

## The clinical implication of the vocal cords–carina distance in anaesthetized Chinese adults during orotracheal intubation

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**Background.** Previous studies have identified no strong correlation between patients' height and tracheal length in anaesthetized patients. We have attempted to compare vocal cords–carina distance (VCD) in Chinese patients with the dimensions of five commonly used tracheal tubes. In addition, we attempted to find a surface anatomy measurement that would identify patients with 'short tracheas'.

**Methods.** We measured VCD in 130 anaesthetized Chinese patients with a fiberoptic bronchoscope. Also measurements were obtained of the distal ends of five commonly used tracheal tubes. We undertook various surface anatomy measurements on the patients' chest and neck region to predict those patients with short tracheas.

**Results.** VCD averaged 12.6 (SD 1.4) cm. In seven patients (5%) this distance was particularly short (between 8.8 and 10.4 cm). Many of the commonly used tracheal tubes would be placed close to or beyond the carina when the black intubation guide mark(s) is (are) at the level of the vocal cords. The VCD of  $\leq 11$  cm (short trachea) could be predicted by patient height of  $\leq 167.5$  cm and a thyrosteral distance of  $\leq 28.5$  cm with limited reliability.

**Conclusions.** A significant number of patients with short VCD in our study group could be at risk of endobronchial intubation with many of the tracheal tubes. Patient height and thyrosteral distance can be useful in predicting short tracheas.

*Br J Anaesth* 2006; **97**: 489–95

**Keywords:** complications, intubation endobronchial; equipment, tubes tracheal; lung, trachea; measurement techniques, fiberoptic

Accepted for publication: June 9, 2006

The optimal placement of a tracheal tube (TT) should ensure that the tip is sufficiently distant from the carina to avoid endobronchial intubation, especially during movement of the head and neck.<sup>1,2</sup> In addition the TT cuff should be distal to the cricoid ring to avoid damage to the vocal cords and inadvertent extubation.<sup>3,4</sup> In an attempt to reduce the risk of such events, many TT manufacturers place one or two black mark(s) proximal to the cuff to guide the practitioner during the intubation as to the correct depth of tube insertion; the TT is placed so that these marks are at level with the vocal cords or, where there are two marks, the vocal cords are between them. Previous studies have suggested formulae to guide optimal depth of insertion<sup>5–7</sup> but there appears to be variable correlation between these formulae and actual tracheal dimensions in many anaesthetized patients.

The trachea starts at the lower end of the cricoid ring and ends at the carina. This length is said to be 10–15 cm in adults with 5 cm of this above the suprasternal notch.<sup>8,9</sup> Although the tracheal length in anaesthetized adult patients averaged  $\sim 12$  cm<sup>10,11</sup> unfortunately only a moderate correlation could be established with the patients' height. It is, therefore, difficult to predict those patients who have short tracheas and an increased risk of endobronchial intubation.

Identifying a surface anatomy measurement that could predict patients with increased likelihood of having a short trachea would be useful to reduce the risk of endobronchial intubation. In addition, it is important to be aware of the length of the TT that needs to pass through the vocal cords (with or without the assistance of surface markings), which will allow safe distances between the TT tip and the carina and between the TT cuff and the vocal cords.

This study was undertaken to determine the appropriateness of five commonly used tracheal tubes in the Chinese population. The second part of our investigation attempted to ascertain a surface anatomy measurement that would be clinically useful for predicting those patients who may have a particularly short trachea. In the present study we have measured the distance from the vocal cords to the carina, which yields a longer airway length than the true anatomical tracheal length. Although this does not represent a distinct anatomical organ, we have chosen this distance because this part of the upper airway accommodates the TT from the black mark(s) to its tip and therefore is important during clinical airway management.

## Materials and methods

Our local institutional Ethics Review Board approved the study and written informed consent was obtained from all participants. The patients were permanent residents of Hong Kong and of self-declared Chinese racial descent, and were ASA I–III undergoing general anaesthesia. Patients with a history of or features suggestive of difficult intubation [including Mallampati grade 3 or 4, limited mouth opening, thyromental distance (TMD) <4 cm, limited neck movement or upper airway disease], patients with distorted anatomy of the trachea and those at high risk of aspiration were excluded.

