Cricoid Pressure in Emergency Department Rapid Sequence Tracheal Intubations: A Risk-Benefit Analysis

Daniel Y. Ellis, FCEM
Tim Harris, FACEM
David Zideman, FRCA

From the Department of Emergency Medicine, The Townsville Hospital, Douglas, Queensland, Australia (Ellis); the Department of Emergency Medicine and Pre-hospital Care (London Helicopter Emergency Medical Service), Royal London Hospital, London, UK (Harris); and the Department of Anaesthesia, Hammersmith Hospital, London, UK (Zideman).

Cricoid pressure is considered an integral part of patient safety in rapid sequence tracheal intubation and emergency airway management. Cricoid pressure is applied to prevent the regurgitation of gastric contents into the pharynx and subsequent aspiration into the pulmonary tree. This review analyzes the published evidence supporting cricoid pressure, along with potential problems, including increased difficulty with tracheal intubation and ventilation. According to the evidence available, the universal and continuous application of cricoid pressure during emergency airway management is questioned. An awareness of the benefits and potential problems with technique allows the practitioner to better judge when cricoid pressure should be used and instances in which it should be removed. [Ann Emerg Med. 2007;50:653-665.]

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INTRODUCTION

Cricoid pressure was described by Sellick[1] in 1961 as a method to reduce the risk of aspiration during the induction phase of anesthesia. Sellick's[1] technique was to apply backwards pressure to the cricoid cartilage, compressing the esophagus against the underlying vertebral body. Theoretically, this would occlude the esophageal lumen, preventing the passage of regurgitated gastric contents into the pharynx and subsequent aspiration into the pulmonary tree. The cricoid cartilage is a complete ring, with a larger posterior than anterior surface. Sellick[1] tested his theory on a cadaver and then on human subjects. Sellick's publications will be discussed in more detail below.

Death from aspiration during anesthesia was first described by Simpson[2] in 1848. In 1946, Mendleson[3] identified acid aspiration in 66 of 44,016 obstetric patients, all of whom underwent facemask anesthesia for labor and delivery. The Confidential Enquiry into Maternal Deaths in England and Wales in the 1950s and 1960s noted aspiration as a major cause of maternal morbidity and mortality.[4]

After Sellick's[1] article, cricoid pressure was incorporated into an overall approach to minimizing the risk of aspiration through "rapid sequence induction" of anesthesia.[5] Unlike traditional anesthesia practice, in this technique there is no interspersed ventilation (and delay) between the induction agent and the muscle relaxant. The goal is to minimize gastric insufflation and place a cuffed endotracheal tube as quickly as possible. After preoxygenation, the induction agent and muscle relaxant were given in rapid sequence, cricoid pressure was applied, and positive-pressure ventilation was withheld until the endotracheal tube was placed.[6] Indications for rapid sequence induction have since been expanded from the obstetric patients to include all anesthesia patients considered at high risk of aspiration, particularly patients believed to have a full stomach.[7,8]

"Rapid sequence induction" was adapted by emergency physicians to allow ventilation as required to prevent hypoxia and subsequently termed *rapid sequence tracheal intubation* (rapid sequence tracheal intubation will refer to this technique in this article).[9,10] Rapid sequence tracheal intubation is the now most widely used technique for tracheal intubation in the emergency department (ED),[11,12] and cricoid pressure is taught as a standard component of emergency airway management.[13,14]

In modern anesthesia practice, although cricoid pressure is widely used, its method of application, its timing, and its role in difficult airways are not standardized.[15-20] Cricoid pressure has been described as the "lynchpin of physical prevention [of aspiration]"[21] and a minimum standard of care, implying any trials to prove its worth could be unethical.[22] Conversely, more recent reviews and case reports have questioned the effectiveness and safety of the technique, even in obstetric anesthesia.[22-27] Questions have arisen about whether cricoid pressure should be abandoned altogether,[22-25] and some anesthetists have, in their own words, "more or less discontinued the application of cricoid pressure."[26] Doubt has also been cast on the efficacy of cricoid pressure from within emergency medicine practice.[28]

This review will explore the evidence supporting cricoid pressure and its potential detrimental effects, in particular on laryngoscopy and ventilation.

METHODOLOGY

Data Sources

An electronic search was carried out independently by the first 2 authors, using the terms "cricoid ADJ pressure" and "Sellick$ ADJ manoeuvre." The only limit applied was English language. Searches were made of the following electronic databases, using Dialog Datastar by Athens (Eduserv Technologies Ltd., Bath, UK): MEDLINE (1950 to June 2006; 240/254 titles identified), EMBASE (1974 to June 2006; 216/233 titles identified) and CINAHL (1982 to June 2006; 79/80 articles identified). These searches were combined and duplicate articles removed, leaving 345 of 357 titles. A further search using MEDLINE through Pubmed (1966 to June 2006) produced 340 of 372 titles. All abstracts were read and relevant articles identified. Further literature was identified by hand-searching the reference sections. The Cochrane library was also searched, but no relevant articles were identified.

