

HANS-JOACHIM PRIEBE

Department of Anaesthesia
University Hospital Freiburg
Freiburg, Germany

Sunday, June 1, 2008

10:30-11:15

Auditorium 15

In 1961 Sellick introduced the concept of cricoid pressure (CP) [1]. In his publication, he described the technique of using CP during induction of anaesthesia in 26 patients whom he considered at high-risk for pulmonary aspiration. In 23 of them there was no regurgitation or vomiting before or during application of CP, or after its release following inflation of the cuff of the tracheal tube. In the remaining three patients the release of CP after tracheal intubation was immediately followed by regurgitation of gastric or oesophageal content into the pharynx. Sellick interpreted the latter as evidence for the effectiveness of CP in preventing aspiration. Accordingly, he summarised his findings as follows: 'Backward pressure of the cricoid cartilage against the cervical vertebrae can be used to occlude the oesophagus, (a) to control regurgitation of stomach or oesophageal contents during induction of anaesthesia, or (b) to prevent gastric distension from positive-pressure ventilation applied by facepiece or mouth-to-mouth respiration'.

The study had several serious limitations. Firstly, Sellick did not provide any quantitative data on the force applied during CP at the various stages of induction of anaesthesia. Second, no information on the quality and ease of laryngoscopy and intubation during application of CP was provided. Third, he did not randomise patients to receive or not receive CP. At a time when the technique of CP had not yet been introduced into clinical practice and, therefore, was not a standard of care, it would have been a golden opportunity to perform a randomised trial in patients considered at risk for aspiration, in particular the effect of CP during induction of anaesthesia on the incidence of pulmonary aspiration. Fourth, Sellick postulated that 'extension of the neck and application of pressure on the cricoid cartilage obliterates the oesophageal lumen at the level of the body of the 5th cervical vertebra'. This was based on just two lateral neck x-rays taken in a single anaesthetised patient in whom a latex tube had been inserted into the oesophagus. The tube was distended by contrast medium to a pressure of 100 cmH₂O. Following hyperextension of the head and application of CP, the x-ray showed obliteration of the lumen at the 5th cervical vertebra. Fifth, Sellick postulated that CP '... can be used to occlude the oesophagus ... to control regurgitation of stomach or oesophageal contents during induction of anaesthesia ...'. This was based on the finding in the three patients who regurgitated after release of CP, and on findings in a cadaver showing that '... when the stomach was filled with water and firm pressure was applied to the cricoid, ... a steep Trendelenburg tilt did not cause regurgitation of fluid into the pharynx. Moreover, the flow of water from the pharynx could be controlled by varying the pressure on the cricoid cartilage'. Sellick concluded that CP '... can be used ... to prevent gastric distension from positive-pressure ventilation applied by facepiece or mouth-to-mouth respiration'. This is pure speculation. The entire publication does not provide a single piece of evidence to support this conclusion. This aspect was simply not the subject of the investigation. In summary, his paper reported a non-randomised, poorly controlled observational study in a relatively small number of patients. The absence of several pieces of essential information makes useful interpretation of the findings impossible. Several of Sellick's conclusions were not supported by his findings. For all these reasons, the publication was rightly published under the category of 'Preliminary Communications'.

Despite these major deficiencies, the practice of CP was adopted rapidly and, rather uncritically, by the anaesthesia community worldwide. It soon became a standard of care during rapid sequence induction (RSI) of anaesthesia. At the time of Sellick's description there was considerable concern about death due to aspiration during induction of anaesthesia in the surgical population in general, and the obstetric population in particular. At such time, his approach must have appeared highly attractive. However, is this still the case more than 45 years later, during which time overall anaesthetic management has changed considerably?

