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Accuracy of finger-tip palpated tracheostomy tube cuff pressure readings among otolaryngologists

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Abstract

The tracheal mucosa is very a delicate structure, and pressure–ischaemia problems following the use of cuffed tracheostomy tubes are well documented. Iatrogenic tracheal stenosis is one of the consequences of mucosal ischaemia and is very difficult to treat. In this study the accuracy of finger-tip tested tracheostomy tube cuff inflation pressure, as judged by consultants and non-consultants, was assessed by comparison with manometric pressure readings. The estimated pressure readings from the consultant group were more accurate than those from the non-consultant group, but a high standard deviation and very big difference between low and high readings in both these groups showed the real extent of the problem. Participants who performed 10 or more tracheostomies a year obtained more accurate results. No definite correlation was observed between the readings and the experience of the participants in otolaryngology or the size of the tube used. The authors recommend that instrumental monitoring of cuff pressure be considered good practice among junior otolaryngologists.

Key words: Tracheostomy; Intubation; Manometry

Introduction

Following operations such as tracheostomy and laryngectomy, a cuffed tracheostomy tube is used in the immediate post-operative period as a short-term measure to prevent secretions and blood from flowing down into the lungs. A cuffed tracheostomy tube is also used in patients receiving mechanical ventilation, to prevent air leak around the tube. A high cuff pressure can damage the delicate ciliated mucosa of the trachea and the subsequent pressure necrosis can lead to iatrogenic tracheal stenosis. It is necessary to take extreme care to prevent the development of this complication in tracheostomized patients as its management is very difficult. Other complications related to over-inflation of the cuff include ulceration of the mucosa, tracheal rupture, perforation and scarring, and fistula formation. Under-inflation can also cause complications such as air leak around the tube and aspiration of secretions. Therefore, it is very important to maintain an optimum cuff pressure to prevent the development of these complications.

Otolaryngologists estimate the cuff pressure by finger-tip palpation of the pilot balloon attached to the cuff or by listening for an air leak when the patient is ventilated. The accuracy of the inflation pressure is not usually checked by an objective method. The cuff pressure can be measured by various pressure gauges.

This study assessed otolaryngologists' accuracy of finger-tip palpated cuff pressure readings, compared with manometric pressure readings, in a tracheal model. The estimated cuff pressure readings were also correlated with the number of tracheostomies done by each participant in a year and with the experience of each participant in the field of otolaryngology.

Materials and methods

Otorhinolaryngologists from two different NHS trust hospitals in the UK took part in the study. We excluded from the study ourselves, doctors with less than 12 months experience in otolaryngology and those without any exposure to the use of cuffed tracheostomy tubes. The doctors from each hospital were grouped into 'consultants' and 'non-consultants'. We also noted each participant's number of years of otolaryngological experience and the average number of tracheostomies they performed in a year.

Two tracheal models were used in this study (Figure 1). The inner rubber tube was covered with an outer acrylic tube. Acrylic block was used to cover the gap between the two tubes at both ends. The smaller model (length 8.5 cm, inner diameter 12 mm and outer diameter 25 mm) was fitted with a size 6 Portex cuffed trachostomy tube. The bigger model

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FIG. 1

Tracheal models with cuffed tracheostomy tube *in situ,* the smaller model with the covering bag.

(length 8.5 cm, inner diameter 18 mm and outer diameter 50 mm) was fitted with a size 8 tube of a similar kind. Both the models were enclosed in a bag with only the cuff and the attached tubing outside the bag (Figure 1). The participants were asked to inflate the cuff to an optimum level, as they would in a clinical setting, and to estimate the inflation pressure by finger-tip palpation of the pilot balloon attached to the cuffed tracheostomy tube. A hand-held Portex manometer (Portex SK, Sperdel & Keller, Smith Medicals, UK & USA) with a pressure range of 0-120 cm H_2O was used in this study to objectively measure the cuff pressure by attaching the sensor end of the manometer to the air inflation port of the cuffed tracheostomy tube. The calibration of the equipment was checked at the beginning and end of the study. To get statistically significant data, each participant was tested 25 times using each tube (a total of 50 readings from each participant). The cuffed tracheostomy tubes were changed after every

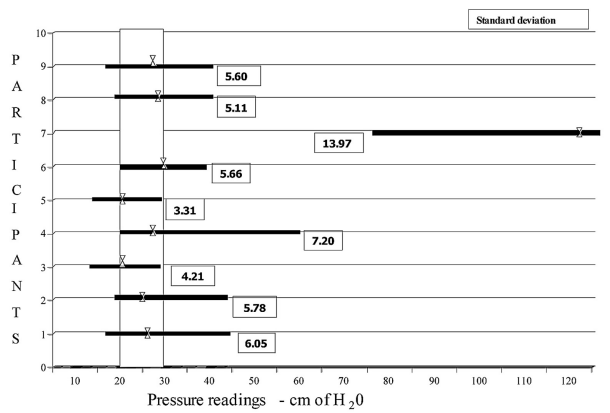

FIG. 2

Estimated tracheostomy tube cuff pressure readings from the consultant group. – = range of readings; hourglass figure = mean; boxed values = standard deviation

