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An animal tissue simulation assessing three directional displacement forces on five common tracheostomy securing techniques

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ABSTRACT

INTRODUCTION Several methods of securing a tracheostomy tube have been described in the literature including using ties or tapes around the neck and suturing the plastic flange to the neck in various ways. However, there are no wet lab-based studies to objectively determine the force required to displace the tracheostomy tube using different securing techniques. Ours is the first animal tissue simulation study published in the literature.

METHODS A simulated tracheostomy stoma was created on a sheep neck model. A tracheostomy tube was inserted into the stoma and secured using various methods. Tension tests were conducted to significantly displace the tube from the stoma. Each technique was repeated six times on different sheep necks. All results were analysed using SPSS®.

RESULTS Repeat measurements indicated that the largest displacement forces come from an oblique direction while the lowest force values were found at the lateral angle. Averages of displacement showed that medially placed sutures required the largest forces in comparison with other securing methods. Wilcoxon signed-rank testing indicated that medial and continuous suture security resists displacement at forces that otherwise displace flange and interrupted sutures.

CONCLUSIONS This study has shown that any type of securing suture requires a greater displacement force than the strap of the tracheostomy tube holder alone. Medially placed sutures require a greater displacement force than those placed laterally. Displacement in the lateral direction requires the least force in comparison with movement at perpendicular or oblique angles.

KEYWORDS

Tracheostomy – Suture techniques – Neck – Airway management – Torque

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Unintentional decannulation of a tracheostomy is a life threatening complication.[1] Tube displacement occurs in up to 7% of cases.[2] Reinsertion of a decannulated tube can be difficult in the early period following a tracheostomy and may result in the formation of a false passage.[3] In addition to obesity, postoperative swelling and tube length, factors contributing to tube displacement include frequent patient repositioning and the tube securing method.[1]

Several methods of securing a tracheostomy tube have been described in the literature including using ties or tapes around the neck and suturing the plastic flange to the neck in various manners.[4–7] Schaetzel *et al* observed that medially placed sutures require more force for displacement than laterally placed sutures.[1]

Given the wide variation in techniques of securing a tracheostomy, the aim of our study was to determine the impact of five common securing techniques when challenged by three separate directional forces, representative of different stresses due to patient movement or repositioning. This paper is the first of its kind to describe various suture securing techniques and directional force displacement characteristics using animal tissue.

Methods

Simulated tracheostomy stomas were created on fresh sheep neck specimens for their haptic similarity to the human patient. In the construction of the tracheostomy stoma, a 3cm skin incision was made and dissected down to the trachea. One tracheal ring was removed to create a box stoma.

Use of a Shiley™ (Medtronic, Dublin, Ireland) low pressure tracheostomy tube with inner cannula (size 8, inner diameter: 7.6mm, outer diameter: 12.2mm, length: 81mm, maximum balloon diameter: 27mm) ensured that any variables associated with tube characteristics were standardised. For all securing methods, a Trachi-Hold® (Kapitex, Wetherby, UK) strap (size small) was used. The sutures were not intended to replace the strap but to support it.

The models were tested using five methods of securing the tracheostomy tube (Fig 1). Four sutures were placed for each tracheostomy tube and method of suturing: two on the superior aspect of the flange and two on the inferior aspect. All techniques used 2/0 Mersilk® (Ethicon, Somerville, NJ, US) on a 3/8 circle reverse cutting mount tied with four knots (a surgeon's knot overlaid with two further reef knots) for each suture.

Tension testing was conducted in three separate directions (Fig 2) using digital luggage scales (Go Travel, London, UK), which can measure up to 40.0kg. Each technique was repeated six times on individual sheep necks. Significant displacement was deemed to occur when a suture snapped or started to cut through tissue, when the upper border of the cuff was seen on the stoma or when there was displacement of the tracheostomy tube from its attachment socket.

Measurements of force tension were represented by the number of kilograms shown on the luggage scales since force is directly proportional to mass. The data were analysed using SPSS® version 23.0 (IBM, New York, US).

Limitations to the securing methods

Placement of a medial suture line through the plastic flange was attempted but this consistently bent the needle, rendering penetration of the tracheostomy tube difficult. It was felt that this technique would represent clinically unsafe practice and as a result, it was omitted from our study.

