A new tracheal tube for difficult intubation

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Summary
We have compared a new Portex tracheal tube with the Oxford tube in performing simulated grade 3 difficult intubations. The Portex tube was modified so that the bevel faced backwards, as in the Oxford tube. A gum elastic introducer was used with both tubes. The time taken and number of attempts needed were recorded, with changes in arterial pressure, heart rate and incidence of sore throat. Both tubes were successful in avoiding the problem of obstruction at the cords, which occurs when a standard Magill tube is used with an introducer. Thus the new tube has the merits of the Oxford tube without the disadvantages of rubber. It is suitable for both easy and difficult intubations with advantages in safety, cost and convenience. An unexpected but important finding was a clear learning effect, despite both investigators being familiar with the technique at the outset. Over the course of the study, intubation time decreased progressively (P < 0.001). This provides new evidence of the need for trainees to practise the art of intubation when the cords are not visible. Our estimate of the learning "half-life" was 15 intubations; we conclude that 30 simulated grade 3 intubations would be a reasonable objective for trainees to handle high-risk cases. (Br. J. Anaesth. 1996; 76: 673–679)

Key words

Difficult intubation remains a key problem [1] and the value of a flexible introducer (gum elastic or wire) as a first approach is well recognized in the UK and USA [2]. It is the simplest method, effective for all grade 2 laryngoscopies, where at least the arytenoids are visible and most grade 3 laryngoscopies, where the epiglottis can be seen but no part of the glottis. Macintosh initiated the method [3] and also devised the Oxford tube [4] for use with an introducer. When a Magill tube is used with an introducer, it commonly becomes impacted at the cords, but the Oxford tube avoids this problem. However, it is made of rubber which is a disadvantage. This prompted us to see if a plastic version would be as effective as the original.

The Oxford tube also has a feature intended to minimize kinking, that is a reinforced bend, the effectiveness of which was confirmed in 18 000 patients [5]. Our study was designed to compare the Oxford tube with a new plastic tube, primarily in relation to these two problems, snagging at the cords and kinking [6].

Patients and methods
The study took place at two hospitals, Guy's and Northwick Park. After obtaining Ethics Committee approval and informed consent, we studied 96 patients. Intubations were carried out by one trainee at each centre (M.M.J. and M.R.J.W.), each of whom had about 2 yr experience of anaesthesia and was familiar with the handling of bougies and the technique of simulated difficult intubation.

Misleading results could occur if, for example, one group had a larger number of edentulous patients, as it would appear to perform better even if the two tubes had identical properties. To avoid this error, patients were selected in pairs, matched roughly for ease of intubation. In practice this implied excluding patients with known stigmata of difficulty. Most were easy cases, converted to difficult intubations by a standard procedure. The pairs were healthy adults, allocated randomly to have a Portex or an Oxford tube. The study could not be performed blind, so the possibility of observer bias was kept in mind; the observers endeavoured to report not what was expected, but what happened. In the measurements recorded there is minimal scope for observer bias.

THE NEW TUBE
Portex Ltd agreed to manufacture a batch of tubes to our specifications. A standard tube was modified so that the bevel faced backwards, as in the Oxford tube. In all other respects it was identical to the widely used Portex Magill cuffed orotracheal tube.
After surgery, the patient was interviewed. If no complaint was volunteered a specific question was asked about sore throat.

**INTEGRATION OF POSTOPERATIVE SORE THROAT**

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**SIGNIFICANCE TESTING**

Routine t-tests were applied to arterial pressure measurements, which were Gaussian; airway pressure was skewed, so Wilcoxon’s rank sum test was used. Intubation times were also skewed (fig. 1), but after log transformation, they did not differ significantly from a normal distribution; the one-sample t-test was used for paired data (comparing tubes) and the two-sample t-test for unpaired data (comparing observers), both on logged data. Routine linear regression analysis was used to test if the progressive decrease in intubation time resulted from chance.

**INCIDENCE OF POSTOPERATIVE SORE THROAT**

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**INTUBATION PROCEDURE**

The key feature of a simulated difficult intubation [7] is to intubate while the vocal cords are not visible. Patients’ lungs were ventilated for about 3 min with 2.5% enflurane and 66% nitrous oxide in oxygen. Laryngoscopy was carried out to expose the glottis, and the blade was deliberately lowered until the epiglottis obscured the cords. Size 8 (females) and size 9 (males) were used, with the introducer projecting 6–8 cm from the tube. Macintosh [4] pointed out that one of the advantages of the introducer is that it prevents the tube blocking the view at the critical moment; it must project far enough for this purpose. The introducer was directed immediately behind the epiglottis, in the mid-line, and advanced together with the tube. The introducer was then removed and the position of the tube verified clinically and by capnography. If the tube was in the oesophagus it was removed and the procedure repeated up to a maximum of three attempts.