Surface anatomy measurements were obtained from all patients before operation. All measurements were conducted by one of the investigators in order to reduce inter-observer variation. Height, weight and surface anatomy measurements with clearly defined landmarks were made. The cricoid ring and sternal angle are the accepted surface anatomical landmarks of the beginning and end of the trachea. However, we found the sternal angle to be an ill-defined landmark in the majority of the patients and recorded more distinct surface anatomy features as possible replacements. These consisted of the inferior border of the mentum, the thyroid notch, the base of the sternal notch and the xiphisternum. The TMD and sternomental distance (SMD) were measured with the neck in maximal extension. The sternothyroid length (STL) and sternal length (SL) were measured with the head in the neutral position (i.e. forward facing gaze to a distant point on the horizon). The combination of the latter two gave the thyrosternal length (TSL). All surface anatomy distances were linear measurements.

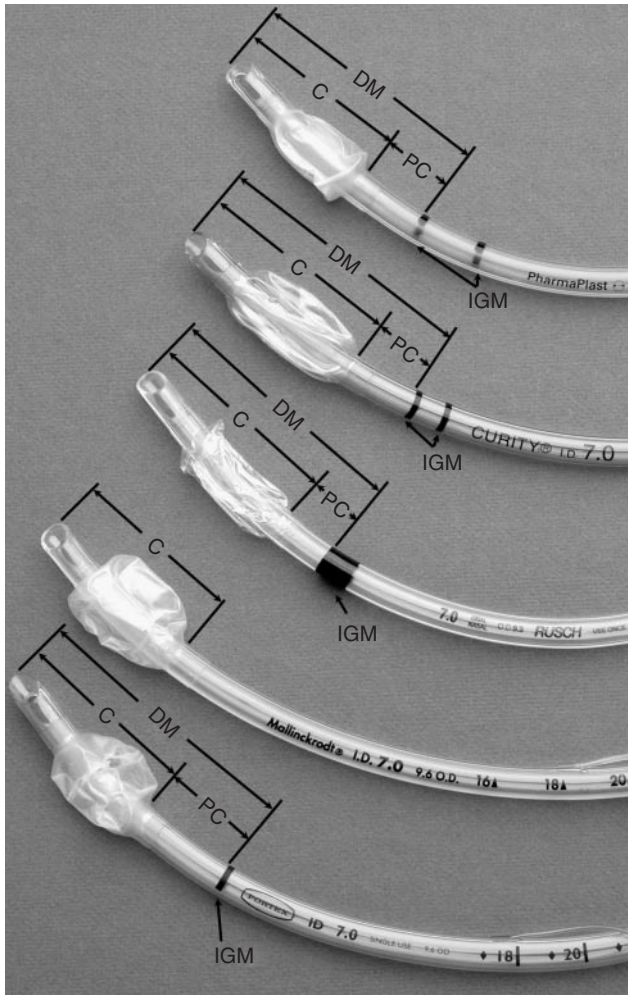
After establishing routine non-invasive monitoring (ECG, non-invasive blood pressure measurement, pulse oximetry and end-tidal CO<sub>2</sub> analysis), the patient was placed in the classic ‘sniffing position’ with a small pillow under the occiput. General anaesthesia was induced and full muscle relaxation was monitored with a peripheral nerve stimulator [TOF Watch (R) SX Organon Teknika BV, Boxtel, The Netherlands] using train-of-four stimulation of the ulnar nerve at the wrist. Tracheal intubation was performed using a Profile Soft-Seal Cuff (Portex Ltd, Hythe, Kent, UK)

tracheal tube with the black intubating guide mark placed at the vocal cords. The size 7 and 8 mm ID (internal diameter) tracheal tubes were used in females and males respectively. Unlike a previous study<sup>11</sup> we found that it was difficult to view the vocal cords through the wall of the TT because of respiratory condensation. It was, therefore, decided that the tracheal tube would be inserted until the intubation guide mark was level with the vocal cords and the head and neck was strictly maintained in the neutral position throughout the intubation by an anaesthetic assistant to avoid any movement of the tube while the laryngoscope was being removed. All patients were graded Cormack-Lehane 1 or 2 in this study, which ensured that the anaesthetist performing the orotracheal intubation could position the intubation guide mark at the level of the vocal cords. After the haemodynamic variables had stabilized and the volatile anaesthetic had reached an adequate concentration, the TT was disconnected from the anaesthetic circuit and a fiberoptic bronchoscopy was performed through it. The measurements were, therefore, all obtained at the end of expiration.