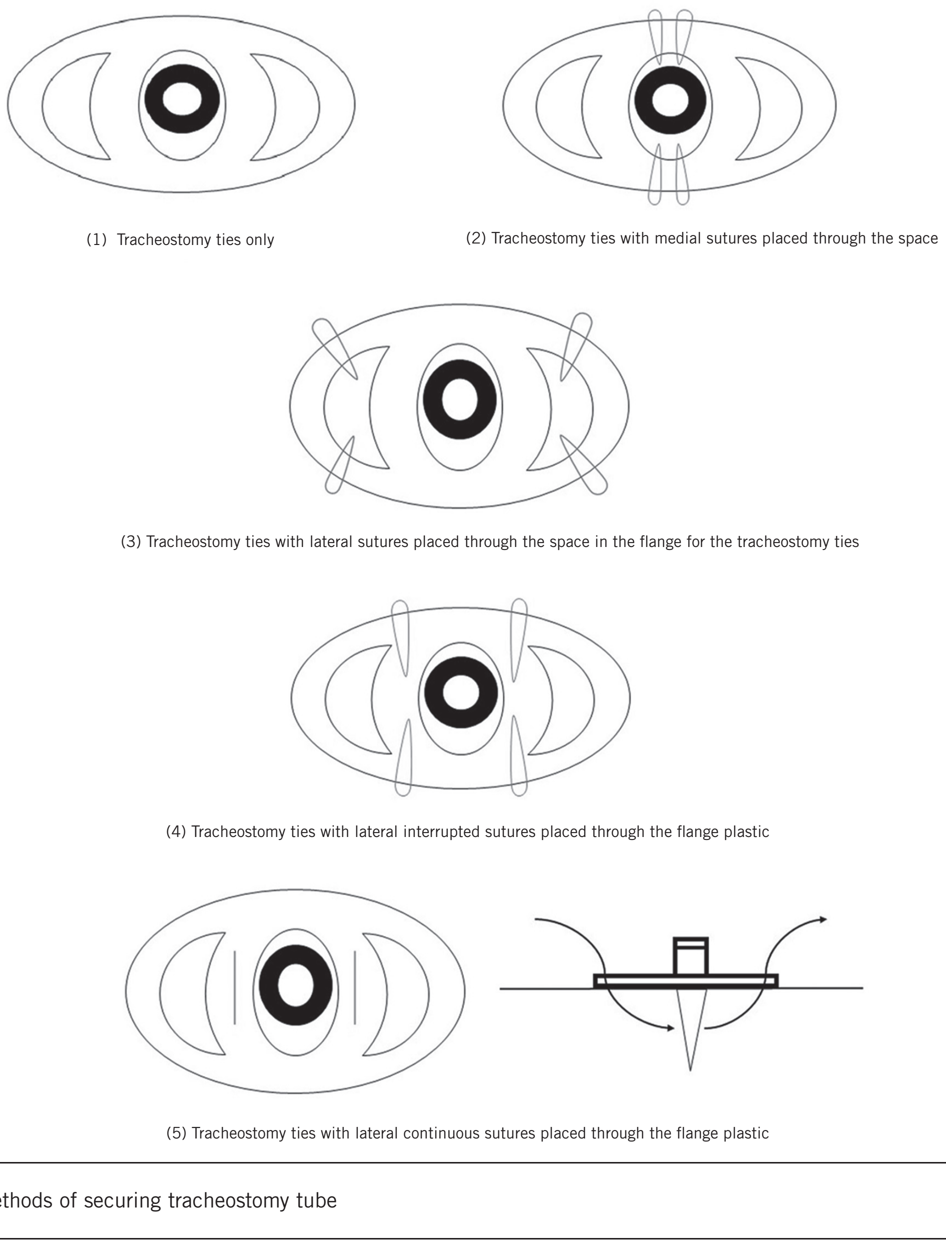

Figure 1 Five methods of securing tracheostomy tube

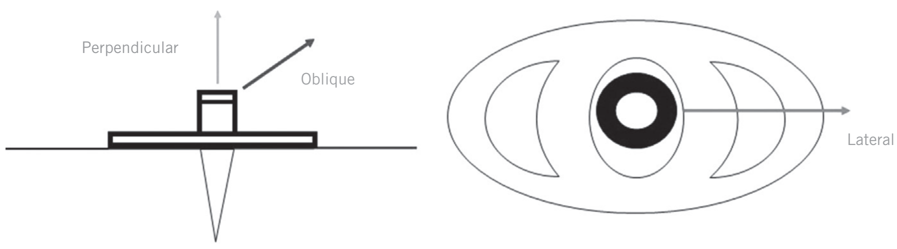

Figure 2 Directions of tension testing

An inflatable cuff exists around the base of the tracheostomy tube to facilitate permanent placement. As we were unable to standardise a pressure reading for cuff insufflation, the cuff was left uninflated for the whole study.

