Effect of cricoid force on airway calibre in children: a bronchoscopic assessment

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Background. Cricoid pressure or to be more exact cricoid force (CF) can cause airway obstruction and subsequent difficulty with airway management during an emergency induction.

Methods. We studied 30 children with an age range of 3 months to 15 yr who presented for routine bronchoscopy or other surgical procedures requiring tracheal intubation. We looked at the effect of CF on the calibre of the subglottic airway and objectively measured the force which caused 50% or greater distortion/compression of the subglottic airway.

Results. There was a linear relationship between both age and weight and CF. No patient suffered any adverse effects. Overall, the mean force required to compress the airway was 10.5 N. However, this force could be as low as 5 N in children < 1 yr of age, and up to between 15 and 25 N in teenagers.

Conclusions. Forces well below the recommended value of 30 N will cause significant compression/distortion of the airway in a child.

Keywords: airway, patency; anaesthesia, paediatric; anaesthetic techniques, bronchoscopy; induction, rapid sequence; larynx, cricoid pressure

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The term cricoid pressure is a misnomer and refers to the application of a force to the cricoid cartilage. The use of cricoid force (CF) has been an integral part of a rapid sequence induction to prevent regurgitation of stomach contents since its introduction into modern clinical practice by Sellick1 in 1961. There remains, however, some evidence that up to 50% of paediatric anaesthetists do not use CF in situations where precautions for a ‘full stomach’ would normally be taken.2 This is because of perceived potential airway problems caused by the application, either correct or incorrect, of CF. CF has been called an ‘empirically derived, scientifically unproven and outdated manoeuvre’.3

There have been studies in the adult literature looking at the effect of CF on the subglottic airway, but to date no studies in children have been reported.4 We have performed an open observational study to determine the effects of differing amounts of CF on the calibre of the subglottic airway in different paediatric age groups.

Methods

Ethical approval was obtained from the local ethics committee. We then recruited 30 healthy ASA I or II patients undergoing routine bronchoscopy or who were being intubated for another procedure. Patients presenting for routine bronchoscopy were consented but only included in the study if the airway was normal after bronchoscopic examination. Those patients presenting for other forms of surgery were included only if tracheal intubation was required. It was explained to those patients that only a limited bronchoscopy would be necessary to visualize the subglottic area and the bronchoscope would sit high in the trachea and would be performed immediately before tracheal intubation. Parents gave consent for the procedure, but older children who were able to understand the issues were all given the opportunity to consent or object. Patients with airway pathology or cervical spine pathology were excluded.

Patients were anaesthetized using either an i.v. induction or a gaseous induction using sevoflurane. Standard non-
invasive monitoring was used before the induction. Two anaesthetists were present for each case. One was responsible for the safe conduct of the anaesthetic and the second for the application of the cricoid pressure device (Fig. 1). In those cases in which the child had presented for bronchoscopy, the bronchoscopy was first carried out by an ENT surgeon. In cases requiring tracheal intubation for another procedure, the bronchoscopy was performed by the principal investigator and a further anaesthetist was present to supervise the anaesthetic. All bronchoscopies were carried out using a 4 mm Hopkins Rod rigid telescope (Karl Storz, Germany).

Two basic anaesthetic techniques were used. Patients who presented for bronchoscopy were induced with sevoflurane in oxygen 100%. I.V. access was then obtained. When the patients were deeply anaesthetized, the airway was sprayed with lidocaine (3 mg kg\(^{-1}\)), and a nasopharyngeal airway was placed. The anaesthetic circuit was then attached to the nasopharyngeal airway and the patient continued to breathe spontaneously with oxygen 100% and sevoflurane throughout the procedure. This allowed the bronchoscopist complete access to the airway. Those patients presenting for other procedures were generally anaesthetized using an i.v. induction and were given a standard dose of a neuromuscular blocking agent (atracurium 0.5 mg kg\(^{-1}\)). The patient was then preoxygenated before the bronchoscopy.

The cricoid pressure device included a force gauge (Mecmesin Compact Force Gauge, Mecmesin Ltd, UK), which was fully calibrated and accurate to ±1 N.

To mimic the action of the fingers when applying cricoid pressure, a device was made which would allow a variable aperture to allow for the varying size of patient in the study (Fig. 1). This device was placed on the neck of the study patients at the level of the cricoid cartilage. After placement of the rigid bronchoscope to a subglottic level, that is, just below the vocal cords, and with the image on a screen for all to visualize, the cricoid pressure device was carefully pushed backwards in a perpendicular angle. The force through the device was slowly increased until the calibre of the subglottic airway became distorted or narrowed to a degree of 50% or greater. The CF was then stopped and the force in Newtons (N) recorded. The anaesthetic was then continued and the airway secured. Fifty per cent narrowing of the airway was simply calculated using a sheet of paper which was placed on the monitor during the bronchoscopy and the anteroposterior diameter measured. This measurement was halved and marked on the paper. This measurement was then used to confirm 50% distortion or narrowing of the airway after application of the CF. In some cases, the bronchoscopic view deteroriated during the application of CF. In such cases, the force was removed and the position of the CF device and the bronchoscope checked and the force then reapplied. If this failed to correct the view, the procedure would have been abandoned. However, readings were successful in all patients after one or two attempts.

Statistical analysis was carried out on the data as a whole and also as four groups based on age: A <1 yr, B 1–4 yr, C 4–8 yr, and D <8 yr. Linear regression was used to test the relationship between age and weight against airway closure force (a reduction in the A-P diameter of the airway of 50% or more). The individual groups were compared using an appropriate Student’s t-test after testing for sample normality (Kolmogorov and Smirnov test) and equality of standard deviations (Bartlett’s test).