The tip of the fiberoptic bronchoscope was inserted to two separate depths—the carina and the tip of the tracheal tube. At each depth an adherent marker was placed on the bronchoscope where it entered the connector of the tracheal tube. Measurements from the tip of the fiberoptic bronchoscope to each of the markers were made and from this measurement the distance from the tip of the tracheal tube to the carina was ascertained. The vocal cords–carina distance (VCD) was then calculated by adding the distance of the tip to carina to the length of the tracheal tube from the tip to the black intubating mark (8.8 and 9.5 cm for size ID 7 and 8 mm, respectively). The fiberoptic examination and measurements were completed within 30 s with no adverse events occurring.

In addition we checked the dimensions of five commonly used TTs that were available in 2004/5 when this study was conducted, to determine whether their size is appropriate for this patient population. These brands were Portex Profile Soft-Seal Cuff (Portex Ltd, Hythe, Kent, UK), Mallinckrodt Hi-Lo™ (Mallinckrodt Ltd, Tucson, AZ, USA), Rusch Ruschelit® Super Safety Clear (Teleflex Inc., Limerick, PA, USA), Kendall Curity® (Tyco Healthcare, Mansfield, MA, USA) and PharmaPlast Murphy (Pharmplast Ltd, Redditch, UK) (Fig. 1). Fifteen samples of size ID 7.0, 7.5, 8.0 and 8.5 mm were reviewed. The TTs were measured with metal callipers with the tube straightened for the measurement. All were measured along the line of the air channel for cuff inflation with the cuffs inflated to allow clear identification of the proximal edge.

Correlation coefficients and multiple regression modelling were used to investigate the relationships between the anatomy measurements and tracheal length. Area under Receiver Operating Characteristic (ROC) curves, sensitivity, specificity and positive predictive values were used to evaluate the detection power of the various anatomy measurements for short tracheal lengths. The statistical



**Fig 1** Distal ends of the five tracheal tubes. In order from top—PharmaPlast Murphy (Pharmplast Ltd, Redditch, UK), Kendall Curity® (Tyco Healthcare, Mansfield, MA, USA), Rusch Ruschelit® Super Safety Clear (Teleflex Inc., Limerick, PA, USA), Mallinckrodt Hi-Lo™ (Mallinckrodt Ltd, Tucson, AZ, USA) and Portex Profile Soft-Seal Cuff (Portex Ltd, Hythe, Kent, UK). DM: distance between the distal edge of intubation guide mark (distal intubation mark in Kendall and Pharmplast) and the tip. C: distance between the proximal edge of the cuff and the tip. PC: distance between the distal edge of intubation guide mark and the proximal edge of cuff. IGM: intubation guide mark. In Mallinckrodt tubes, no intubation guide marks were present.

software used was SPSS for Windows, Release 13.00 (SPSS Inc., USA).  $P < 0.05$  was considered significant.

## Results

A total of 130 patients were studied during 1 month period. The patient characteristics and measurements are presented in Table 1. The VCD measurements in our study are shown in Table 2 with seven patients (5%) having a distance of 10.5 cm or less. In one female patient who was 156 cm tall, the tip of the size 7 mm ID. Portex tracheal tube was already at the carina with a measured carina to vocal cord

length of 8.8 cm. One male patient who was 159 cm tall had a VCD of 10.6 cm.

In measuring the TTs, the Portex Profile Soft-Seal Cuff, Kendall Curity and PharmaPlast Murphy tubes were found to be accurately manufactured with little variation in the measurements. The measured lengths of various tracheal tubes are shown in Table 3.