Cricoid pressure was applied throughout to provide some indication of how the tubes would perform in emergency cases. The two-handed manoeuvre was used, the assistant placing one hand behind the neck to counteract displacement caused by his other hand. After successful intubation, a record was made of the number of attempts and intubation time, the time lapse between receiving the tube and verifying intubation. Arterial pressure was recorded before and 1 min after intubation.

**TEST FOR OBSTRUCTION TO AIRFLOW**

Airflow may be blocked by kinking or by the end of the tube becoming opposed to the tracheal wall. Both events cause an increase in airway pressure and both are most likely to occur on flexing the neck. After allowing 10 min for the tube to warm up towards body temperature, the neck was flexed gently to its maximum and the change in airway pressure recorded, using an aneroid manometer.

**CURVE-FITTING—UNDERLYING EQUATION**

The next step was to fit a more realistic model to the data. Common sense suggests that the true relation cannot be a straight line because that implies that intubation time decreases to zero. Moreover, learning is known to be a non-linear process in which the rate of improvement diminishes steadily, becoming zero when peak performance is reached. Scope for improvement is maximal at the start and zero at the end. If the rate of change is proportional to scope for change, an exponential curve results for reasons clearly explained by Nunn [8]. Learning involves several processes so the true relation is likely to be not a single exponential, but the sum of several.

However, the components of such a process cannot be disentangled realistically when the random error is large. We concluded that the most useful model would be a single exponential decline, such as occurs with radioactive decay. This is a reasonable compromise between the absurdity of a straight line and the ambiguity of a multi-exponential model. The equation of a simple exponential “die-away” curve is:

$$y = y_0 e^{-nt} + y_\infty$$

where $y$ = dependent variable (intubation time) and $n$ = independent variable (serial number of the intubation). There are four constants, the universal constant, $e$, and three others: $y_\infty$ = “expert time”, the time taken by the fully trained anaesthetist, the asymptote (i.e. if $n = \infty$ then $y = y_\infty$); $y_0$ = additional time required when there is no previous experience, so the “novice time” is $y_0 + y_\infty$ (i.e. if $n = 0$ then $y = y_0 + y_\infty$); $k$ = learning constant, which measures the steepness of the curve, high values of $k$ indicate quick learning (p. To simply descriptions of radioactivity, physicists have developed the concept of “half-life”; it may help to use the same idea here.)

The “half-life” can be thought of as the number of intubations needed to halve the distance between the novice time and the expert time. It is exactly predictable from $k$, using this equation:

$$\text{Half-life} = -\frac{\log_{1/2}(4)}{k} = \frac{0.693}{k}$$

If the half-life is 15 then after 15, 30 and 45 intubations the amount of learning still to be done is 1/2, 1/4, 1/8, and so on. Serial numbering starts...
from 0, not 1, because most descriptions of exponential equations have the independent variable as time, starting at zero time. Thus allowing \( n = 0 \) for the first intubation leads to an equation identical to the one most commonly used and provides the useful results shown above in parentheses. \( y_0 \) can then be thought of as the extra time required when \( n = 0 \), that is previous experience is zero. Strictly our estimate of \( y_0 \) is that for a small \( n \), not for \( n = 0 \), but that does not affect the other estimates, notably half-life.

**CONFIDENCE LIMITS OF THE LEARNING CURVE**

For linear regression the confidence limits of the slope are found by assuming that, in repeated sampling, the slopes follow a normal distribution and the same approach has been advocated for non-linear functions [10]. Computer simulations enable us to test this, as discussed elsewhere [11]. A program to simulate our study first uses the best fit values of \( y_0, y_\infty \) and \( k \), found already, to produce a “perfect” set of \( y \) values with no scatter. Next a random number generator superimposes a scatter such that the \( y \) values acquire the same residual SD as the clinical observations. Each cycle of the program then yields results similar to the real data, on which a least squares analysis is carried out. The distribution of the variables was found to be highly skewed, particularly \( k \); this invalidates the conventional route to the confidence limits. The modern computer displays the problem very clearly; it can also solve it. The main point of clinical importance is the lower 90 % confidence limit of the half-life. To find this we must establish what half-life in the simulation produces exactly 5 % of values as large as, or larger than, the best fit value for the real data. This is found by trial and error; after two “bracketing” shots the third estimate, by linear interpolation, is close to the required value, because over narrow ranges the relation is nearly linear.