Results

The tension tests showed that irrespective of suture securing method, measurements for directional tension required to displace the tracheostomy tube were highest for the oblique angle while the lateral angle had the lowest measurements. The results of the tension tests are illustrated in Figure 3.

Friedman's two-way analysis of variance (a non-parametric signed-rank test) showed that the difference between oblique, perpendicular and lateral directional tensions in our study was statistically significant (p=0.009).

Chosen for its powerfulness with regard to related samples (after amalgamation of directional data), the Wilcoxon signed-rank test showed that compared with use of a tracheostomy tube holder strap alone, all suture methods required significantly higher displacement forces (Table 1). Medial suture placement was statistically superior to the flange and interrupted methods. The other techniques were not significantly different from each other.

Discussion

The use of tracheostomy has increased dramatically over recent years. Traditionally, tracheostomy has only been indicated in emergency management of upper airway obstruction but more recently, indications for tracheostomy have been extended to include prolonged mechanical ventilation, chronic respiratory insufficiency, failure of airway protective reflexes, management of excessive secretions and obstructive sleep apnoea.[8] Percutaneous tracheostomy is becoming a popular bedside intervention performed by intensive care physicians, with similar complication rates to those for open surgical procedures.[8]

Unintentional tracheostomy tube decannulation is a life threatening complication and is not easy to manage, especially if the tracheocutaneous fistula is not properly formed.[1,2,9] Reinsertion of a tube following accidental decannulation can be difficult and may result in formation of a false passage, in particular in the early postoperative period.[2,9]

Common practice at the end of a tracheostomy operation is to suture the plastic wings of the tube to neck skin, which has been shown to reduce the incidence of early accidental decannulations.[4] Various methods of securing tracheostomy tubes have been described but just one paper to date has objectively studied suture variants.[1] However, only lateral versus medial suture placement was described in that study, using cardboard tubing cut to represent neck tissue. To our knowledge, this paper is the first of its kind to describe the impact of directional forces on various securing techniques in a representative animal specimen.

Limitations of the experiment

It was not possible to account for the contribution of acceleration and torque variables to the forces measured. Although it is assumed that repetition helps mitigate this, further experimental design might reveal whether this is a significant factor. Moreover, we had no access to a manometer capable of standardising the balloon cuff pressure. All experiments were therefore conducted without balloon insufflation to avoid bias.

Significant differences exist between species in terms of anatomy, metabolism, physiology, genetics and pharmacology. These variates can confound translation of laboratory animal experimental results to humans.[10]

The displacement forces required in this study have not been extrapolated to measurement in a typical clinical environment (ie with varying skin elasticity and friction within an airway with moisture). It is not possible to say whether our results demonstrate any clinical resemblance with regard to real life forces encountered by the patient and clinician.

Factors affecting tube placement

Certain factors affect the placement of the tracheostomy tube, such as tube length, thickness of the subcutaneous tissue, positive end-expiratory pressure and patient position. Among these, the most important is considered to be choosing the appropriate proximal tube length for the amount of subcutaneous tissue.[1] In our study, these were set variables; nevertheless, further work to quantitatively assess their contribution would be worthwhile.