The correlation of the different measurements with the tracheal length is shown in Table 4. The two variables that most correlated with VCD were the patients' height and TSL ( $r = 0.55$  and  $0.51$ , respectively). Stepwise multiple linear regressions yielded the following model:

Predicted tracheal length

$$= -2.01597 + (0.06314 \times \text{Height}) + (0.16033 \times \text{TSL})$$

$$R^2 = 0.3381 (r = 0.5815).$$

The definition of a 'short' VCD for tracheal intubation depends upon the dimensions of the particular tracheal tube used at the time. Given the mean value of VCD of 12.6 cm and SD of 1.4 cm (Table 1), the lower end of the range for VCD is 11.2 cm. Therefore  $\leq 11$  cm is a reasonable measure for a 'short' VCD and this compares favourably with the measurements used in Table 5 that indicates the tracheal lengths that are too short for the TTs studied in this series.

To detect a VCD of  $\leq 11$  cm, ROC curves (Fig. 2) were constructed for individual measurements as well as for the multiple linear regression model. The area under the curve and the 95% CIs of the three curves are shown in Table 6.

Table 7 summarizes the positive predictive value of the various measurements for different VCD predictions with a sensitivity of 100%; VCD of  $\leq 10$  cm occurred in individuals with height of  $\leq 159$  cm and a TSL of  $\leq 24.5$  cm, while based on the multiple linear regression model an equivalent value of VCD was  $< 12.0$  cm. However the positive predictive values (PPV) for the three different predictors namely height, TSL and the regression model were only 5.1, 23.1 and 8.8%, respectively. The prediction only improved to 15.9% in the multiple linear regression model for VCD of  $\leq 10.5$  cm. For detecting a VCD  $\leq 11$  cm, the cut-off of height  $\leq 167.5$  cm and TSL  $\leq 28.5$  cm gave the best diagnostic results among the four predictors (specificity 47.0 and PPV 19.7%) examined.

## Discussion

The mean (SD) VCD in the present study for both sexes was 12.6 (1.4) cm. The shortest VCD recorded was 8.8 and 10.6 cm in females and males, respectively. Our results are close to the findings in a similar study by Cherng and colleagues,<sup>11</sup> where the mean tracheal length was 12.1 (1.8) cm and the shortest tracheas were 8.5 and 9.2 cm for females and males, respectively. It is difficult to position the TT in patients with such short tracheas first to provide adequate clearance of the vocal cords by the tracheal cuff above and second to avoid endobronchial intubation.

**Table 1** Patient characteristics and measurements. Values are in mean (range) or (SD) [95% CI]

	Female (n=72)	Male (n=58)	Total (n=130)	P-value (female vs male)
Age (yr)	48.9 [22–76]	54.3 [18–81]	51.3 [18–81]	0.04
Weight (kg)	55.7 (10.2) [53.3–58.1]	64.8 (10.9) [62.0–67.7]	59.8 (11.8) [57.8–61.8]	<0.0001
Height (cm)	156.1 (6.5) [154.6–157.7]	166.7 (7.1) [164.8–168.5]	160.8 (8.7) [159.3–162.3]	<0.0001
BMI (kg m <sup>-2</sup> )	22.9 (4.3) [21.9–23.9]	23.3 (3.4) [22.4–24.2]	23.1 (3.9) [22.4–23.8]	0.58
Thyromental distance (TMD) (cm)	6.5 (0.9) [6.3–6.7]	7.6 (1.0) [7.3–7.8]	7.0 (1.1) [6.8–7.2]	<0.0001
Sternomental distance (SMD) (cm)	16.3 (1.8) [15.9–16.7]	17.2 (2.2) [16.6–17.7]	16.7 (2.0) [16.3–17.0]	<0.05
Sternothyroid length (STL) (cm)	7.4 (1.3) [7.1–7.7]	7.6 (1.4) [7.2–8.0]	7.5 (1.4) [7.2–7.7]	0.33
Sternal length (SL) (cm)	19.6 (1.4) [19.2–19.9]	21.5 (1.5) [21.1–21.9]	20.4 (1.7) [20.1–20.7]	<0.0001
Thyroid notch to xiphisternum (TSL) (cm)	26.9 (2.0) [26.5–27.4]	29.1 (1.9) [28.6–29.6]	27.9 (2.2) [27.5–28.3]	<0.0001
Vocal cords–carina distance (VCD) (cm)	12.0 (1.2) [11.7–12.3]	13.4 (1.3) [13.0–13.7]	12.6 (1.4) [12.4–12.9]	<0.0001

