THE RESISTANCE OF CORRUGATED ENDOTRACHEAL CATHETER MOUNTS

BY

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SUMMARY

Observations made on a patient who was being artificially ventilated suggested that the newer type of corrugated rubber endotracheal catheter mounts might have a higher resistance than the older straight-sided ones. This possibility was verified using steady flows of air with the catheter mount straight. In these circumstances the difference between the two is small. However, corrugated tubes are designed to be flexible and when they are bent through 180 degrees the resistance increases sharply, being doubled.

Corrugated rubber endotracheal catheter mounts have recently been introduced. These tubes can be occluded by twisting but not by bending. The advantages over parallel-sided mounts are the greater manoeuvrability and the reduced risk of kinking by bending.

However, we heard of a patient in another hospital who was being ventilated by a volume-regulated mechanical ventilator whilst connected to the machine by one of these mounts. Despite pressures of 25 to 30 cm H₂O, and at times even more, adequate ventilation was not obtained. The catheter mount was replaced by a parallel-sided one and immediately the pressure dropped to 15 to 17 cm H₂O. A suggested explanation was that the irregular lumen of the corrugated tube caused increased turbulence and a greater resistance. However, the second mount was much shorter than the first so that it would be unwise to draw definite conclusions from this case. The suggestion was plausible, though, because Macintosh, Mushin and Epstein (1958) have stressed that "irregularities of the inner wall of a tube and sudden alterations in the bore of tubes and connections are frequent offenders causing a change from laminar to turbulent flow". Orkin, Siegel and Rovenstine (1957) in their work on expiratory valves, Smith (1961b), testing endotracheal tubes and their mounts and connections, produced results which support this view. For this reason it was thought unnecessary to perform a more complicated experiment.

METHOD

The apparatus used was similar to that used by Galloon (1957) except that a T-piece was used instead of a Y-piece. Galloon used a cylinder to deliver gas via a flowmeter at a steady rate of 25 l./min to a Y-piece, a water manometer being fixed to another limb of the Y-piece and the various connections under investigation being attached to the other limb.

Air was driven by a compressor into a large oil drum out of which a steady flow emerged. This flow was controllable and passed via a flowmeter to one horizontal limb of the T-piece. The flow-meter was graduated from 15 to 150 l./min at intervals of 5 l./min. The catheter mount being tested was attached to the other horizontal limb of the T-piece and a water manometer to the vertical limb (fig. 1). The metal part of the catheter mount was fixed at the beginning and not disturbed until all the readings with the tubes lying straight had been taken. It was confirmed that with this apparatus pressure-flow readings were reproducible.

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Four catheter mounts were used, all of which are in clinical use in the London Hospital. Their sizes were:

(1) Corrugated, length 143 mm, diameter 9 mm.
(2) Straight sided, length 138 mm, diameter 9 mm.
(3) Corrugated, length 89 mm, diameter 10.5 mm.
(4) Straight sided, length 91 mm, diameter 9.5 mm.

Measurements were made on each of these tubes in three different conditions with the mounts lying straight:

(1) With the catheter mount discharging directly into the atmosphere.
(2) With the mount connected to a size 7 endotracheal tube via a Magill oral connection and discharging into the atmosphere.
(3) With the mount connected to the same endotracheal tube via a Cobb connection and discharging into the atmosphere.

Flows from 15 to 150 l./min were used.

A test was now made of the effects of bending the long corrugated mount through 180 degrees.

RESULTS

The increased resistance of the corrugated mount when lying straight is clearly shown in figures 2 and 3, but the importance of this is perhaps better appreciated by comparing the differences due to using a corrugated mount, rather than a straight one, at various flows, with the differences due to using a Cobb connector rather than a Magill in otherwise identical conditions. This is shown in tables I and II and in figure 4.