CRICOID PRESSURE AND AIRWAY ANATOMY

Since Sellick's publication it has been assumed that the oesophagus lies directly behind the cricoid cartilage, and that the cricoid cartilage, the oesophagus and the vertebral body are juxtaposed along the axial plane. The claimed effectiveness of CP relies on direct compression of the oesophagus by the cricoid cartilage. However, in a retrospective review of 51 cervical CT scans, some degree of lateral displacement (1.4-5.7 mm) of the oesophagus was found in 49% of images [2]. Furthermore, MRI images of the necks of 22 healthy awake volunteers revealed lateral displacement of the oesophagus relative to the midline of the vertebral body in 53% of subjects without CP and in 91% of subjects with two-handed CP [3]. The oesophagus was not completely

opposed between the cricoid cartilage and the vertebral body in 48% of subjects without CP and in 71% of subjects with CP. The airway was displaced relative to the middle of the vertebral body in 33% of subjects without and in 67% of subjects with CP. Airway compression (defined as a decrease in the antero-posterior diameter by at least 1 mm) was observed in 81% of subjects during CP. These findings show that CP may increase the frequency and the degree of lateral displacement of the oesophagus, and the frequency of the oesophagus being unopposed between the airway and the vertebral body, possibly facilitating regurgitation of gastric contents. Furthermore, CP may distort airway anatomy and cause airway obstruction when applied with the recommended force of 20-30 Newtons (N).

Using a cricoid force of 20 N applied by a padded yoke in anaesthetised patients, occlusive deformation of the cricoid cartilage (defined as the anterior aspect of the cricoid cartilage coming into contact with the posterior) and vocal cord closure were observed (using a fibrescope advanced through a laryngeal mask airway) in seven (24%) and 12 (40%) of 30 patients, respectively [4]. The incidence of these adverse effects increased to 43 and 50%, respectively, at a cricoid force of 30 N. At cricoid forces of 20 N and 30 N, ventilation via a laryngeal mask airway was difficult in 50% and 73% of patients, respectively. In the absence of CP all patients could be ventilated without difficulty. Taken together, these findings unequivocally indicate that the application of CP may result in significant distortion of upper airway anatomy.

CRICOID PRESSURE AND LARYNGOSCOPY

In some cases an optimal laryngoscopic view can only be achieved through external manipulation of the hyoid and thyroid cartilages by the free hand of the laryngoscopist. Such external manipulation can make the difference between failed and successful intubation. As the cricoid cartilage is 2-3 cm caudad of the larynx, it is important to realise, particularly in the context of this discussion, that CP does not represent optimal external laryngeal pressure [5]. Even without systematic evaluation, one would hypothesize *a priori* that CP worsens the laryngoscopic view and, thus, increases the incidence of difficult and failed intubations. In view of the considerable differences in baseline airway anatomy and in the force and location of externally applied laryngeal pressure when attempting CP, it is to be expected that the effect of CP on laryngoscopy is complex. Two randomised studies have addressed this issue. Not unexpectedly, they produced conflicting results. Improvement, no change, worsening, and a combination of all [6] have been reported in response to CP [7, 8]. Even when applied correctly or as a modified 'BURP' manoeuvre, CP worsened the laryngoscopic view [9].

The effect of CP on laryngoscopy was investigated quantitatively by photographing the view through a rigid, zero-degree endoscope positioned alongside, and matching the laryngoscopist's line of sight [6]. In some subjects, the laryngoscopic view improved with CP, while in others it worsened. For the group as a whole, only the increase in applied force from 0 to 10 N was more likely to improve (n=19) rather than impair (n=12) the view (unchanged view: n=9). Worsening of the laryngoscopic view was due to down-folding of the epiglottis, adduction of the vestibular folds, encroachment of the pharyngeal soft tissues into the line of sight, and displacement and rotation of the larynx. Application of greater axial force to the laryngoscope was required to counteract the adverse effect of CP on laryngoscopy, and to completely or partially restore the laryngoscopic view. This requirement for a greater force is, in itself, expected to render intubation more difficult.