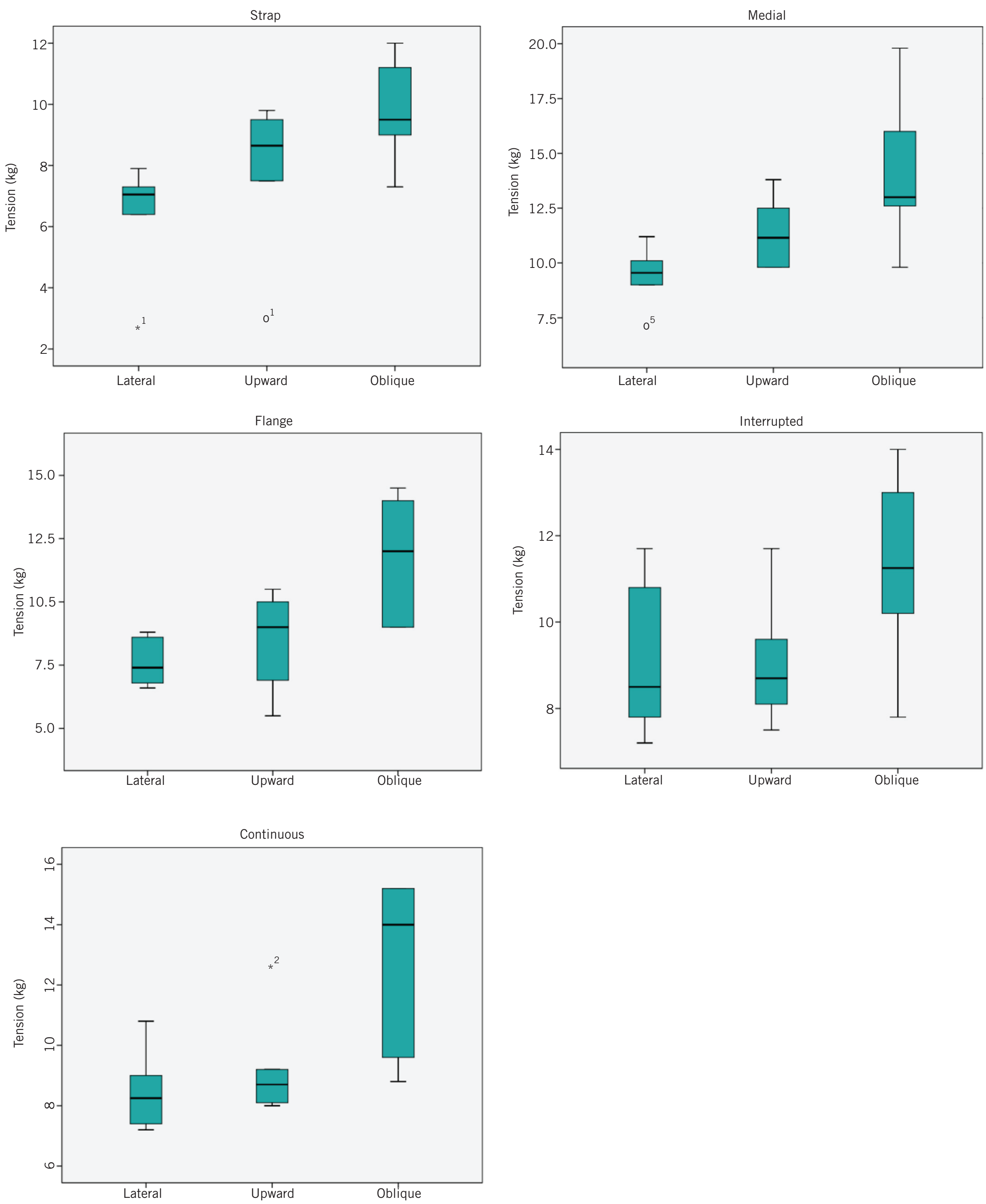

Figure 3 Results of the tension tests

Clinical implications

Our study corroborates the findings of Schaetzel *et al* that medial and lateral sutures exhibit greater resistance to displacement forces than a tracheostomy tube holder strap alone; furthermore, medially placed sutures are less likely to give way to displacement forces than those placed laterally.[1]

Table 1 Wilcoxon signed-rank test *p*-values comparing the various securing methods

	Strap	Medial	Flange	Interrupted	Continuous
Strap		**0.000**	**0.021**	**0.008**	**0.009**
Medial			**0.002**	**0.010**	0.093
Flange				0.422	0.267
Interrupted					0.602
Continuous					

As a result, clinicians should be particularly careful when using lateral movements (eg transferring the patient from the operating table to the bed or attaching the ventilation tube in the intensive care unit). Our findings also highlight that caution should be used when advancing any suture needle through the plastic flange of the tracheostomy tube as this affects the integrity of the suture material.

Further study

This study has reproduced the results of previous experimental work;[1] medially placed sutures required more force than laterally placed sutures to displace a tracheostomy tube. However, in order to compare the remaining suture techniques, an extended laboratory-based study would be necessary to test reproducibility and reliability of these results (construct validity). Moreover, in situ testing of possible displacement forces that could act on a tracheostomy tube would be beneficial to show the extent to which the forces generated in our laboratory were realistic (realism validity).

Conclusions

This study has shown that any form of securing suture is more beneficial in preventing tracheostomy tube displacement than use of a tube holder strap alone. Medial suture placement is a more secure method than placing lateral sutures. Lateral movement requires the least amount of force tension to displace the tube compared with movement at perpendicular or oblique angles.

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