**Results**

Patient co-operation was excellent; none declined. Both observers carried out 24 intubations with each tube, giving a total of 96 intubations for analysis (tables 1 and 2).

**SUCCESS RATE**

Sixty-two of the 96 intubations succeeded the first time, the others at the second or third attempts; the pre-set limit of three failures was never reached. For both tubes, entry to the larynx was smooth with no snagging at the cords. The number of cases in which intubation failed initially was not appreciably different for the two tubes (Oxford 16 of 48, Portex 18 of 48) (ns).

**TESTS FOR OBSTRUCTION TO AIRFLOW**

For observer 1, neck flexion caused changes in airway pressure with median 0 (range 0–6). For observer 2, the corresponding values were 0 (0–5). \( P \) was close to 1 in both.

**CHANGES IN ARTERIAL PRESSURE**

The mean change in arterial pressure 1 min after intubation was +14 % (Oxford) and +12 % (Portex) for observer 1 (ns); for observer 2 the values were +14 % and +16 % (ns). Other studies on routine intubation have shown that the pressor effect is maximal after 1 min and is usually approximately 27 %. Thus the simulated difficult intubation drill caused no undue cardiovascular disturbance.

**SORE THROAT**

The incidence of sore throat was the same for both tubes (33 %), which is close to the 34 % reported for a similar study [12]. This compares favourably with 56 % for routine intubation [13]. Our procedure did not appear to increase the likelihood of sore throat.

**INTUBATION TIMES**

*Oxford tube vs Portex tube (n = 24)*

For observer 1, median intubation time was slightly longer for the Oxford tube (27.5 vs 21.5 s), while for observer 2 the opposite was true (20 vs 25 s). In neither case was the difference significant.

*Observer 1 vs observer 2 (n = 48)*

The (Oxford–Portex) differences did not differ significantly for the two observers and therefore the data were pooled. After pooling, the mean difference between the tubes was 1.3 s (ns), typical of cases
where performance was essentially the same. However, a real difference might have been obscured by the scatter. Routine power analysis shows that if there were a real difference of 11.9 s and our study was repeated many times, then $P$ would be less than 0.05 in 80% of cases. A more rigorous test for, say, a difference of 2 s would need a very large sample. Proving a negative is notoriously difficult when the scatter is large and may not justify the cost.

As neither tubes nor observers differed significantly, all data were pooled ($n = 96$) (fig. 1). Median and interquartile range was 25 (14–40) s.

**LEARNING EFFECT**

The intubation times showed two distinct populations of data, a larger group in which intubation succeeded the first time and a smaller group with one
or two failures. Both showed evidence of a learning effect, but it was more clear-cut in the larger group, in particular, the residuals in this group were Gaussian (W test, \( P = 0.07 \)), as required for least squares analysis [14]. The next section deals with the larger group. Plotting intubation time against serial number of the intubation produced negative slopes for both tubes and both observers (differences between slopes were not significant) and therefore the four data sets were pooled. For the pooled data, the slope was significantly different from zero (\( P = 4 \times 10^{-5} \)); figure 6 in our abstract [6] shows the line of best fit and its asymptote (expert time) was found by the method of least squares. It is an exponential curve with a half-life of 15 intubations.

![Figure 1](image1.png)

**Figure 1** Histogram of intubation times for all 96 intubations carried out. Pooled data for both tubes and both observers.

![Figure 2](image2.png)

**Figure 2** Intubation time vs serial number of the intubation for the 62 cases in which intubation was successful at the first attempt. O = Oxford tube, = Portex tube. (Note the similar performance by the two tubes and the progressive reduction in intubation time over the course of the study. The curve of best fit and its asymptote (expert time) was found by the method of least squares.)

The conventional lower 90% confidence limit (10.34) provided a first estimate. After entering this value in 30,000 simulations, 5% of half-lives (HL) were more than 16.83, which is too high, so a lower value was entered in the next experiment. The third experiment gives the required value of 15 (fig. 3).

The mean is about 5% too high, the mode about 5% too low, but the median has no appreciable error. This supports the view that in a highly skewed population the best estimate of the focal point, as it were, is the not the mean, but the median. Of course
for Gaussian populations, mean, mode and median coincide.

Discussion

OBSTRUCTION TO AIRFLOW CAUSED BY KINKING OF THE TUBE

Kinking, which could be a problem with the rubber Magill, occurs rarely with a standard Portex Magill, at least in adults. The modified Portex tube used in this study, even when subjected to maximum likelihood of kinking, never showed evidence of obstruction, which lends weight to the view that this problem has been overcome.