The search was carried out independently by 2 of the authors (D.Y.E. and T.H.), and the results were combined to produce the review. One hundred forty-one articles were identified and read. The completed review was then adapted by the third author.

Definitions

There are 3 widely used techniques involving manipulation of the anterior laryngeal structures during direct laryngoscopy tracheal intubation. Cricoid pressure, as described above, is applied primarily to reduce the risk of aspiration. Backward, upward, rightward pressure describes thyroid manipulation by an assistant to improve laryngeal view at laryngoscopy.[29] Bimanual laryngoscopy (also known as external laryngeal manipulation) involves operator-directed manipulation of the thyroid cartilage, also to improve the view of the larynx.[30]

The latter 2 techniques are not designed to affect aspiration risk and are not further considered in this article.

WHAT IS THE EFFECT OF CRICOID PRESSURE ON REGURGITATION AND ASPIRATION?

How Common Is Aspiration?

The goal of cricoid pressure is prevention of regurgitation of the gastric contents, with subsequent aspiration into the lungs, and it is important to consider the scope of the problem. Studies have shown that rates of aspiration, particularly in elective anesthesia, are similar across the developed world, with figures between 0.014% and 0.1% for adults and higher figures of 0.08% to 0.1% for pediatric populations.[31-40] These data are for aspiration occurring at any time in the perioperative period and not just at tracheal intubation.[41]

Given the dynamic nature of emergency airways, the fact that many critical patients aspirate before tracheal intubation or ED arrival, and differences in definition, the rate of clinically significant aspiration associated with the procedure itself is unknown. It has been reported in anywhere from 0% of ED-performed rapid sequence tracheal intubations to as high as 22%.[10,42-53] Some of the reported variation may also result from an increasing incidence of aspiration associated with repetitive attempts. Mort's[49] review of 2,833 emergency airways found a 1.9% incidence when laryngoscopy was performed once or twice versus an incidence of 22% with 3 or more attempts.

Mortality from aspiration in anesthetic practice is considered rare, but reported figures vary considerably and have been reported as high as 4.6%.[53-57] Mortality from aspiration in emergency airways is especially difficult to quantify, given the multiple pathologic processes in patients requiring emergency tracheal intubation. Despite the ambiguity about such figures, aspiration contributing to severe hypoxemia is likely to be a significant factor in cardiac arrest occurring in emergency airways. According to Mort's[49] review, when aspiration of gastric contents occurred in emergency airways, hypoxemia followed in 91% of cases, with severe desaturation (<70% SpO_2) in 30%.

What Is the Published Evidence Suggesting Cricoid Pressure Reduces Regurgitation and Aspiration?

Sellick's original articles, published in 1961[1] and 1962,[58] were observational studies of his current practice. His first article, published as a preliminary communication, examined 26 patients who were at high risk of aspiration and undergoing general anesthesia. At induction, he applied cricoid pressure to each patient and removed it after the endotracheal tube was placed. He observed 3 cases of regurgitation when cricoid pressure was released. In addition, Sellick passed a soft latex endotracheal tube down the esophagus of one patient under general anesthesia and filled it with contrast medium to a pressure of 100 cm H_2O. Radiographs taken before and during the application of cricoid pressure showed complete occlusion of the endotracheal tube and therefore, he concluded, of the esophagus.

In Sellick's[1] original article, he also mentions filling the stomach of a cadaver and tilting the body head down while applying cricoid pressure. No regurgitation was observed.

Sellick's[58] 1962 article was another observational study based on a single patient undergoing esophagectomy under general anesthesia. With cricoid pressure applied, the esophagus was distended with saline solution passed through an esophageal endotracheal tube to a pressure of 100 cm H_2O, and no regurgitation was observed. He also anecdotally reported 100 high-risk cases with no episodes of regurgitation when cricoid pressure was applied but 6 cases of regurgitation on release of cricoid pressure.

The limitations of Sellick's[1,58] reports are that they are small, nonrandomized, unblinded, uncontrolled works, with the technique's proponent as the single author. In addition, the force applied to the cricoid was not quantified, and the anesthetic drugs were not described. Cricoid pressure was applied with the head and neck fully extended, in a head-down position.

It was almost a decade later before any more work on cricoid pressure was published, and there then followed 4 cadaver studies[59-62] (Table 1). All 4 studies had similar methodology whereby saline solution was passed into the esophagus through the stomach and cricoid pressure was applied. The pharynx was assessed directly for leakage. All 4 articles found that cricoid pressure prevented reflux of saline solution into the pharynx at esophageal pressures up to 50 cm H_2O and sometimes up to 100 cm H_2O.

In 1983, Wraight et al[63] measured the cricoid force (produced by a cricoid yoke) needed to prevent reflux of saline solution through a modified endotracheal tube placed into the esophagus of 24 patients undergoing elective anesthesia. From these data and previous measurements of intragastric pressure in awake patients, they estimated that cricoid pressure applied with 44 N (9.81 N=1 kg=2.2 lb) would prevent regurgitation for "most" cases requiring emergency anesthesia.