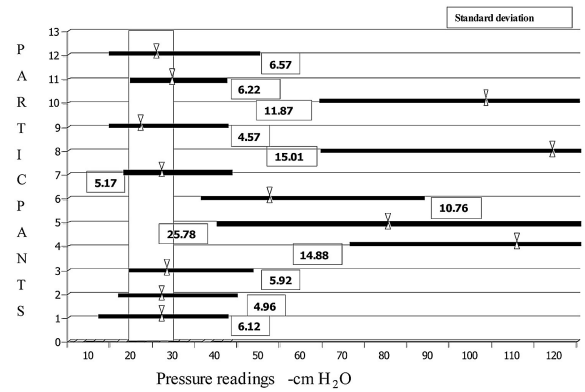

FIG. 3

Estimated tracheostomy tube cuff pressure readings from the non-consultant group. – = range of readings; hourglass figure = mean; boxed values = standard deviation

50 readings to avoid variations in the reading related to change in elasticity of the cuff material following repeated use. The same author took all the readings to avoid bias. The calibration error noticed at the end of the study was mainly for readings below 90 cm H_2O and varied from 1 to 3 cm H_2O.

Results

There were 21 participants: nine consultants and 12 non-consultants. The participants from hospital A comprised four consultants and eight non-consultants. The participants from hospital B comprised five consultants and four non-consultants. The number of years of experience in ENT varied from eight to 31 years (mean 21.6 years) among consultants and from one to 18 years (mean 10.2 years) among non-consultants. The average number of tracheostomies performed in a year by consultants and non-consultants varied from two to 25 (mean 10.6) and from one to 15 (mean 8.2), respectively.

The estimated pressure readings varied from eight to 120 cm H_2O. The ideal range, 16–26 cm H_2O, was observed in 49 per cent of the readings. A low inflation pressure was noticed in 9 per cent, while the remaining 42 per cent were above the required level. Detailed analysis of the high readings showed values above 50 cm H_2O in 57 per cent, above 100 cm H_2O in 32 per cent and above 120 cm H_2O in 18 per cent. Readings above 120 cm H_2O were unable to be assessed accurately as the pressure within the cuff was beyond the measuring capacity of the manometer.

Figure 2 shows details of the readings from the consultant group and Figure 3 shows those from the non-consultant group. In the consultant group the mean was within the required range for all participants except one (participant 7, mean 113 cm H_2O). However, the readings for this group ranged from 8 to 54 cm H_2O and the standard deviation varied from 3.006 to 7.889 (the corresponding values for participant 7 showed high readings, of 70–120 cm

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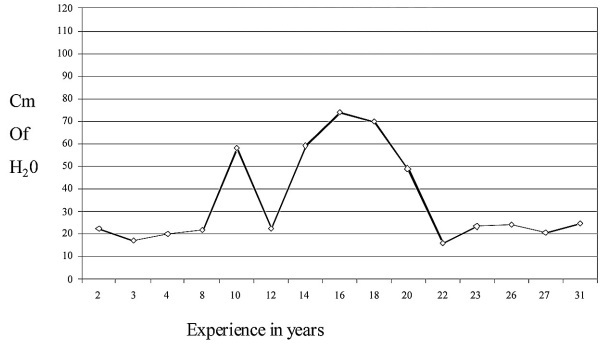

FIG. 4
Mean estimated tracheostomy tube cuff pressure reading vs participant's otolaryngological experience.

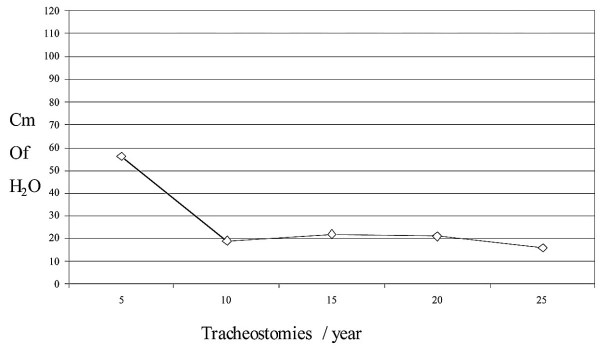

FIG. 5
Mean estimated tracheostomy tube cuff pressure reading vs participant's tracheostomy experience (procedures performed per year).

H_2O and 13.970, respectively). In the non-consultant group the mean was above the required range in five participants out of the total 12. All these values were above 50 cm H_2O and two of them were above 100 cm H_2O. The readings ranged from 8 to 120 cm H_2O and the standard deviation varied from 4.575 to 25.780.

