

An *in vitro* study of tracheostomy tube cuff herniation and inflation characteristics

L. J. HOLLIS, J. S. ALMEYDA, G. MOCHLOULIS, K. S. PATEL

Abstract

Seven of the most commonly used tracheostomy tubes used in the U K were tested for cuff herniation and creasing in synthetic tracheas corresponding to the shapes and sizes found *in vivo*. Results demonstrated that only two tubes of one particular brand herniated and that creasing occurred in tubes disproportionately large for the trachea used. A discussion of modern tracheostomy tube manufacture is included.

Key words: Tracheostomy

Introduction

Tracheostomy and endotracheal tube cuff herniation is an unusual cause of respiratory embarrassment which usually occurs in the per-operative period. Bar-Lavie *et al.* (1995) reported a case of intra-operative cuff herniation involving a Shiley tracheostomy tube. Various other reports have been published of endotracheal tube cuff herniation involving other types of commercially available tubes (Robbie and Pearce, 1959; Ward *et al.*, 1978; Davidson and Zimmer, 1989; Treffers and De Lange, 1989).

These various studies concluded that the causes of cuff herniation are diverse and include inward diffusion of nitrous oxide into the cuff causing an increase in both cuff volume and pressure; inherent structural differences between latex and PVC cuffs as well as placement difficulties resulting in abnormal expansion of the cuff into a main bronchus.

The aim of this study was to compare the commercially available cuffed tracheostomy tubes in the UK for their propensity, if any, to herniate and crease when inflated in a model trachea.

Materials and methods

Polyurethane tubes of internal diameter 18, 20, 22 and 25 mm were used since these sizes correlate well with *in vivo* sizes. Tracheal shapes are known to vary from C-shaped (40 per cent) to Δ (three per cent) and so synthetic tubes of circular, triangular and C-shape were used to fully take account of biological variance (Mackenzie *et al.*, 1979).

Comparison was made between tubes manufactured by Mallinckrodt (Shiley low-pressure cuffed

and 'Hi-Lo'), Bivona ('Tight-To-Shaft' Aire-Cuf and 'Hyperflex'), Rusch and Portex ('Blue Line' and 'Disposable Inner Cannula'). As a method of standardization, comparison was made by internal diameter i.e. 5.0, 6.0, 7.0, 8.0 and 9.0 mm (N.B. Shiley sizes 5.0, 7.0, 8.5 and 9.0 mm). Tracheostomy tubes of each internal diameter were inserted into each size and shape of trachea in turn and maximally inflated and observed for cuff herniation specifically, as well as any other cuff abnormality.

Results

The results clearly demonstrate that only one brand of tube of two sizes did in fact herniate, namely, the Kapitex Bivona TTS (Tight-To-Shaft) Aire-Cuf tube, size 6 and size 7, and that when examined, defects were visible (Table I). These defects were seen to be a line of cuff adherence to the tube shaft in the size 7 tube and an area of asymmetric cuff expansion in the size 6 tube (Figures 1, 2 and 3).

Conclusions

Peri-operative tracheostomy tube cuff herniation is a rare complication which can cause acute respiratory embarrassment. There have been numerous case reports describing cuff herniation involving endotracheal tubes (Robbie and Pearce, 1959; Ward *et al.*, 1978; Davidson and Zimmer, 1989). These problems may have a structural cause by way of a manufacturing defect or may be due to nitrous oxide diffusion into the cuff with resultant expansion and herniation (Stanley, 1975; Treffers and De Lange, 1989). Far fewer case reports have been made

TABLE I

RESULTS OF SEVEN BRANDS OF TRACHEOSTOMY TUBES MANUFACTURED BY FOUR COMPANIES SHOWING WHETHER CUFF HERNIATION OCCURRED, TOGETHER WITH ECCENTRICITIES OF TUBE TIP POSITION AND WHETHER CUFF CREASED SIGNIFICANTLY, FOR EACH SHAPE AND SIZE OF SYNTHETIC TRACHEA.