The final piece of published evidence in our literature search supporting the effectiveness of cricoid pressure for preventing aspiration was a 2003 case report by Neelakanta.[64] A patient had cricoid pressure applied that, when released (after endotracheal tube placement), led to the appearance of gastric fluid in the mouth.

What Is the Clinical Evidence of Cricoid Pressure Failing to Prevent Aspiration?

There are 2 case reports presenting 3 examples of fatal regurgitation and aspiration despite cricoid pressure.[65,66] Two separate surveys showed that 11% to 14% of anesthetists[67] and 11% of operating department assistants and anesthetic nurses[68] had witnessed regurgitation with cricoid pressure applied. In addition, a review of 30 years' worth of medicolegal liability claims in the United States reported that aspiration occurred in 67 cases despite the application of cricoid pressure in 17 of these.[69] A review of 133 cases of aspiration during anesthesia from an Australian incident-monitoring study also highlighted 4 incidents of aspiration even though cricoid pressure had been applied.[57] Schwartz et al[42] published data on 297 "emergency" tracheal intubations that suggested 12 cases of aspiration. Of these patients, 9 had been intubated with cricoid pressure applied. The Thibodeau et al[44] review of 133 ED tracheal intubations found 3 patients aspirated (3.5%), including 1 case of visible aspiration during the procedure, despite the universal application of cricoid pressure.

The Confidential Enquiries into Maternal Deaths also give some data on cricoid pressure. Morgan's[70] review of the report on Confidential Enquiries into Maternal Deaths from 1979 to 1981 showed that aspiration occurred in 8 patients, of whom 6 had cricoid pressure applied before tracheal intubation. The Confidential Enquiries into Maternal Deaths from 1973 to 1975 reported 12 aspiration deaths, with cricoid pressure applied in 5 of these cases. The authors of the report state that in 2 cases, the cricoid pressure was relaxed too early, and in the other 3, it was "inefficient."[71] Concerns about the apparent significant failure rate of cricoid pressure were published around the time this report first came out.[65] The Confidential Enquiries into Maternal Deaths from 1985 to 1987 reports only 1 aspiration death; cricoid pressure was applied in this case.[72]

It is impossible to determine from these case reports and medicolegal reviews whether the failure to prevent aspiration is a consequence of improper application of the technique or the technique itself. This is further complicated by widespread debate as to what amount of force should be applied with cricoid pressure (discussed below).

What Is the Effect of Cricoid Pressure on Gastroesophageal Physiology?

Regurgitation of gastric contents is prevented by the upper and lower esophageal sphincters. Theoretically, cricoid pressure acts mechanically in a similar fashion to the upper esophageal sphincter, although the anatomic basis of this presumption has been questioned by recent imaging studies using computed tomography (CT) and magnetic resonance imaging (MRI) (discussed below). Numerous studies have suggested, however, that cricoid pressure has detrimental effects on the lower esophageal sphincter. The effectiveness of the lower esophageal sphincter is dependent on the difference between lower esophageal sphincter pressure and intragastric pressure. This is known as the barrier pressure. Cricoid pressure has been shown to reduce lower esophageal sphincter pressure and barrier pressure in healthy nonanesthetized patients,[73,74] but this effect did not promote gastroesophageal regurgitation as measured with a pH probe.[75] More recent work, this time on anesthetized patients, confirmed that cricoid pressure does cause a significant (29%) decrease in lower esophageal sphincter pressure, with a corresponding decrease (44%) in barrier pressure.[76] Such reductions in lower esophageal sphincter pressure are associated with increasing gastric distention during bag-valve-mask ventilation.[77]

What Is the Effect of Cricoid Pressure on Gastric Insufflation?

Four studies have shown that cricoid pressure prevents gastric insufflation during mask ventilation.[78-81] (Table 2). A dilated stomach risks regurgitation, diaphragmatic splinting, increasing airway pressures, barotrauma, and hypoventilation. Prevention of these potential complications is a beneficial aspect of cricoid pressure that warrants serious consideration by emergency physicians. The ventilation strategies used in these studies, however, were different from those recommended today, with higher tidal volumes, higher ventilatory pressures, and shorter inspiratory times (Table 2). The lower tidal volumes and lower peak flow rates now recommended[77,82] were adopted to prevent gastric insufflation and may obviate this potential benefit of cricoid pressure.

What Do Radiological Studies Tell Us About the Anatomic Basis of Cricoid Pressure?

The anatomic rationale for cricoid pressure, ie, that the cricoid ring, esophagus, and vertebral body are horizontally

Table 1. Studies showing effectiveness of cricoid pressure.

