ENDOBRONCHIAL CUFF PRESSURES

M. COBLEY, J. F. KIDD, B. A. WILLIS AND R. S. VAUGHAN

SUMMARY

In 20 adult patients (18 male) who presented for thoracotomy, the trachea was intubated using Mallinckrodt disposable double-lumen tubes (18 large and two medium). The endobronchial cuff was inflated by a trained operating department assistant using an air-filled syringe. The volume of air and the initial endobronchial cuff pressure were measured. The minimum cuff pressure required to prevent respiratory gas leakage from the isolated lung was measured also and maintained using the Cardiff Cuff Controller. Mean initial cuff pressure was 69.3 (SEM 6.0) mm Hg, whereas the mean minimum cuff pressure was 29.5 (4.0) mm Hg (P < 0.0001). The results suggest that the method described of inflating the endobronchial cuff may lead to overinflation and subsequent excessive pressure on the endobronchial wall. (Br. J. Anaesth. 1993; 70: 576-578)

KEY WORDS

Equipment: double lumen tubes, endobronchial cuff pressures.

The inflatable cuff of the endobronchial limb of the double-lumen tube has two functions. It allows independent positive pressure ventilation of the one lung and also selectively isolates the other lung. It is recognized that excessive cuff pressure exerted on the tracheal wall is associated with trauma [1]. To minimize these problems, high volume low pressure cuffs and an electropneumatic instrument for measuring and controlling cuff pressures have been devised [2].

Tracheal rupture may be produced by tracheal tubes. Incidents of bronchial rupture have also been reported, but are rarer and have been associated with the use of the older and stiffer high pressure cuffs of the Robertshaw [3] and Carlens [4] types.

Rapid inflation of the endobronchial cuff is thought to be the cause of bronchial rupture [3, 4]. Measurement of tracheal cuff pressure is performed rarely in clinical practice, but an earlier study by Willis, Latto and Dyson [5] showed that such measurements can prevent accidental overinflation of the tracheal cuff. Furthermore, the use of the Cardiff Cuff Controller allows the clinician to maintain the cuff at a predetermined pressure—ideally, the minimum necessary to prevent leakage. It seems reasonable to suppose that the endobronchial cuff is also susceptible to accidental overinflation.

The aim of this study was two-fold: first to measure the initial endobronchial cuff pressure (ECPi) produced by syringe inflation, performed under normal clinical conditions by a trained operating department assistant; second to measure the pressure, in the same endobronchial cuff, which just prevented leakage of gas from the isolated lung, but using the Cardiff Cuff Controller rather than syringe inflation. This pressure was deemed the minimum endobronchial cuff pressure (ECPmin).

METHOD AND RESULTS

Two instruments were used to measure pressure. The first measured ECPi and was a portable, electrically powered pressure transducer with a built-in amplifier and digital display. The transducer possessed a low compliance with a small internal volume (150 μl) which allowed measurement of the pressure within an inflated cuff by connecting the cuff pilot balloon directly to the transducer. The transducer response was linear over the range 0–200 mm Hg, and a built-in reference voltage permitted calibration.

The Cardiff Cuff Controller was used to measure and maintain ECPmin. This instrument is an electropneumatic device which incorporates the same pressure transducer for measurement, but has the additional facility to maintain a constant cuff pressure at a preset value in the range 5–150 mm Hg, to within 1 mm Hg.

We studied 20 patients (18 male) undergoing elective thoracotomy. Their mean age, height and weight were 56.3 (SEM 2.5) yr, 169 (SEM 1.7) cm and 69.3 (SEM 2.4) kg, respectively. After induction of anaesthesia and neuromuscular block, the lungs were ventilated with 66% nitrous oxide and 1% enflurane.

The cuff was inflated using a 50 ml syringe and a volume of air varying from 1.8 to 4.4 ml was required to achieve an initial cuff pressure of 69–85 mm Hg. Use of the Cardiff Cuff Controller allowed the cuff pressure to be maintained at a constant value of 29.5 (4.0) mm Hg (P < 0.0001). The results suggest that the method described of inflating the endobronchial cuff may lead to overinflation and subsequent excessive pressure on the endobronchial wall.

<table>
<thead>
<tr>
<th>ECPi (mm Hg)</th>
<th>Volume (ml)</th>
<th>ECPmin (mm Hg)</th>
<th>ECPi - ECPmin (mm Hg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>69.3 (6.0)</td>
<td>2.3 (0.2)</td>
<td>29.5 (4.0)</td>
<td>39.8 (6.5)***</td>
</tr>
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</table>

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in oxygen. A right- or left-sided, double-lumen, disposable, Mallinckrodt endobronchial tube with high volume and low pressure cuffs was inserted and positioned accordingly. These tubes are manufactured in three sizes, large, medium or small. The large size was used for all male patients (18) and a medium size for females (two). Seventeen tubes were left-sided and three right-sided; all the right-sided tubes were placed in male patients.