The relation between mean values and the number of years of experience in otolaryngology is shown in Figure 4. Even though the readings were better in those with less than eight years and more than 22 years of experience in ENT, statistical analysis failed to show any definite correlation. The mean value of readings from each participant is plotted against the number of tracheostomies performed by each participant per year in Figure 5. Participants who performed 10 or more tracheostomies per year had better results than those who did not ($p < 0.001$). No significant difference was observed when the readings were analysed in relation to the size of the tube used.

Discussion

Tracheal capillary perfusion pressure is 4.3 kPa (43 cm H_2O);[1] therefore tracheostomy tube cuff pressure should ideally be less than this to prevent the disruption of microvascular circulation to the delicate tracheal mucosa. The recommended tracheostomy tube cuff pressure is less than 3.0 kPa (30 cm H_2O).[2] Although the incidence of ischaemic injury to tracheal mucosa and subsequent complications has reduced since the introduction of tubes with high volume, high compliance and low pressure cuffs, tracheal stenosis and tracheoesophageal fistula can still occur.[3] It is reported that even slightly high cuff pressures can result in erosion to the cilial lining after just two hours.[2] When cuff pressure is as high as 120 cm H_2O it can cause tears in the membranous part of the trachea and the neighbouring tissues. This can subsequently cause tracheal rupture.[4] Chemotherapy and steroid treatment make patients vulnerable to this complication.[5]

The pressure–ischaemia problem following use of cuffed tubes is well documented and is notoriously refractory to treatment.[6] The presssure that causes tracheal damage is not the cuff pressure itself but the lateral wall pressure exerted on the trachea;[7] this lateral wall pressure can be summarized by the following equation:

$$\text{Lateral wall pressure} = \text{Measured cuff pressure} - \text{minimal leak pressure}$$

where minimal leak pressure is the intra-cuff pressure that allows a minimal perceptible leak[7]. The measured cuff pressure and the minimal leak pressure are not the same because some amount of pressure is required to overcome the cuff's own elasticity. The lateral wall pressure also varies with the compliance of the cuff material[8] and the size and shape of both the trachea and the cuff.[9] Instrumental measurement of cuff pressure will be accurate if done properly, but it can also be misleading.[10] When a relatively small tube is used in a large trachea the high pressure in a small cuff will not exert any pressure on the tracheal wall. Objective tests in such situations can give either normal or high pressure readings; however the cuff is not serving its purpose.

Nitrous oxide anaesthesia may result in cuff hyperinflation as the gas diffuses into the cuff.[11] It is very important to recognize this problem in the post-operative period in order to prevent tracheal mucosal ischaemia and its complications. A prospective study assessing the risk factors for tracheal stenosis in patients undergoing endotracheal intubation of longer than 8 h duration concluded that cuff pressure monitoring three times per day seemed to help prevent ischaemic lesions and tracheal stenosis.[12] Vyas *et al*. observed hyperinflation of the tracheal tube cuff in 62 per cent of a total of 32 patients in critical care.[13] These authors suggested regular cuff pressure monitoring as such patients are particularly vulnerable to tracheal injury.

In our study the consultant group did better than the non-consultant group. However the high standard deviation observed for both groups denotes the true nature of the problem. More than half of the readings were outside the required range.

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A hand-held pressure gauge for tracheostomy tubes is available in most operating theatres and it is very easy to compare the finger-palpated cuff pressure reading with that of a manometer. Instrumental monitoring of intra-cuff pressure in cuffed tracheostomy tubes is good practice among both junior otolaryngologists and senior otolaryngologists who have limited experience with cuffed tracheostomy tubes. Such instrumental monitoring could also be used as a method of self-validation among consultants. Since the working atmosphere in a dedicated otolaryngology ward differs from that of an intensive care unit it is difficult to use a manometer routinely. However if otolaryngologists regularly check their own finger-palpated cuff pressure against those of a manometer this will definitely improve the quality of patient care.

- **In this study the accuracy of finger-tip assessment of tracheostomy cuff inflation pressure was investigated**
- **Although more experienced staff were better at estimating cuff inflation pressure there was considerable variation in estimates**
- **In order to minimize complications due to cuff over-inflation, instrumental monitoring of cuff pressure is recommended**

Conclusion

In this study more than half of the tracheostomy cuff pressure readings were out of the required range of 16–26 cm H_2O. Over-inflation of the cuff was five times more common than under-inflation. The consultant group did better than the non-consultant group. The current practice among the non-consultant group could be modified by regular use of the manometer that is available either in the operating theatre or in the anaesthetic department. This could also be used as a method of self-validation among consultants. Re-evaluation of the situation after implementing this change of practice would be essential to assess whether improvement had occurred.

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