First Author	Study Group/Details	Study Type	Outcome Measures	Key Results	Comments
Fanning,[59] 1970	Cadavers (2 canine, 5 human). Water-filled catheter inserted into esophagus through the stomach, with increase in catheter pressure while CP was applied	Experiment	Checking the pharynx under direct vision for any leaks	CP prevented regurgitation up to esophageal pressures of 50-74 cm H_2O	Similar for all 4 cadaver-based studies. Small numbers Use of cadavers, some several days old and some of which were not human Force of cricoid applied not quantified but described as "firm" (except Vanner and Pryle)
Salem,[60] 1972	8 infant cadavers. Similar methods to Fanning	Experiment	Checking the pharynx under direct vision for any leaks	No leakage into pharynx with CP applied	
Salem,[61] 1985	6 cadavers. Similar methods to Fanning but cadavers also had nasogastric endotracheal tubes in situ	Experiment	Checking the pharynx under direct vision for any leaks	No regurgitation at 100 cm H_2O, but regurgitation occurred in all cadavers on release of CP.	
Vanner and Pryle,[62] 1992	10 cadavers. Similar methods to Fanning but CP applied with cricoid yoke at 0, 20, 30, and 40 N	Experiment	Checking the pharynx under direct vision for any leaks	30 N Of CP prevented regurgitation in all cadavers, with intraesophageal pressures up to 40 mm Hg.	
Wraight,[63] 1983	24 adults undergoing elective abdominal surgery had a modified endotracheal tube passed into the esophagus and connected to saline solution at various pressures. Different levels of CP were applied with a yoke.	Observational	Effectiveness of CP assessed by checking whether flow down the endotracheal tube was prevented	50% Of patients would be protected by 44 N of CP and 83% by 66 N	Trial not designed to test effectiveness of CP. Potential effects of esophageal endotracheal tube on application of CP.
Neelak-anta,[64] 2003	Single starved patient post–esophageal reconstruction, undergoing unrelated ocular surgery	Case report		Gastric fluid appeared in the mouth on release of CP.	Previous esophageal surgery

CP, Cricoid pressure.

Table 2. Studies showing effect of cricoid pressure on gastric insufflation.

First Author	Study Group/Details	Study Type	Outcome Measures	Key Results	Comments
Salem,[78] 1974	10 children, ventilated with 150% of normal minute volume by facemask	Nonrandomized	Effects of CP on gastric insufflation assessed by mL of air in stomach	Reduction in stomach gas volumes when CP applied	Peak airway pressures 19-25 cm H_2O Orogastric endotracheal tube in situ CP applied variably and "gently" No statistical analysis
Lawes,[79] 1987	20 patients ventilated by facemask with variable airway pressures	Observational	Effects of CP on gastric insufflation, assessed by stethoscope over stomach	No gastric insufflation with CP at peak airway pressures up to 45 cm H_2O	Tidal volume not measured Assessment of adequate ventilation subjective No gastric insufflation detected at 17 cm H_2O with or without CP
Petito,[80] 1988	50 patients ventilated by facemask with tidal volumes of 15 mL/kg and a respiratory rate of 10 breaths/min	Randomized study	Effects of CP on gastric insufflation assessed by mL of air in the stomach	Patients with CP applied had less gas in the stomach ($P<.001$)	High tidal volumes Nasogastric endotracheal tube in situ
Moynihan,[81] 1993	59 children ventilated by facemask. Airway pressures increased by gradual closure of pressure-release valve.	Part randomized, crossover	Effects of CP on gastric insufflation, assessed by stethoscope over stomach	CP prevented gastric insufflation up to an airway pressure of 40 cm H_2O	No gastric insufflation detected at 16 cm H_2O with or without CP Force of CP highly variable Orogastric endotracheal tube in situ

aligned, has been undermined by recent radiographic studies of neck anatomy. A retrospective review of 51 cervical CT scans[83] and a prospective analysis of 21 MRI scans[84] showed that the esophagus was laterally displaced in 49% of CT scans and 53% of MRI scans. The MRI study compared images before and after cricoid pressure application and found that cricoid pressure increased the incidence and degree of esophageal displacement. With cricoid pressure (20 to 30 N), the esophagus was laterally displaced relative to the cricoid ring in 90.5% (19/21) of patients. The esophagus was incompletely opposed between the cricoid cartilage and vertebral body in 71.4% (15/21) of scans with cricoid pressure.

Lateral displacement of the esophagus has also been documented in CT images of cricoid pressure with nasogastric endotracheal tubes[85] and during real-time ultrasonography of endotracheal tube placement with the transducer held just above the suprasternal notch.[86]

WHAT ARE THE EFFECTS OF CRICOID PRESSURE ON THE AIRWAY AND BREATHING?

What Are the Effects of Cricoid Pressure on Mask Ventilation?

There have been 10 published articles reporting the effects of cricoid pressure on mask ventilation (Table 3). In every study, cricoid pressure reduced tidal volumes, increased peak inspiratory pressure, or prevented ventilation.[79,80,87-94] Functional occlusion of the airway occurred between 6% and 50% of the time. Two studies of cricoid pressure on gastric insufflation incidentally observed cases of airway obstruction with the application of cricoid pressure.[79,80] There are also 2 case reports describing complete airway obstruction with cricoid pressure.[92,93]

What Is the Effect of Cricoid Pressure as Documented by Endoscopic and Radiographic Studies?