A recent large randomised study in 700 patients receiving either CP or sham CP during laryngoscopy and intubation failed to demonstrate any difference between groups in terms of the number of patients who could not be intubated within 30 s, the quality of laryngoscopic view or difficulty with intubation [10]. These findings seem to contradict a commonly held clinical impression that CP unpredictably impairs the laryngoscopic view and renders intubation more difficult. The findings also seem to contradict several case reports and investigations documenting airway distortion and increased difficulty with airway management during CP. Several factors could explain the lack of effect of CP on the rate of successful intubation in this study. First, baseline intubating conditions were optimised by excluding non-elective surgery, pregnant and morbidly obese patients. Second, baseline upper airway anatomy was generally favourable. Optimal baseline conditions for a smooth intubation are reflected by a mean intubation time of just over 11 s in the control group. Third, and probably most importantly, CP was applied by anaesthesia assistants who had been trained daily in the correct identification of the cricoid cartilage and in the application of a force of 30 N (~ 3 kg) using a simulator. The findings could, therefore, be interpreted as showing that application of CP by highly trained and supervised anaesthesia personnel in healthy patients with normal upper airway anatomy is unlikely to hinder tracheal intubation. In clinical practice, however, CP is frequently applied by less well-trained individuals to patients presenting with risk factors for difficult intubation. In general, anaesthesia personnel have a limited knowledge of the optimal technique of CP [11]. If the manually applied pressure is excessive, too far from the midline or applied to the thyroid cartilage, the laryngoscopic view will worsen, and intubation will become more difficult.

COMPLICATIONS OF CRICOID PRESSURE

The application of CP is associated with numerous side-effects and some serious complications including distortion of upper airway anatomy, distorted laryngeal view, interference with the insertion of the laryngoscope and passage of an introducer, laryngeal trauma, oesophageal rupture, difficult placement of a laryngeal mask airway, difficult ventilation via a face mask or laryngeal mask airway, and airway obstruction [7, 8]. By decreasing the lower oesophageal sphincter tone [12, 13] CP facilitates regurgitation of gastric contents. CP has also been described as a cause of failed intubation [14]. In view of the numerous adverse effects of CP on upper airway anatomy, this is hardly surprising. In the event of a failed intubation, oxygenation may prove impossible during continued CP [4, 15].

Pulmonary aspiration of gastric content has occurred despite CP. The reasons for failure of CP to prevent regurgitation include incorrect application of pressure, anatomical airway changes induced by CP and anatomical differences between individuals. I postulate that in some cases CP may contribute *per se* to eliciting regurgitation by reducing the lower oesophageal sphincter tone, by increasing the need for mask ventilation as a result of a greater incidence of failed initial intubations, and by prolonging the time until successful intubation, resulting in some instances of wearing-off of the muscle relaxant, sympathetic stimulation and hypoxaemia.

PRACTICE OF CRICOID PRESSURE

In a national postal survey of the practice of RSI by 220 respondents (senior anaesthetists 60%, trainees 40%), all reported using CP during RSI [16]. Although CP was applied universally, the technique of application varied widely. With the patient still awake, applied forces varied between 1 and 44 N; with the patient asleep, forces varied between 2 and 80 N. A considerable number of respondents did not record any force, did not know what force they were using, or used descriptive terms (such as 'enough', 'force to break an egg', 'thumb force', 'varies'). Interestingly, although CP was applied universally, 28% of the respondents had seen 99 cases of regurgitation during RSI (resulting in 15 aspirations, one oesophageal rupture, and three deaths). In addition, half of the respondents had experienced failure to intubate. One cannot help wondering whether any of these complications were due to use of RSI of which CP is an integral part.

Cricoid pressure applied too early and too forcefully may provoke coughing, straining or retching during induction of anaesthesia resulting in pulmonary aspiration or oesophageal rupture. But what exactly is 'too early' and 'too forcefully'? During induction of anaesthesia, the latter may be defined as a force of more than 20 N. Following unconsciousness, cricoid force of more than 40 N can cause airway obstruction and difficulty with tracheal intubation. The recommendations vary between an applied force of 10 N (~ 1kg) and 20 N (~ 2 kg) when the patient is awake, and between 30 N and 40 N when the patient is asleep. If one wants to adhere to the various existing recommendations, training is required to apply the correct force by practicing on weighing scales. There is no agreement on whether single-handed or bimanual (addition of neck support) CP provides the better laryngoscopic view.