OBSTRUCTION TO AIRFLOW AT THE END OF THE TUBE

The end of the tube may become applied to the wall of the trachea, a blockage which can be relieved with a Murphy eye [15]. Making the bevel face backwards arguably increases the likelihood of this type of obstruction, particularly when there is fixed neck flexion (a notorious cause of difficult intubation). However, maximal neck flexion never caused serious impedance to airflow in our 96 cases. If in a larger sample obstruction did occur, then the simplest solution would probably be to push the tube in further. Blockage is likeliest at the point of maximal curvature of the airway, near the larynx; advancing the tube into the straight part should relieve it. This is not possible with the Oxford tube because of its fixed bend, but would be easy with our tube. If that worked, there would be no need for a Murphy eye.

OBSTRUCTION TO THE PASSAGE OF THE TUBE BETWEEN THE VOCAL CORDS

It is well known that if an introducer is used with a standard Magill tube, the end of the tube commonly becomes impacted at the cords; the Cardiff team [16] reported this in 50 % of cases. To prevent this, Cossham [17] advocated rotating the tube 90° anticlockwise to make the bevel face backwards, and two surveys [12, 16] found this manoeuvre to be effective. Macintosh had a different solution, that is to alter the tube so that the bevel faced backwards. Both tubes used in this study had this feature and in all cases this was completely effective in preventing snagging at the cords. When the introducer was in place, entry of the tube was so smooth that it was hard to say at what point it traversed the cords. It is unfortunate that in his original report Macintosh did not explain why he had changed the direction of the bevel; had he done so it seems likely that this simple solution would have been adopted a long time ago. When a standard Magill tube is used with an introducer [12, 16] intubation appears to take longer than with our procedure, but firm conclusions are not possible because of differences in study design. A formal comparison would be instructive. Conclusions need to be confirmed in genuine cases of difficult intubation, but when research is hindered by the paucity of real cases, simulation provides a useful guide.

LEARNING EFFECT

The simulated difficult intubation drill is a straightforward technique that can be carried out by the novice; in some units it has been routine for many years to start teaching it as soon as the trainee is confident with simple intubations. We were surprised therefore to find a definite learning effect, even in those who are familiar with the drill. The case for the simulated difficult intubation drill, when it was originally proposed [7], suffered from the absence of precise data at that time on the incidence of difficult intubation. It is now known [18] that if care is taken with laryngoscopy, approximately 1.3 % of cases are grade 3. A recent survey [19] found that anaesthetists generally perform approximately 200 intubations a year, so each will see two or three cases per year, on average. But, because of random variation (Poisson effect [20] 25 % of anaesthetists will see 4–7 grade 3 cases in 200 consecutive intubations; at the opposite extreme, 26 % will see only one, or none. Clearly those in the second group (the lower tail of the distribution), will have learnt little about difficult intubation in 1 year.

The learning effect that we have detected underlines these conclusions. The objection may be raised that the scatter of our results rules out exact inference. However, even if the true learning half-life were the lower 90 % confidence limit of our data (fig. 3), nine intubations would be needed to become half-trained; not even the first group above (the upper tail of the distribution) will see that many grade 3 intubations in a year. The most probable inference from our data is a half-life of 15, which leads to the same conclusion, a fortiori.

If training is 50 % complete after 15 intubations, then 30 is 75 % of the way, and so on. Thirty intubations would seem a reasonable objective for a trainee before handling a high-risk case, such as a possible difficult intubation in a patient with a full stomach. Without such training the failed intubation rate in obstetrics, recently re-analysed [21], is likely to remain high.

Estimates of learning rates based on two individuals may not be typical for anaesthetists in general, but are unlikely to be seriously misleading. The principles underlying this measurement have been described in detail because it may prove useful for further studies. For example, it would be valuable to know if individual tuition increases the rate of learning, as shown for fibreoscopy [22]. With fibroscopic intubation it is accepted that teaching must be done on patients who do not, strictly speaking, need fibrescopy. Hitherto it has not been obvious that the same applies to the handling of grade 3 cases, but from the evidence cited above any training strategy which relies on their random natural occurrence needs to be re-evaluated.

In summary, simulating the difficult intubation is a well-tried and trouble-free procedure for both training and research. The optimum design of the introducer and similar details require further study, but one factor seems clear, when choosing the right tube for use with an introducer, the new Portex tube...
New tracheal tube

is a strong contender. If it proves acceptable for difficult cases, it seems logical to use it for routine cases. There are advantages in safety, cost and convenience if the tube used for difficult intubations is the one we are most familiar with in everyday work.

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References

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