**Table 2** Frequencies of vocal cords–carina distance (VCD)

VCD (cm)	Frequency	Percentage	Cumulative frequency	Cumulative percentage
≤9.5	2	1.5	2	2
>9.5–10.0	1	0.8	3	2
>10.0–10.5	4	3.1	7	5
>10.5–11.0	8	6.2	15	12
>11.0–11.5	18	13.9	33	25
>11.5–12.0	15	11.5	48	37
>12.0–12.5	11	8.5	59	45
>12.5–13.0	26	20.0	85	64
>13.0–13.5	12	9.2	97	65
>13.5–14.0	13	10.0	110	85
>14.0–14.5	11	8.5	121	93
>14.5–15.0	2	1.5	123	95
>15.0–15.5	4	3.1	127	98
>15.5–16.0	1	0.8	128	98
>16.0	2	1.5	130	100

The distance between the intubation guide mark and the proximal edge of the tracheal cuff should be adequate to avoid critical incidents such as inadvertent extubation and recurrent laryngeal nerve compression by the cuff. To that end several authors have suggested<sup>13,12,13</sup> that the intubation guide mark should be somewhere between 1.5 and 3 cm proximal to the cuff. Bennett and colleagues<sup>14</sup> examined 13 fresh cadavers and found that the midline distance from the vocal cords to the bottom of the cricothyroid membrane is 23.5 mm. Randestad and colleagues<sup>15</sup> determined the height of the cricoid ring anteriorly to be 7.2 mm. Based on these two studies, the tracheal cuff should be ~31 mm below the vocal cords before it is clear of the cricoid ring.

It seems prudent to avoid the cricoid ring, as this part of the airway is a complete ring as opposed to the trachea which has a membranous posterior wall that may act to relieve the pressure of an over-inflated tracheal tube cuff. As the amount of contact between the tracheal cuff and the tracheal mucosa varies depending on various factors including cuff profile, intracuff inflation pressures and tracheal cross-sectional area, we have obtained a view that if the proximal edge of the cuff is distal to the cricoid ring then subglottic damage by the tracheal cuff will be minimized.

From the tracheal tubes examined, the PC (distance between distal edge of intubation guide mark to proximal

**Table 3** Lengths of five different brands of tracheal tubes median [range]. DM, distance between the distal edge of intubation guide mark (distal intubation mark in Kendall and Pharmaplast) to the tip. C, distance between the proximal edge of the cuff to the tip. PC, distance between the distal edge of intubation guide mark to the proximal edge of cuff. All measurements are in millimetre. \*In Mallinckrodt tubes no intubation guide marks were present

Brand/size of tracheal tubes	7 mm ID	7.5 mm ID	8 mm ID	8.5 mm ID
Portex Profile Soft-Seal Cuff				
DM	88 [88–89]	88 [88]	95 [94–95]	96 [95–96]
C	58 [58–59]	58 [58–59]	60 [60–61]	62 [61–62]
PC	30 [30–31]	30 [29–30]	35 [34–35]	34 [34–35]
Mallinckrodt Hi-Lo™*				
C	55 [54–57]	55 [52–58]	63 [62–65]	66 [66–67]
Rusch Ruschelit® Super Safety Clear				
DM	79 [79–80]	80 [79–81]	86 [85–86]	86 [86–88]
C	61 [61–62]	63 [61–64]	69 [67–70]	67 [65–69]
PC	18 [17–19]	17 [16–18]	17 [16–18]	20 [19–21]
Kendall Curity®				
DM	85 [84–85]	86 [86]	90 [90–91]	92 [91–92]
C	64 [64–65]	65 [64–65]	66 [66–68]	69 [69–70]
PC	20 [19–21]	21 [21–22]	24 [22–25]	23 [22–23]
PharmaPlast Murphy				
DM	75 [75–76]	74 [74]	78 [78–79]	Not available
C	54 [53–54]	54 [52–54]	60 [59–61]	
PC	21 [21–23]	20 [20–22]	19 [17–19]	