CRICOID PRESSURE: RECOMMENDATIONS AND GUIDELINES

Some of the airway management recommendations and guidelines for the management of CP during RSI reflect the ambiguity surrounding this issue. A cricoid force of 20 N in an awake patient, and 30 N after loss of consciousness has been recommended [17]. It is interesting to note that in the case of an initially poor laryngoscopic view or failed intubation the recommendation on how to proceed is made dependent on the peripheral blood oxygen saturation (SpO₂) [17]. If the SpO₂ remains stable, the authors recommend maintaining CP but reducing it to 20 N. If, on the other hand, the SpO₂ falls during the first attempt of intubation, or if intubation fails during the second attempt with reduced but maintained CP, the authors recommend release of CP.

The guidelines for unanticipated difficult intubation during RSI in non-obstetric adult patients issued by the Difficult Airway Society (DAS) recommend a cricoid force of 10 N in an awake patient [18]. During laryngoscopy in an anaesthetised patient, a cricoid force of 30 N as well as the possible use of external laryngeal manipulation by the laryngoscopist are recommended. (It is left up to the practicing anaesthetist to figure out how to simultaneously apply CP and externally manipulate the larynx). If the laryngoscopic view is poor, or if mask ventilation following failed intubation is difficult, the guidelines recommend reducing CP.

By recommending reduction and, ultimately, release of CP under difficult intubating conditions, both recommendations obviously acknowledge the real possibility that CP may impair laryngoscopy, intubation and ventilation by mask. Based on the existing literature, one cannot help but think that the insistence on CP is likely to contribute to an undefined number of failed intubations with all its consequences in this patient population at increased risk for gastric regurgitation.

CRICOID PRESSURE: WHERE DO WE STAND IN 2008?

More than 45 years after Sellick's description of the technique of CP, no randomised controlled trial has been conducted to assess, let alone prove the effectiveness of CP in preventing pulmonary aspiration of gastric contents. Although the use of CP seems to make intuitive sense, its scientific basis is weak at best and lacking at worst [7, 8]. Although there is some limited evidence that CP may prevent regurgitation of gastric contents, the technique is associated with considerable risks.

Despite the lack of proof of effectiveness, many anaesthetists remain convinced of the essential role of CP. Uncertainty remains about the optimal mode of applying CP, and its safety and efficacy in clinical practice. It is highly unlikely that it will ever be possible to define in the individual patient the appropriate force necessary to make the cricoid cartilage (a rigid tubular structure) compress the oesophagus (a semi-mobile, non-rigid tubular structure of varying thickness) against the vertebral body (a rigid structure with a curved surface) in the presence of potentially large variations in intraluminal oesophageal pressures (induced by regurgitation and vomiting). By using CP we may endanger more patients by interfering with optimal airway management than save lives through prevention of aspiration of gastric contents. When tracheal intubation fails, effective ventilation of the lungs becomes essential. Continued CP pressure may prevent effective ventilation. This may then result in a 'cannot intubate, cannot ventilate' scenario. Thus, the risks of failed airway management may outweigh those of aspiration. Ultimately, it may be more important to avoid coughing, straining or retching during induction of anesthesia by ensuring rapid onset of anesthesia and muscle relaxation than applying CP. It may be dangerous to consider CP to be effective in most cases and become complacent about the many factors that contribute to regurgitation and aspiration. By today's standards, CP can not be considered evidence-based practice. This is why more and more anaesthetists (including myself) have abandoned the application of CP.

KEY LEARNING POINTS

- Cricoid pressure was introduced into anaesthetic practice based on a single case series that lacks information on the force applied and on the method of application during induction of anaesthesia.
- There are no controlled, prospective randomised trials that document that cricoid pressure reduces the incidence of regurgitation, pulmonary aspiration and aspiration-related morbidity and mortality.
- Numerous studies have shown that cricoid pressure has multiple adverse effects, the most important being interference with airway management.
- Numerous surveys have shown that most anaesthetists lack adequate knowledge about all aspects of cricoid pressure.
- More patients are seriously harmed (including hypoxic brain injury and death) by difficulties in airway management than by pulmonary aspiration. By using cricoid pressure, we may be endangering more lives by interfering with optimal airway management than we are saving by preventing pulmonary aspiration.

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