MacG Palmer and Ball[94] evaluated the endoscopic view of the larynx in 15 men and 15 women during cricoid pressure at different forces (20, 30, and 44 N), as measured with a strain gauge affixed to a cricoid yoke. Deformation of the cricoid cartilage, vocal cord closure, and difficult mask ventilation occurred in a large number of patients and correlated with increasing force. Occlusion of the cricoid and difficult ventilation was more prevalent and more significant in women, presumptively because of a smaller internal diameter of the cricoid ring and greater deformability.

In the Smith et al[84] MRI imaging of cricoid pressure, airway compression (>1 mm) occurred in 81% of patients.

What Are the Effects of Cricoid Pressure on Insertion and Function of the Laryngeal Mask Airway?

The interplay between cricoid pressure and the laryngeal mask airway is increasingly relevant because the laryngeal mask airway is becoming widely used as a rescue ventilation device.[95-102] As described by Brimacombe,[95] there is an "anatomic conflict" between the manner in which cricoid pressure "compresses the hypopharyngeal space" and the intended position of the laryngeal mask airway in the laryngopharynx and hypopharynx. In Brimacombe's[95] meta-

Table 3. Studies showing effect of cricoid pressure on ventilation and airway patency.

First Author	Study Group/Details	Study Type	Outcome Measures	Key Results	Comments
Allman,[87] 1995	50 patients under GA having facemask ventilation +/– CP.	Randomized blinded and crossover	Degree of airway obstruction	In 24/100 applications, tidal volume reduced by 50%, and 11/100 applications had total airway occlusion	Force of CP not measured; "approx" 44 N 23 Anesthetists used
Hartsilver,[88] 2000	52 patients receiving: -no CP, 30 N CP, 30 N CP (applied like BURP*) or 44 N CP	Randomized blinded and crossover	Airway obstruction evidenced by a decrease in tidal volume	% Of obstructed airways: 0% (no CP), 2% (30 N CP), 56% (30 N CP applied like BURP), 35% (44 N CP)	Force of CP was an estimate
Hocking,[89] 2001	50 patients: No CP, CP supine, CP and 15° lateral tilt or no CP and 15° lateral tilt	Randomized blinded and crossover	Airway obstruction evidenced by a decrease in Tv and PIP	Tilt had no effect but CP decreased Tv and increased PIP. Three cases of complete airway obstruction	Force of CP (44 N) was an estimate.
Saghei,[90] 2001	80 adult patients already intubated CP vs no CP	Randomized and blinded	Assess pressor response and airway effects of CP	Significant decrease in Tv and increase in PIP Strong pressor response	Study initially designed to examine pressor response only
MacG Palmer,[91] 2005	30 Awake patients with CP applied	Observational	Airway obstruction evidenced by a decrease in PEFR and relation to discomfort	CP caused cricoid compression and reduced Tv Discomfort suggested complete airway obstruction	Not randomized or blinded
Lawes,[79] 1987	20 patients anesthetized and ventilated by facemask	Observational	Effects of CP on gastric insufflation	Reduction in gastric insufflation with CP 15% Of cases had airway obstruction with CP	Not the primary outcome of the trial No controls
Petito,[80] 1988	50 patients anesthetized and ventilated by facemask	Randomized study	Effects of CP on gastric insufflation	Reduction in gastric insufflation with CP Three times as many CP patients had airway obstruction	Not the primary outcome of the trial No controls
Georgescu,[92] 1992; and Ho,[93] 2001	2 patients	Case reports		Complete airway obstruction with CP	Case reports
Palmer,[94] 2000	30 patients for elective surgery. LMA sited, then fiberscope. CP applied by a yoke at 20, 30, and 44 N.	Observational	Fiberoptic assessment of laryngeal view and ability to ventilate through LMA	Increasing cricoid deformation, vocal cord closure, and difficult mask ventilation as CP increased. Degree and incidence of problems higher in female patients	Assessments done with LMA in situ View assessed subjectively Use of cricoid yoke may be a confounder

GA, General anesthesia; *BURP,* backwards, upwards and to the right pressure; *Tv,* tidal volume; *PIP,* peak inspiratory pressure; *PEFR,* peak expiratory flow rate; *LMA,* laryngeal mask airway.
*A technique designed to improve view, not prevent regurgitation.[29]

analysis of laryngeal mask airway studies, he concluded that cricoid pressure reduces successful insertion (from 94% to 67%) and also impedes tracheal intubation through the device (from 76% to 40%). Several studies have also shown that cricoid pressure impedes laryngeal mask airway ventilation, although the cricoid pressure does decrease gastric insufflation during laryngeal mask airway ventilation.[101,102]

In situations of inadequate mask ventilation, Brimacombe[95] recommends that cricoid pressure be released if laryngeal mask airway insertion fails with cricoid pressure applied. The Difficult Airway Society of Great Britain and Ireland recommends release of cricoid pressure as needed during mask ventilation and also for laryngeal mask airway insertion in cannot intubate, cannot ventilate situations.[103]

What Is the Effect of Cricoid Pressure on Laryngeal View and Tracheal Intubation?