Tube type	Internal diameter (mm)	Triangular (25 mm)	Circular (18 mm)	Circular (20 mm)	Circular (22 mm)	D-shape (20 mm)	D-shape (25 mm)
Rusch	5	None	None	None	None	None	None
	6	None	None	None	None	None	None
	7	None	None, creased	None	None	None	None
	8	None	None, creased	None, creased	None	Creased	None
	9	None, creased	None, creased	None, creased	None, creased	Creased	None
	10	None, creased	None, creased	None, creased	None, creased	Creased	Creased
Bivona TTS-Aire-Cuf	6	None, tube tip lay anterior	None, tube tip lay anterior	None, tube tip lay anterior	None, tube tip lay anterior	Herniated to tip	Herniated to tip
	7	None	Herniated to tip	Herniated distal to tip	None	Herniated distal to tip	Herniated distal to tip
	8	None	None	None	None	None	None
Hyperflex	7	None	None, creased	None	None	None	None
	8	None	None	None	None	None	None
	9	None	None, creased	None, creased	None	Creased	None
Mallinckrodt Hi-Lo	5	None	None	None	None	None	None
	6	None	None	None	None	None	None
	7	None	None, creased	None, creased	None	Creased	None
	8	None	None, creased	None, creased	None, creased	Creased	None
Shiley	5	None	None, creased	None	None	None	None
	7	None	None, creased	None, creased	None	Creased	None
	8.5	None, creased	None, creased	None, creased	None, creased	Creased	None
	9	None, creased	None, creased	None, creased	None, creased	Creased	None
Portex Blue Line	6	None	None	None	None	None	None
	7	None	None, creased	None	None	None	None
	8	None	None, creased	None, creased	None	Creased	None
	9	None	None, creased	None, creased	None, creased	Creased	None
D.I.C.	6	None	None	None	None	None	None
	7	None	None, creased	None	None	None	None
	8	None	None, creased	None, creased	None	Creased	None
	9	None	None, creased	None, creased	None, creased	Creased	None

examining the problem existing with tracheostomy tubes (Bar-Lavie *et al.*, 1995).

This study was designed to examine the potential problem of tracheostomy tube cuff herniation in the tubes currently available in the UK.

Tracheostomy tubes, which are currently available, are made of synthetic materials in contrast to those of the previous 20 years or so, which were manufactured from latex rubber which had inherent

problems. Modern plastics such as PVC and silicone are advantageous in that they help to ensure uniform expansion of cuffs and so avoid cuff herniation, tube tip eccentricity and resultant tracheal mucosal erosion. Synthetic materials are also less irritant to body tissues, are easier to manipulate in the manufacturing processes and soften at body temperature thus conforming to anatomical structures. Inherent properties of plastics also allow the

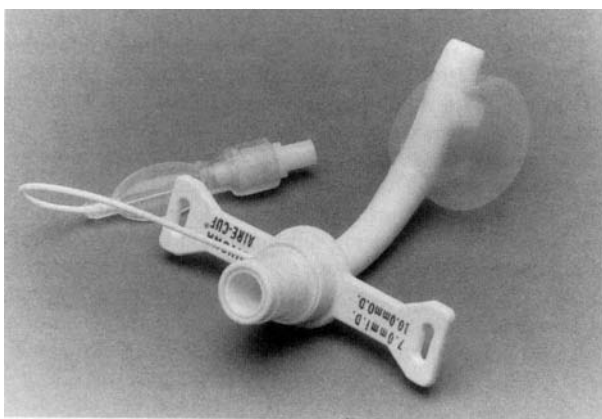


FIG. 1

Bivona 'Aire-Cuf' showing area of cuff adherence to shaft.