**Table 4** Correlations of anatomical measurements with vocal cords–carina distance (VCD). Two variables most correlated with VCD were Height and thyrosternal distance (TSL) ( $r=0.55$  and  $0.51$ , respectively). \*Significant at 0.05 level

Measurements	Correlation coefficient (r)	P-value
Age	0.05	0.5776
Weight	0.22	0.0107*
Height	0.55	<0.0001*
BMI	-0.10	0.2792
Thyromental distance (TMD)	0.33	<0.0001*
Sternomental distance (SMD)	0.34	<0.0001*
Sternothyroid length (STL)	0.27	0.0021*
Sternal length (SL)	0.44	<0.0001*
Thyroid notch to xiphisternum (TSL)	0.51	<0.0001*

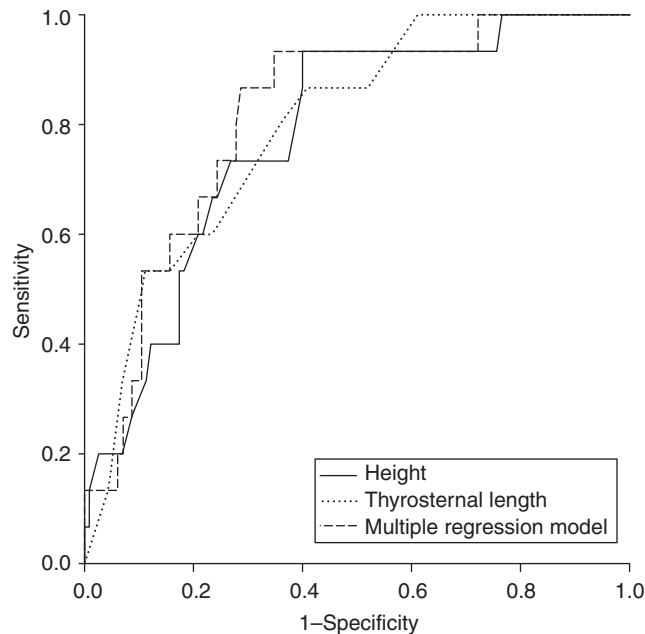
edge of cuff) measurements for the Portex and Rusch tubes ranged from 27 to 35 mm and would, therefore, be generally adequate in this aspect. However, the PC measured on the Kendall and PharmaPlast brand tubes ranged from 19 to 24 mm possibly bringing the cuff too close to the vocal cords.

**Table 5** Number and percentage of patients with vocal cords–carina distance (VCD) shorter than the distance between intubation guide mark to the tip (DM)+2.5 cm clearance above carina, who would be at risk of endobronchial intubation. TT, tracheal tube

TT Brand	TT size (ID) (mm)	DM (cm) [a]	Minimal clearance of TT tip above carina to avoid endobronchial intubation (cm) [b]	Required distance from intubation guide mark to carina (cm) [a+b]	Number/total of patients with VCD <[a+b]	% Patients with VCD <a+b
Portex	7	8.8	2.5	11.3	19/72	26
	8	9.5	2.5	12.0	8/58	14
Rusch	7	7.9	2.5	10.4	6/72	8
	8	8.6	2.5	11.1	2/58	3
Kendall	7	8.5	2.5	11.0	12/72	17
	8	9.0	2.5	11.5	2/58	3
PharmaPlast	7	7.5	2.5	10.0	3/72	4
	8	7.8	2.5	10.3	0/58	0

**Table 6** Areas under the ROC curves (detecting vocal cords–carina distance  $\leq 11.0$  cm). \*Significant

Variable	Area	95% CI	P-value (H <sub>0</sub> : area=0.5)
Age	0.60	0.47–0.73	0.205
Weight	0.65	0.50–0.80	0.067
Height	0.78	0.67–0.89	<0.001*
Thyromental distance (TMD)	0.62	0.47–0.77	0.123
Sternomental distance (SMD)	0.62	0.48–0.76	0.139
Sternothyroid length (STL)	0.65	0.51–0.80	0.056
Sternal length (SL)	0.74	0.61–0.88	0.002*
Thyroid notch to xiphisternum (TSL)	0.80	0.69–0.90	<0.001*
Model	0.82	0.72–0.92	<0.001*



**Fig 2** ROC curves for detecting VCD (distance between vocal cords and carina)  $\leq 11$  cm.

Mallinckrodt brand tracheal tubes have no intubation guide marks proximal to the cuff. This omission would present problems for appropriate placement of the cuff in relation to the vocal cords during its insertion into the trachea.