Ten published articles have reported the effects of cricoid pressure on laryngeal view and tracheal intubation[93,104-112] (Table 4). The results of these studies are somewhat contradictory.

Turgeon et al[104] conducted a large, blinded, randomized, controlled trial in elective anesthesia cases, with daily practicing of cricoid pressure applied at 30 N, and found no appreciable effect on tracheal intubation success, laryngeal view, or time to tracheal intubation. A smaller randomized, blinded, crossover trial in 1997 showed an improvement in laryngeal view when a "modified" cricoid pressure (cricoid pressure applied in an upward and backward direction) was applied.[105] A randomized study designed to examine airway management in the lateral position also reported an improvement in laryngeal view with cricoid pressure in both the lateral and supine positions.[106]

Conversely, there have been several studies showing adverse effects on laryngoscopy and tracheal intubation. In a prospective study in 181 patients, designed to identify the location of optimal external laryngeal manipulation (bimanual laryngoscopy), pressure on the cricoid cartilage optimized the view in only 11% of patients compared with pressure on the thyroid cartilage in 88% of cases.[112] A large study of 1,530 laryngoscopies by 104 intubators on 106 cadavers compared the effects of cricoid pressure; backward, upward, rightward pressure; and bimanual laryngoscopy on laryngeal view.[107] Bimanual manipulation was significantly more effective at improving laryngeal view than cricoid pressure or backward, upward, rightward pressure, and cricoid pressure caused a deterioration of laryngeal view in 29% of cases.[107] This study involved emergency physicians and did not standardize cricoid pressure force.

A randomized study in 2003, designed to examine the effect of cricoid pressure on passing a bougie, incidentally found that cricoid pressure significantly worsened the laryngeal view,[108] and a study combining laryngoscopy, cricoid pressure force measurement, and endoscopic photography down the laryngoscope blade found that 8 of 40 patients had marked deterioration of laryngeal view.[109] Finally, 3 case reports claimed that cricoid pressure made tracheal intubation difficult or impossible, but on releasing the cricoid pressure, tracheal intubation became straightforward.[93,110,111]

WHAT OTHER COMPLICATIONS OF CRICOID PRESSURE HAVE BEEN DESCRIBED?

Ralph and Wareham[113] reported a case of ruptured esophagus in a patient who vomited with cricoid pressure applied, and Vanner and Pryle[114] observed that 3 cadavers (30%) had rupture of the esophagus during their study.

There are 3 reports of fractured cricoid cartilage, one of which led to fatal airway obstruction.[115-117] In 2 of these cases, the cricoid was thought to have been fractured by trauma at injury, but the fracture had been displaced by cricoid pressure.

Three studies have examined the effects of cricoid pressure on movement of the cervical spine, with 2 reporting "significant" movements of the spine[118,119] and a third claiming minimal movement.[120] A fourth study questioned the clinical relevance of any movements by retrospectively analyzing patients who had cervical spine injuries and were intubated at a US trauma center and finding no neurologic sequelae.[121]

The effect of cricoid pressure on the pressor response is unclear, with Saghaei and Masoodifar[90] finding a significant increase in pulse rate and blood pressure in the cricoid pressure group, whereas Mills et al[122] found the opposite result during a similar study. Differing methodology (including drugs used to induce anesthesia) makes comparison of these 2 articles difficult. There have also been case reports of severe hemorrhage into a goiter as a result of cricoid pressure[123] and a subconjunctival hemorrhage as a result of coughing in the presence of cricoid pressure.[124]

HOW SHOULD CRICOID PRESSURE BE APPLIED, AND CAN WE PERFORM IT CORRECTLY?

The optimal force and timing of the application of cricoid pressure have been debated since cricoid pressure came into common use. Sellick did not specify an exact amount of force but recommended that "firm" cricoid pressure be applied to the awake patient as the induction agent is given.[1] More recent studies advise against cricoid pressure while the patient is conscious because it is uncomfortable and may induce vomiting, aspiration, and esophageal injury.[54,99]

The initial force recommendation of 44 N came from the Wraight et al[63] study of 24 elective anesthesia cases in 1983. Vanner[125] originally recommended that 20 N of cricoid pressure be applied before loss of consciousness and the full force of 40 N be reserved for the onset of anesthesia, but Vanner and Asai[126] recently changed these recommendations to 10 N for the awake patient, increasing to 30 N once the patient is unconscious. The degree of force is an important variable with cricoid pressure because excessive force is commonly cited as contributing to difficulty with laryngoscopy, ventilation, and other complications.

Table 4. Studies showing effect of cricoid pressure on laryngeal view and tracheal intubation.