A three-way tap was connected to the pilot balloon of the endobronchial cuff and the cuff was inflated carefully by a trained operating department assistant using a 5-ml, air-filled syringe via this tap. The air was injected in small increments of 0.5 ml until no discernible leak was detected by the anaesthetist. Assessment of the presence of leak past the endobronchial cuff, at a standardized inflation pressure of 25 cm H₂O, was achieved by auscultation of both sides of the chest during one-lung ventilation, with only the bronchial cuff inflated. The lung port of the non-dependent, unventilated lung was open to atmosphere and helped to determine any leak past the bronchial cuff by noting the presence or absence of expired gases. If, during the incremental injection of air, resistance to injection was felt, the final 0.5-ml increment was decreased carefully until no leak was detectable as assessed by our method. The final volume of air injected was noted. The three-way tap was connected to the pressure transducer and ECPi measured.

The investigators consider this method of endobronchial cuff inflation to be the technique practised most commonly. Although great care is exercised not to over inflate the cuff, we suspect that the obvious lack of sensitivity of this method may inadvertently produce overinflation of the endobronchial cuff.

Subsequently, the three-way tap was attached to the Cardiff Cuff Controller and the pressure in the cuff (ECPi) was modified precisely until the cuff pressure was just sufficient to prevent gas leakage from the isolated lung as detected by auscultation, in the same manner as described earlier and at the same inflation pressure. At this point, the new cuff pressure (ECPmin) was noted. The cuff was maintained at this preset pressure for the duration of the operation. Any leak that occurred during the procedure was noted and the new cuff pressure necessary to prevent leakage was recorded. This pressure was maintained for the remainder of the operation. The mean duration of operation was 3 (SEM 0.1) h.

In addition, in vitro endobronchial cuff pressure vs volume curves were plotted for the double-lumen tubes used.

The mean pressures and the volumes of air injected into the cuff to achieve the mean ECPi and the mean ECPmin are shown in table I. The overall mean ECPi was 69.3 (SEM 6.0) mm Hg, with a mean ECPi for right-sided tubes of 65.7 mm Hg and mean ECPi for left-sided tubes of 69.9 mm Hg. This compared with an overall mean ECPmin of 29.5 (SEM 4.0) mm Hg: right-sided tube mean ECPmin 24.6 mm Hg and left-sided mean ECPmin 30.32 mm Hg. Using a paired Student's t test, a significant difference was demonstrated between mean ECPi and ECPmin (P < 0.0001).

When they were inflated in vitro with 4 ml of air (maximum in vivo inflation volume) the bronchial cuff of both the large and medium size tubes had a diameter of 2.3 cm and they developed cuff pressures of 65 mm Hg and 44 mm Hg, respectively. Inflation with 2.5 ml of air (mean in vivo volume) produced a cuff diameter of 2.0 cm and cuff pressures of 13 mm Hg and 10 mm Hg, respectively (fig. 1). These diameters compare with the actual bronchi sizes of right bronchus (male 1.2–2.1 cm (mean 1.7 cm); female 1.1–2.0 cm (mean 1.5 cm)) and left bronchus (male 1.0–1.8 cm (mean 1.5 cm); female 0.9–1.5 cm (mean 1.2 cm)). Thus the greater cuff pressures in vivo are caused by pressure exerted against the bronchus.

**COMMENT**

The difference between manual syringe inflation of the cuff and the electropneumatic method lies in the relative lack of sensitivity of the former method. Small changes in the volume injected into the cuff result in relatively large increases in cuff pressure. The Cardiff Cuff Controller controls pressures to within 1 mm Hg and, although the end-point is the same (absence of auscultated leakage passed the cuff), the manual inflation method usually overshoots that end-point pressure. Therefore, syringe inflation, however carefully performed, clearly produces overinflation of the endobronchial cuff and this can exert an unnecessarily great pressure on the bronchial mucosa.

In the absence of an auscultated leak, aspiration is an unlikely event. However, an overinflated cuff may result in ischaemic damage to the mucosa with subsequent stenosis or, in cases of gross overinflation, bronchial rupture. The optimum pressure for a cuff is the pressure which prevents aspiration, allows leak-free ventilation and does not produce bronchial mucosal ischaemia. As the incidence of bronchial mucosal damage is not known, it is safer to maintain the bronchial cuff at that pressure which just prevents auscultated leakage.

The tracheal cuff pressure has been shown to equal the pressure exerted on the tracheal wall with
high volume, low pressure cuffs. There seems no reason to suppose that the high volume, low pressure endobronchial cuff differs. Tracheal damage is attributed to both increased lateral wall pressure and the duration of anaesthesia, with lateral wall pressure the more important factor (6). Moreover, a linear increase in cuff pressure over a 3-h period has been demonstrated when the inspired gases contain nitrous oxide. These risk factors are no less relevant when considering endobronchial cuffs. The high lateral bronchial wall pressure which may develop with overinflated cuffs can impair mucosal blood flow and thereby contribute to the risk of bronchial rupture.

To reduce the risk of inadvertent overinflation, the anaesthetist should instruct the assistant to inflate the cuff just enough to abolish a leak from the isolated lung. The temptation to add additional volume for good measure should be strongly discouraged. We have shown that careful syringe inflation alone is not necessarily enough to prevent overinflation of the cuff. The use of a cuff pressure controller such as the Cardiff Cuff Controller [2], with its greater sensitivity of control, enables cuff pressure to be set more precisely and accurately to a specific value known just to eliminate leakage. The cuff pressure can also be maintained at the chosen pressure even in the presence of nitrous oxide when significant pressure increases resulting from diffusion of nitrous oxide into the cuff have been reported.

REFERENCES