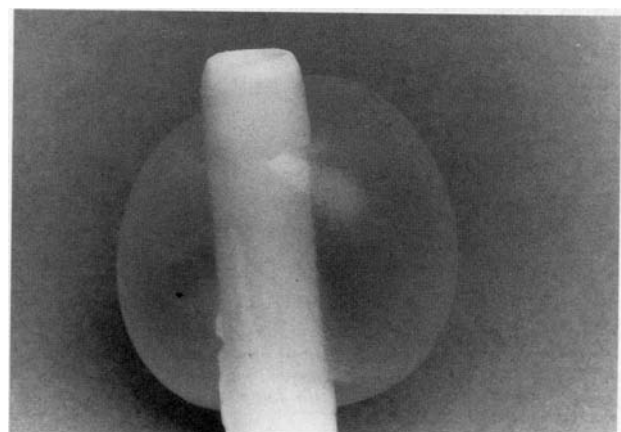


FIG. 2

Higher power view of above.

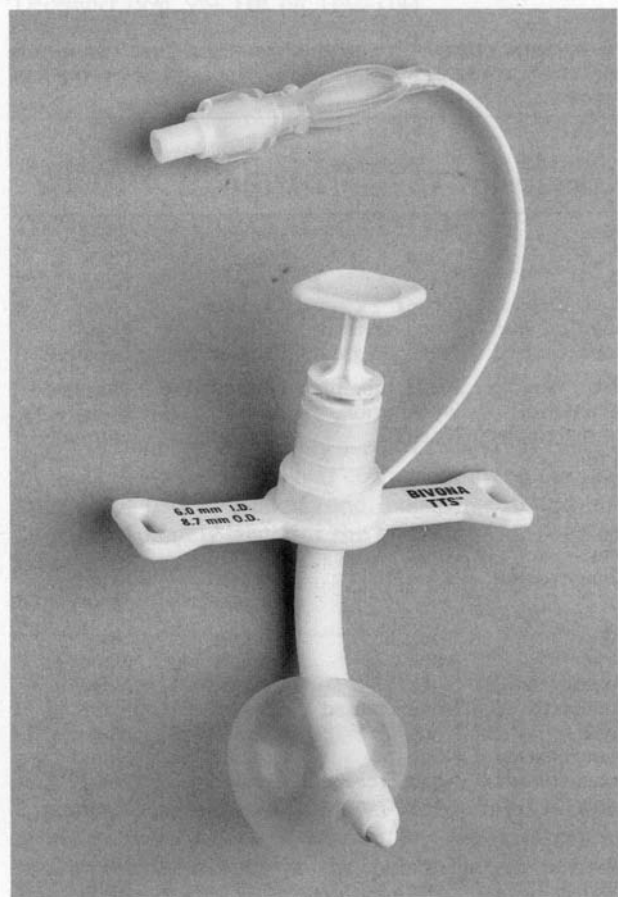


FIG. 3

Bivona 'Tight-To-Shaft' cuff showing asymmetric expansion.

production of minimal cuff wall thickness which helps to lessen cuff creasing and avoids ventilator gas leakage or fluid overspill in patients with a tendency to aspiration.

Modern tracheostomy tubes are generally designed to have high volume-low pressure cuffs which aid prevention of ischaemic damage to the tracheal mucosa since capillary perfusion pressure (approximately 25 mmHg), is not exceeded (Bernhard *et al.*, 1985).

It is noteworthy that strict guidelines have been laid down by the Health Care Standards Committee which apply to the manufacture of tracheostomy

tubes and encompass materials, dimensions, cuff characteristics and packaging. This standard is known as BS 3487 Part 5 1986 and is identical to the international standard ISO 5361/5-1984 (British Standards Institution, 1993).

To prevent per-operative complications as a result of herniation, the tube and cuff should be thoroughly checked pre-operatively and a high index of suspicion held in the case of ventilatory problems during surgery or shortly afterward. In order to prevent complications as a result of cuff creasing the correct size tube must be carefully chosen to suit the size of the patient's trachea and awareness of possible discrepancies of tracheal anatomy maintained.

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Address for correspondence:

Mr L. J. Hollis,
Flat 7, The Helme,
10 Lake Road,
Wimbledon,
London SW19 7EN.