First Author	Study Group/Details	Study Type	Outcome Measures	Key Results	Comments
Levitan,[107] 2006	106 fresh cadavers, 104 intubators 1,530 sets of data, each comparing laryngeal view with no neck manipulation, BURP,* CP and BL	Randomized observational	Laryngeal view as measured by the Percentage of Laryngeal Opening score	BL improves laryngeal view as compared to BURP or CP. CP worsens laryngeal view in 29% subjects with a partially viewed larynx.	Cadaver study No blinding of laryngoscopist No measure of cricoid force
Benumof,[112] 1996	181 elective anesthesia cases; patients served as their own control	Observational	Laryngeal view as reported by Cormack and Lehane grades†	Pressure on cricoid cartilage optimized view in only 11% of cases; pressure on thyroid cartilage optimized view in 88%	Designed to identify location of optimal external laryngeal manipulation (bimanual laryngoscopy)
Vanner,[105] 1997	50 patients allocated to no CP, standard CP, or CP (applied like BURP*) CP at 30 N	Randomized, blinded, and crossover	Probability of a "best view" with different applications of CP	Probability that each group would result in the best view: No CP 6% Standard CP 11% CP (applied like BURP) 44%	No real-time assessment of CP force Subjective assessments of view BURP not CP
Turgeon,[104] 2005	700 patients 344 CP 356 mock CP CP applied at 30 N	Randomized unblinded intervention study	Completion of tracheal intubation within 30 s Laryngeal view,† time to tracheal intubation and laryngeal position	No difference for completion of tracheal intubation in 30 s Comparable views Slightly longer tracheal intubation time; more lateral laryngeal shift in CP group	Exclusion criteria extensive and poorly defined All emergency cases were excluded
McCaul,[106] 2005	70 elective surgical cases. LMA or TT inserted in left lateral position +/– CP	Randomized, blinded, controlled trial	Success of LMA versus TT in left lateral position. Laryngeal view supine/lateral +/– CP	View improved with CP in 26% of cases when supine and 30% when left lateral	Laryngeal view not primary aim CP not at all standardized; possible use of BURP instead
Noguchi,[108] 2003	60 elective surgical cases, laryngeal view assessed with and without CP at 30 N	Randomized study	Assess if gum elastic bougie eased tracheal intubation if CP was applied. View at laryngoscopy	View worsened with CP	Coincidental study finding, not primary aim CP use not randomized
Haslam,[109] 2005	40 patients for elective surgery. CP applied from 0 N to 60 N in 10-N increments	Observational	Assessment of laryngeal view from photographs and endoscopic video footage. Rima glottis also measured	More best views in 0-30 N range of CP Eight subjects had a marked deterioration obscured view with CP	Assessment subjective Findings from the best view not backed up by measuring the rima glottis
Ho,[93] 2001; Williamson,[110] 1989; Lyons,[111] 1985	3 patients	Essentially case reports		Tracheal intubation was difficult or impossible in the presence of CP yet became easy when CP was released	Case reports

BL, Bimanual laryngoscopy; *TT,* endotracheal tube.
*A technique designed to improve view, not prevent regurgitation.[29]
†Laryngeal view refers to the assessment of laryngeal view as described by Cormack and Lehane.[139]

Optimal positioning for anesthesia induction and ventilation has been significantly modified since Sellick's[1] 1961 cricoid pressure article. His original report includes a photograph showing extreme atlanto-occipital extension and the head lowered relative to the chest. Such positioning is in conflict with current practices demonstrating the benefits of head elevation on safe apnea times, improved ventilation, and facilitation of laryngoscopy.

Several surveys have examined the application of cricoid pressure, focusing on the theoretical knowledge (ie, how much force and when) and the practical application (measuring force applied, using a specially designed rig). These international studies have consistently shown that the majority of physicians, nurses, and other personnel in the operating room and the ED are unable to apply cricoid pressure correctly.[17,67,68,127-135] The range of forces applied to the testing models in these surveys was very wide (0-120 Newtons). The ability of staff to apply cricoid pressure consistently improved with immediate training,[68,127,129,130,135] but only 1 study followed up staff for 3 months, and it found an inability to retain the improved skills. In addition, the teaching of cricoid pressure to medical students with a model and verbal description of the force required gave poor results.[136]

DISCUSSION

The evidence supporting the widespread use of cricoid pressure to prevent aspiration is unconvincing by current standards of evidence-based medicine.[137,138,139] Equally, there is no robust evidence to suggest that cricoid pressure causes harm, and as such, cricoid pressure has become an established technique on the back of experience, not evidence.

It is a fact that the risk of aspiration is reducing with time,[27] but it is also important to add that anesthesia and airway management have evolved significantly since the 1960s. Induction agents, ventilation strategies, and positioning are all very different from when cricoid pressure first came into common use. There are many reasons why aspiration rates could have decreased, and the contribution of cricoid pressure to the reduction of aspiration is uncertain.

The initial supporting evidence for cricoid pressure comes from relatively small cadaver studies, and the difference between a cadaveric response to regurgitation and the response of an anesthetized human is poorly defined. The interplay between the upper esophageal sphincter, lower esophageal sphincter, and intragastric pressure is complicated. The tone of the sphincters and the degree of intragastric pressure vary significantly between cadavers, patients in cardiac arrest, emergency patients with decreased mental status or other acute conditions, and elective anesthesia cases. Recent anatomic investigations on live patients undermine the conclusions of initial cadaver studies validating the technique.

