	Golden retriever	Galgo Español	Crossbreed	Bouvier	Great dane	German shepherd dog	Rottweiler	Crossbreed		
iMin, right	44.00	49.00	38.00	35.00	34.00	39.00	48.00	47.00	41.00	30.00	40.50	6.45
iMin, left	45.00	48.00	39.00	35.00	33.00	40.00	45.00	47.00	44.00	32.00	40.80	5.88
iMax, right	72.00	81.00	77.00	73.00	74.00	75.00	58.00	69.00	80.00	75.00	73.40	6.48
iMax, left	72.00	81.00	73.00	72.00	74.00	75.00	57.00	66.00	80.00	72.00	72.20	6.83
Optimal insertion angle, right	76.00	74.00	70.50	71.00	70.00	72.00	85.00	79.00	70.50	67.50	73.55	5.20
Optimal insertion angle, left	76.50	73.50	73.00	71.50	69.50	72.50	84.00	80.50	72.00	70.00	74.30	4.69
Phase 2											**Mean**	**sd**
Sex	M	F	M	MN	MN	FN	MN	M	M	F		
Age (months)	61.00	96.00	168.00	84.00	110.00	96.00	108.00	84.00	72.00	48.00	92.70	33.01
Weight (kg)	44.50	29.10	31.40	28.70	39.80	22.70	41.20	18.00	32.50	26.20	31.41	8.40
BCS (1–5)	3.00	3.00	3.50	3.50	3.00	2.50	4.00	3.00	3.50	3.50		
Breed	Rottweiler	German shepherd dog	Belgian shepherd dog	Labrador retriever	German shepherd dog	Galgo Español	Labrador retriever	Border collie	Labrador retriever	Belgian shepherd dog		
Thyroid zone/subzone, right	Middle/2	Middle/2	Middle/2	Middle/2	Caudal/2	Middle/2	Caudal/2	Caudal/2	Middle/2	Middle/2		
Thyroid zone/subzone, left	Middle/2	Middle/2	Middle/2	Middle/2	Caudal/2	Middle/2	Caudal/2	Middle/2	Caudal/2	Middle/2		
Phase 3											**Mean**	**sd**
Sex	M	M	M	F	M	F	F	M	M	F		
Age (months)	72.00	60.00	120.00	84.00	96.00	96.00	120.00	96.00	60.00	60.00	86.40	23.19
Weight (kg)	35.20	32.10	34.30	21.70	52.30	25.40	32.10	28.20	29.70	24.90	31.59	8.47
BCS (1–5)	3.00	3.50	3.50	3.00	3.50	3.00	3.00	3.00	3.50	3.50		
Breed	Rottweiler	Labrador retriever	Labrador retriever	Labrador retriever	Newfoundlander	Labrador retriever	German shepherd dog	German shepherd dog	Belgian shepherd dog	Labrador retriever		
Preprocedural cross-sectional area (mm^2)	49.66	64.99	63.98	47.85	72.15	49.53	71.78	68.88	62.22	59.59	61.06	9.21
Postprocedural cross-sectional area (mm^2)	109.88	131.33	143.23	113.13	176.19	106.47	164.61	169.95	149.51	119.42	138.37	26.12
Percentage cross-sectional area increase	121.26	102.07	123.87	136.42	144.21	114.96	129.33	146.73	140.30	100.40	125.96	16.54
Thyroid zone/subzone, right	Middle/2	Middle/2	Middle/2	Middle/2	Middle/2	Middle/2	Middle/2	Middle/2	Middle/2	Middle/2		

BCS, body condition score; F, female; FN, female neutered; iMax, maximal insertion angle (from wire 2); iMin, minimal insertion angle (from wire 1); M, male; MN, male neutered have resulted in uniform tension between the two toggle anchors. It is uncertain what effect an increase in suture tension will have, but it would likely predispose to toggle anchor pull-through. To the authors' knowledge, the ideal tension for cricoarytaenoid or thyroarytaenoid lateralisation has not been reported. Wignall and Baines (2012) demonstrated that increasing suture tension for thyroarytaenoid lateralisation from 100 to 500 g did not significantly increase the cross-sectional area of the *rima glottidis*, although it did result in a significant decrease in airway resistance at low and high airflows. This effect was presumably due to a more rigid fixation of the arytaenoid cartilage that prevented narrowing of the airways due to displacement of the arytaenoid cartilage (Wignall and Baines 2012). Similarly, it can be argued that the toggle anchor suture system will result in increased stabilisation of the arytaenoid cartilage due to its more rostral position compared with the conventional suture placement for thyroarytaenoid lateralisation. This rostral position of the toggle could potentially lead to more significant decrease in airflow resistance compared with the more conventional arytaenoid lateralisation techniques.

The percentage of change in the *rima glottidis* cross-sectional area compares well with other studies that evaluated cricoarytaenoid (Bureau and Monnet 2002, Wignall and Baines 2012) and thyroarytaenoid lateralisation (Griffiths and others 2001, Wignall and Baines 2012), although it should be kept in mind that active abduction of the arytaenoid cartilage is not a prerequisite to decrease the laryngeal resistance (Bureau and Monnet 2002, Greenberg and others 2007).

Complications of the meniscal suture anchor system or similar devices used for meniscal tear repair include device migration, cartilage damage, synovial cyst formation, aseptic synovitis and haematoma formation (Kelly and Ebrahimpour 2004, Kurzweil and others 2005, Lee and Diduch 2005, Barber and others 2008). The toggle anchor suture system is made from a 2-0 ultra-high molecular weight polyethylene braided suture material. Braided suture materials are prone to wicking (Katz and others 1981), and might result in perilaryngeal abscess formation by conveying resident laryngeal bacteria and respiratory secretions. Foreign material in the larynx can also potentially lead to the formation of laryngeal granulomas (Lano and others 1999) due to mucosal irritation around the toggle anchor, which can result in increased resistance to airflow and recurrence of clinical signs. In addition to this, if migration of the device does occur into the laryngeal lumen, the potential does exist that it gets aspirated.

This study did not focus on the airflow resistance and safe corridors for insertion, neither did it assess whether these insertion angles will be achievable if the larynx is left in situ. Further studies are needed if all the limitations for application and infection risk can be addressed appropriately. Currently, the device cannot be recommended for use in clinical patients.

The authors conclude that the FF can be used for thyroarytaenoid lateralisation from intralaryngeally in an experimental set-up in canine larynges ex vivo. An insertion angle of 70° from the centre point of the part of the arytaenoid cartilages' vocal process visible from intralaryngeally (point X), parallel to the trachea in the dorsal plane resulted in penetration of the thyroid cartilage in all dogs. Placement of FF resulted in a significant opening of the *rima glottidis*.

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