The placement of black intubating marks at the level of the vocal cords may result in the tip of the tracheal tube being too close to the carina in some Chinese patients. We measured the distal edge of the intubation guide to the tip of the tube (DM in Table 3) and added 2.5 cm as a reasonable clearance above the carina to avoid endobronchial intubation<sup>16–19</sup> that may occur in such situations as neck flexion, head-down position and pneumoperitoneum. This derived figure was then compared with the VCD in our patients (Table 5). The Portex, Kendall and Rusch tubes appeared to be too long in 26, 17 and 8% of female patients, respectively, and in 14, 3 and 3% of male patients, respectively. In contrast the PharmaPlast tubes were too long in 4% of the female patients and never too long in males.

The lack of an intubation guide on the Mallinckrodt brand may present problems for correct placement of this tube. Assuming that a mark was present 3 cm proximal to the edge of the cuff, the Mallinckrodt brand may be expected to be too long similar to the PharmaPlast Brand in females and somewhere between Kendall and PharmaPlast in the case of males.

During the study, we found that in some patients intermittent positive pressure ventilation caused the carina to move up and down and the Portex tube tip repeatedly struck the carina. This low safety margin may be further compromised in circumstances where the mediastinum may shift such as during head-down tilt and pneumoperitoneum. It would certainly be impossible to implement Goodman’s<sup>20</sup> criteria of 5 (2) cm above the carina and still not endanger the vocal cords. In one patient the TT was already at the carina and we had to change the tube. The Portex Profile Soft-Seal size ID 6 mm was measured at that time to be 8 cm from the intubation guide mark to the tip. This tube was placed with the cuff 2.5 cm below the vocal cords, thus allowing slightly more than 1 cm distance from the carina. Fibreoptic bronchoscopy was performed to ensure no endobronchial intubation after Trendelenburg positioning.<sup>19</sup>

As in previous studies,<sup>3,10,11</sup> the correlation between patient height and VCD in the present study was poor. Though Cherng and colleagues found a good correlation for height vs distance between carina and mouth angle

**Table 7** Cut-off value, and specificity (spec) and positive predictive values (PPV) of the various measurements when sensitivity of the test is 100%. VCD, vocal cords–carina distance. TSL, distance between thyroid notch and xiphisternum

VCD	Height	TSL	Combination	Regression model
10.0 cm	≤159 cm Spec=55.9% PPV=5.1%	≤24.5 cm Spec=92.1% PPV=23.1%	Ht ≤159 cm and TSL ≤24.5 cm Spec=92.1% PPV=23.1%	<12.0 cm Spec=75.6% PPV=8.8%
10.5 cm	≤159 cm Spec=57.7% PPV=11.9%	≤28.5 cm Spec=36.6% PPV=8.2%	Ht ≤159 cm and TSL ≤28.5 cm Spec=63.4% PPV=13.5%	<12.3 cm Spec=69.9% PPV=15.9%
11.0 cm	≤167.5 cm Spec=23.5% PPV=14.6%	≤28.5 cm Spec=39.1% PPV=17.7%	Ht ≤167.5 cm and TSL ≤28.5 cm Spec=47.0% PPV=19.7%	<13.1 cm Spec=27.8% PPV=15.3%
12.0 cm	≤170 cm Spec=22.0% PPV=42.9%	≤31.0 cm Spec=12.2% PPV=40.0%	Ht ≤170 cm and TSL ≤31.0 cm Spec=28.1% PPV=44.9%	<13.4 cm Spec=25.6% PPV=44.0%