<table>
<thead>
<tr>
<th>Flow rate (l./min)</th>
<th>Long catheter mount</th>
<th>Short catheter mount</th>
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<tbody>
<tr>
<td></td>
<td>Cobb</td>
<td>Magill</td>
</tr>
<tr>
<td>15</td>
<td>0</td>
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</tr>
<tr>
<td>20</td>
<td>-1</td>
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<td>30</td>
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</tr>
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<td>0</td>
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<tr>
<td>70</td>
<td>+6</td>
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<table>
<thead>
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<th>Flow rate (l./min)</th>
<th>Long catheter mount</th>
<th>Short catheter mount</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pressure with Cobb connector minus pressure with Magill connector (mm H₂O)</td>
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<tr>
<td>15</td>
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<td>2</td>
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FIG. 2
Pressure-flow curves of long catheter mounts, corrugated and straight sided.

O Corrugated mount only
• Straight sided mount

D Corrugated mount with Cobb and endotracheal tube
• Straight sided mount with Cobb and endotracheal tube

A Corrugated mount with Magill and endotracheal tube

FIG. 3
Pressure-flow curves of short catheter mounts, corrugated and straight sided.

O Corrugated mount only
• Straight sided mount

D Corrugated mount with Cobb and endotracheal tube
• Straight sided mount with Cobb and endotracheal tube

A Corrugated mount with Magill and endotracheal tube

Flow (l./min) 0 20 40 60 80 100 120 140

Pressure (mm H₂O) 0 50 100 150 200 250

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Figure 5 shows the striking effect of bending the catheter mount through 180 degrees. The extra resistance due to attaching the endotracheal catheter mount to the tube is almost exactly doubled if the mount is bent (see also table III). Comparing the results in table III with those in table II, and with Smith's results using a size 10 endotracheal tube (Smith, 1961b), it appears that the effect of bending the mount is about half the effect of substituting a Cobb for a Magill connector.

<table>
<thead>
<tr>
<th>Flow rate (l/min)</th>
<th>Endotracheal tube only</th>
<th>Endotracheal tube with long corrugated mount lying straight</th>
<th>Endotracheal tube with long corrugated mount bent through 180°</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>6</td>
<td>$6\frac{1}{2}$</td>
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<td>134</td>
<td>190</td>
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**TABLE III**

*Increase in resistance due to attaching the corrugated mount when this is both straight and bent.*

**FIG. 5**

Pressure-flow curves of long catheter mount, straight and bent through 180 degrees.

- Endotracheal tube + Magill connection.
- Endotracheal tube + Magill + corrugated mount straight.
- Endotracheal tube + Magill + corrugated mount bent.

**FIG. 4**

Comparison of increased resistance due to corrugation with increased resistance due to use of Cobb connector.

- Increase in pressure due to using a corrugated catheter mount rather than a straight sided mount (from table I).
- Increase in pressure due to using a Cobb connection rather than a Magill (from table II).
DISCUSSION
The four tubes were of different diameters and lengths. Poiseuille’s law cannot be applied exactly to these tubes but it is reasonable to use it as a rough guide to what might be expected. It would seem that the difference between the lengths of the long mounts might cause a slight apparent increase in the resistance of the corrugated tube, but in the case of the short mounts the bias would be very much in the opposite direction, since the corrugated tube is both wider and shorter.

The apparatus available did not allow flow rates greater than 150 l./min to be measured. Orkin, Siegel and Rovenstine (1954), quoting other workers, state that the normal maximum flow in healthy adults ranges from 30 to 50 l./min, although maximum flow in tachypnoea and hyperpnoea may reach 90 l./min, and in coughing much higher flow rates occur. Mushin, Rendell-Baker and Thompson (1959) describe 40 to 80 l./min as a high flow rate in speaking of mechanical ventilators. Although Galloon (1957) has recorded 400 l./min, this seems to be exceptional, and measurements up to 150 l./min would appear to cover a wide enough range for practical purposes.

The effects of increasing airway resistance have been discussed by Smith (1961a) who reviews experimental work in conscious and anaesthetized man and dogs. Most ill effects appear to occur when the airway pressure rises above 10 cm H₂O. The results presented indicate that the airway pressure increase due to using one of the newer catheter mounts is likely to be small in comparison with the pressures which might harm the patient, provided the mount is straight. However, the advantage of these mounts lies in their flexibility and, as soon as use is made of this, the price has to be paid in terms of a considerably higher resistance. The bend of 180 degrees tested is perhaps more than would often be used, but the impossibility of kinking by bending invites the anaesthetist to do this if convenient to him.