The documented beneficial effect of cricoid pressure lessening gastric distention has yet to be retested using currently recommended ventilation guidelines of lower tidal volumes, lower ventilation rates, and slower insufflation times.

The risk-benefit analysis for cricoid pressure involves the potential impairment of ventilating and intubating conditions against the prevention of possible regurgitation and aspiration. There are observational data to support the use of cricoid pressure as part of a package of care to reduce the incidence of pulmonary aspiration, but no studies have validated its efficacy in emergency care. Cricoid pressure consistently reduces tidal volume and increases peak inspiratory pressures when applied during bag-valve-mask ventilation, and even controlled, well-applied cricoid pressure can adversely effect ventilation and cause airway obstruction.

The application and results of cricoid pressure involve many variables, including the operator and patient. The effect of cricoid pressure on laryngeal view is likely to vary from patient to patient and with the individual applying it, improving the view in some and causing deterioration in others. Likewise, the effectiveness of cricoid pressure in preventing regurgitation is likely to vary on the method of application, as well as the ventilation technique and numerous patient-specific variables. Imaging studies suggest that the variable results of cricoid pressure may be due to variability in the anatomic relationships between the cricoid ring, the esophagus, and the vertebral body. Considering the mobility of the neck and laryngeal cartilages relative to the esophagus, coupled with operator variables, cricoid pressure is unlikely to provide uniformly effective esophageal compression.

The optimal method, timing, and force of cricoid pressure lack a robust evidence base. There is solid evidence that cricoid pressure is applied inconsistently in all intubating environments. Indeed, if we are not able to perform it as recommended (ie, without excessive force at the correct location) whether or not it is a useful technique becomes a secondary argument. The quantity of training and quality assurance suggested as being necessary for the proper application of cricoid pressure is unlikely to be matched in the acute clinical environment.[104]

The potential benefits of cricoid pressure in minimizing gastric distention and possibly lessening the risk of aspiration should be balanced against impaired gas exchange and ventilation. This is best performed on a case-by-case risk-benefit analysis. A patient at "high-aspiration low-desaturation risk" (for example, a previously fit patient with a stomach full of alcohol and a head injury) may be more likely to benefit from cricoid pressure than a patient at "low-aspiration high-desaturation risk" (for example, a patient with progressive hypoxia and tachypnea from pneumonia). The risks and benefits of cricoid pressure are also likely to change not only between patients but also during a prolonged and problematic tracheal intubation sequence on the same patient.

CONCLUSIONS

Cricoid pressure entered medical practice on a limited evidence base but with common sense supporting its use. Given that the risks of cricoid pressure worsening laryngeal view and reducing airway patency have been well described, we recommend that the removal of cricoid pressure be an immediate consideration if there is any difficulty either intubating or ventilating the ED patient.

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Address for reprints: Tim Harris, FCEM, Department of Emergency Medicine, Royal London Hospital, Whitechapel, London, UK E1 1BB; 44 207377000 Ext 6303, fax 44 2073777014; E-mail Tim.Harris@bartsandthelondon.nhs.uk.

Address for correspondence: Daniel Ellis, FACEM, care of: Tim Harris, FCEM, Department of Emergency Medicine, Royal London Hospital, Whitechapel, London, UK E1 1BB; 44 207377000 Ext 6303, fax 44 2073777014; E-mail danellis@doctors.org.uk.

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IMAGES IN EMERGENCY MEDICINE

(continued from p. 645)

DIAGNOSIS:

Immune thrombocytopenic purpura. This patient had a CBC count that was remarkable for a platelet count of 2,000, and a diagnosis of immune thrombocytopenic purpura was considered. Subsequent study results, including a computed tomography scan of the head, were normal.

Severity of immune thrombocytopenic purpura can range from asymptomatic thrombocytopenia to spontaneous intracranial or other significant internal bleeding. Physical manifestations of immune thrombocytopenic purpura include easy bruising (Figure 1), bleeding gums, palpable purpura (Figure 2), and petechiae (Figures 3, 4). In dark-skinned individuals, cutaneous signs of immune thrombocytopenic purpura can be easily overlooked without close and purposeful inspection of the skin. In these patients, it is important to examine the mucosal membranes, which are less pigmented, to help make a diagnosis of thrombocytopenia. In this patient, inspection of the mucosal membranes revealed significant mucosal hemorrhages (Figure 5).

Immune thrombocytopenic purpura is a diagnosis of exclusion, and a medical evaluation should exclude other causes of thrombocytopenia.[1,2] Acute treatments include prednisone 1 to 2 mg/kg and anti-D immunoglobulin for Rh-positive individuals. Platelet transfusions are indicated for emergency treatment of internal bleeding or preparation for major surgery.[1,2] Some patients require splenectomy if they fail initial interventions.

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