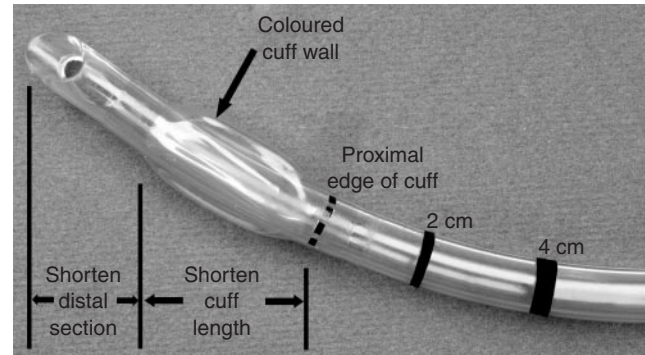
( $r=0.7925$ ), the latter is a composite value for both the tracheal length and upper airway and ignores the vocal cord-proximal edge of the TT cuff distance, which is critical when examining TT design. We have focused purely on VCD and its impact on the ‘intratracheal’ section of tracheal tubes.

In addition we attempted to find a surface anatomy measurement that will indicate those patients with a short VCD. Measurements not previously studied such as TMD, SMD, STL and TSL all provided mild to moderate correlation only (Table 4). Despite having ROC curves of high area under the curve and achieving significance, the PPV of all tests were poor. This aspect of the study was surprising, as there seems to be only moderate correlation between external chest measurements and VCD in the patients studied here.

A high level of vigilance is recommended to reduce the risk of endobronchial intubation when patients have a height ≤167.5 cm or a TSL ≤28.5 cm. When other contributing factors to endobronchial intubation exist, such as flexion of the neck,<sup>113</sup> increased intra-abdominal pressure from distended bowel<sup>20</sup> or pneumoperitoneum,<sup>16–18 21</sup> subdiaphragmatic surgical packs,<sup>19</sup> subcostal retractors<sup>19</sup> and surgical positioning such as Trendelenburg,<sup>19</sup> then the operator performing the intubation may need to take further steps such as flexible bronchoscopy to confirm optimal placement of the TT or use the shortest sub-vocal cord tube possible. The presence of an easily visible intubating guide mark at or above the vocal cords will allow verification of correct TT placement.

In conclusion, we recommend the tracheal tube manufacturers to consider the following (Fig. 3):

- (i) Tracheal tube cuff should be coloured for easy identification.
- (ii) The proximal edge of the cuff should be marked for easy identification.
- (iii) Distance markers should be placed at 2 and 4 cm from the proximal end of the cuff. These two marks cover the range that previous authors have recommended for the distance between the tracheal cuff and the vocal cords.

**Fig 3** A tracheal tube showing the suggested modifications.

Two marks would allow at least one intubation guide mark to be above the vocal cords if reassessment of the depth of TT insertion is required.

- (iv) Shorten the tracheal cuff to provide an overall shorter intratracheal tube length. A balance of a shorter cuff length and maintenance of overall surface area in contact with the tracheal wall should be considered. One possibility is to increase the cuff size in an attempt to maintain its low pressure/high volume characteristics.
- (v) Possibly shorten the post cuff distance while still including a ‘Murphy eye’. The shortening of this distance, however, should not be such as to increase the risk of cuff herniation.

Based on our findings we have the following recommendations to make to clinicians performing tracheal intubations on Chinese patients:

- (i) The use of PharmaPlast tubes may be more appropriate than the other tubes studied in this population to reduce the risk of endobronchial intubation.
- (ii) Orotracheal intubation of patients with a height of ≤167.5 cm and a thyrosteral distance of ≤28.5 cm should be performed cautiously and with a heightened awareness of possible endobronchial intubation.
- (iii) Careful physical examination of the chest to exclude endobronchial intubation and, if necessary, the use of a fiberoptic bronchoscope should be considered to

check the relationship of the tracheal tube tip and the carina.

## Acknowledgements

The authors thank Ms J. S. F. Man B.A. (Hons), MStat (H.K.), Technician, Department of Anaesthesiology, University of Hong Kong, for statistical analysis. Sources of financial support: Department of Anaesthesiology, Queen Elizabeth Hospital, Kowloon, Hong Kong SAR. Work carried out in Department of Anaesthesiology, Queen Elizabeth Hospital, Kowloon, Hong Kong SAR.

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