Smith (1961b) has condemned the use of the Cobb connection because of its higher resistance. The corrugated catheter mounts are open to the same objection if they are going to be bent. If they are not, and if the mount will be accessible to the anaesthetist throughout the operation, there seems no reason to use them.

It may be arguable that when there is a risk that the catheter mount might become kinked in an inaccessible site during operation, the increased resistance is acceptable. The possibility of occlusion by twisting must, however, not be forgotten. If they are to be used, it is important for the anaesthetist to be aware of the increased resistance and alert to its possible ill effects.

ACKNOWLEDGMENTS
These measurements were made in the Research Department of Anaesthetics in the Royal College of Surgeons and I am grateful to Dr. D. W. Hill for allowing me to work in his laboratory and to Drs. A. I. Parry Brown, B. R. J. Simpson and W. D. A. Smith for help and advice.

REFERENCES

LA RESISTANCE DES SONDES ENDO-TRACHEALES EN CAOUTCHOUC STRIE

SOMMAIRE
L'auteur a remarqué chez un patient ventilé artificiellement que le nouveau type de sonde en caoutchouc strié semblait présenter au passage de l'air une résistance plus grande que les anciennes sondes lisses. Il procéda à une vérification et constata, que tant que le courant d'air passa par la sonde maintenue droite, la différence entre sondes lisses et sondes striées était insignifiante. Cependant les sondes striées — créées ainsi pour être plus flexibles — présentaient, une fois courbées à 180 degrés, une résistance brusquement augmentée et qui
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atteignit presque le double de celle offerte par la sonde striée maintenue droite.

DER LUFTWIDERSTAND VON GEWELLTEN ANSÄTZSTÜCKEN FÜR ENDOTRACHEAL-KATHEDER

ZUSAMMENFASSUNG

Beobachtungen an einem Patienten, der künstlich beatmet wurde, ließen vermuten, daß die neuere Art der Ansatzstücke für Endotrachealkatheder aus gewelltem Gummi einen höheren Widerstand hat als die älteren mit geraden Seiten. Dies wurde mittels eines kontinuierlichen Luftstroms bei geradem Kathederansatzstück bestätigt. Unter diesen Umständen ist der Unterschied zwischen den beiden gering. Gewellte Schläuche sind aber entworfen, um biegsam zu sein, und wenn sie um 180 Grad gebogen werden, steigt der Widerstand stark an; er wird tatsächlich verdoppelt.

CORRESPONDENCE

ESTIMATION OF BLOOD LOSS

Sir,—I read with interest the article "Estimation of blood loss with particular reference to cardiac surgery" by Dr. J. A. Thornton et al. (Brit. J. Anaesth., 35, 91) but was surprised to see no reference made to the machine developed in Aberdeen (Roe, Gardiner and Dudley, 1962). This machine also utilizes the colorimetric method; it has an overall accuracy of 3 per cent and incorporates a spin-drier through which the swabs are finally put. This both facilitates the swab count and avoids change in the volume of the bath contents.

W. N. ROLLASON
Aberdeen

REFERENCE


BOOK REVIEW


The Obstetric Unit at Portsmouth is well known to all anaesthetists due to the excellent work carried out there by the late Dr. Hamer Hodges and his colleagues. In November 1961 a conference was organized in that city by the South Western Obstetrical and Gynaecological Society, and attended by leading members of the profession. The book is a record of the papers presented at the five half-day sessions and of the discussion that followed. The subjects considered were Unstable Presentation, Obstetric Anaesthesia, the Place of the General Practitioner in Obstetrics, Asphyxia Neonatorum, and Management of the Third Stage. Anaesthetists will find points of interest in every section, but the most challenging is that on Asphyxia Neonatorum, epitomized in Professor Ian Donald’s opening phrase as “not a diagnosis but an emergency”. This is a valuable work, containing many useful statements of fact and intention. It is not, nor is it intended to be, comprehensive, but anyone with an interest in obstetric anaesthesia should be aware of its contents.

W. D. Wylie