**Results**

Thirty patients (14 males) were enrolled into the study and measurements were made successfully in all patients (Table 1). There was a wide range of age (3 months to 15 yr) and weight (4–66 kg). Five were listed for a procedure requiring tracheal intubation and 25 patients for bronchoscopy. There were no anaesthetic complications, no patient had coughing or bucking, and there were no postoperative complications that could be ascribed to the study.

The patients were allocated into four groups of increasing age (Table 2). The mean CF used showed no statistical difference between Groups A, B, and C but was significantly greater in Group D, the older children (\(P<0.01\)).

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<th>Table 1 Patient characteristics</th>
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<tr>
<td>Male/female</td>
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<td>Mean age (yr) (range)</td>
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<tr>
<td>Mean weight (kg) (range)</td>
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<tr>
<td>Mean CF (N) (to reduce the airway calibre by ≥50%)</td>
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Fig 1 The force monitor and the CF apparatus.
vs D, *P*<0.001 A vs D and B vs D). Linear regression using all the data showed a significant relationship between both age (*P*<0.0001) and weight (*P*<0.0001) against CF (Figs 2 and 3).

**Discussion**

After the description of cricoid pressure by Sellick in 1961, the technique was quickly taken up as a technique to prevent passive regurgitation. He showed that ‘with a simple manoeuvre during induction of anaesthesia, regurgitation can be controlled until intubation is completed’. He showed in cadaveric studies that this pressure or force (unmeasured) placed externally on the cricoid cartilage would prevent flow of fluid into the pharynx to a pressure of 100 cm H₂O. The technique was evaluated by Salem and colleagues in 1972 for use in paediatric practice in a study of eight cadavers which found CF to be effective in preventing regurgitation again up to an intra-oesophageal pressure of 100 cm H₂O. He showed that ‘firm’ pressure prevented reflux in all cadavers with and without a nasogastric tube in place. This study forms the evidence base for the use of CF in paediatric anaesthetic practice today.

Cricoid pressure has thus become a cornerstone of both adult and paediatric anaesthetic practice. However, recent editorials have questioned the lack of evidence on prevention of aspiration and an increase in airway complications as a result of its use. Correct application of cricoid pressure/force requires that an appropriate externally applied force is transmitted through the cricoid ring to occlude the upper oesophagus at the level of the cricopharyngeus muscle against the lower cervical vertebrae. The original suggestion was that the required force was 44 N in adults, but a force of 30 N is now generally accepted as sufficient to prevent regurgitation. There is little information as to what the pressure or force should be used in a child and no studies so far have been done to assess the appropriate CF in paediatric practice. A benchtop investigation suggested forces between 20 and 25 N. However, the recommendation for paediatric practice currently mirrors adult practice and is 30 N. Females were at particular risk.

It would seem a reasonable assumption that in the paediatric age groups, the force required to deform the airway would be less than in the adult population, which is what our results show. We set out to replicate clinical practice and used a force monitor in conjunction with a device adapted to mimic the human hand. The device was made from a pair of dividers and the ends had plastic stoppers to mimic the application of CF by a hand using the thumb and middle finger. There is of course an element of ‘feel’ in applying cricoid pressure in a clinical situation and the operator will get feedback and make their own judgement on the correct amount of force. We wanted to make purely objective measurements in different age groups. To minimize the risk of trauma, we started at zero and slowly increased the force while visualizing the subglottic airway with a rigid bronchoscope attached to a camera system and monitor, and stopped when the level of distortion or calibre of the subglottic airway was ≥50%. It was sometimes difficult to be exact as to the degree of distortion as the increase often happened quickly, and we...
therefore described it as a significant distortion of \( \geq 50\% \). We felt this degree of distortion would impede tracheal intubation and the ability to ventilate the lungs with a facemask.

Our results show a linear relationship between both age and weight and the cricoid distorting force. In children who weighed less than 10 kg, the force required to significantly distort the airway was less than 10 N and in those weighing 4–5 kg, the distorting force was in the region of 5–7.5 N. In older children, the force required was slightly greater, but even in the teenagers studied, only one patient required a force of more than 20 N to significantly distort the airway. This suggests that current recommendations for CF in the paediatric age groups are excessive and need to be reduced. It may be, based on these limited data, that there is a case for continuing the practice in older children using a force in the region of 15 N. This is probably reasonable as in older children, especially in post-pubertal children, the structures are maturing and act more like adult structures. From our limited data, a force in the region of 15 N would be reasonable in children of 10 yr or older.

The main weakness in our study is the small number of patients in the older age group and more work is required. There are of course other weaknesses in this study. Five patients received neuromuscular blocking agents before bronchoscopy and the application of CF and this may have reduced the CF necessary. Another weakness is the relatively crude measurement technique of the anteroposterior diameter and then of 50% or greater narrowing or distortion. This method was chosen as the size of the image on the monitor was always slightly different and this was a simple and repeatable method of assessing the size. Repeat measurements of CF in the same patients would have also been useful to assess the repeatability of the measurements, but this had the potential to introduce unnecessary trauma, and therefore, we only performed a second measurement if on the first occasion there was a technical problem.

The question of the routine use of CF in children remains. The results of this study suggest that there is a need to measure the amount of CF applied if the practice is to continue in children. This may also be the case in older children and adult practice. There are, however, no commercially available devices which allow the measurement of CF to be measured and it will continue to be applied by the ‘experienced hand’. Further work is required to show if lower forces used in children will occlude the upper oesophageal junction, and also to verify the values found in this study for distortion of the upper airway.

In conclusion, we have shown that there is a linear relationship between age, weight, and the cricoid distortion force of the airway in children. The current recommendation of 30 N for CF appears to be excessive in all paediatric age groups and the effect of the compressive force on the airway must be balanced very carefully against the perceived benefit of the technique.

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