Review Article

Cricoid pressure

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Purpose: Although cricoid pressure (CP) is a superficially simple and appropriate mechanical method to protect the patient from regurgitation and gastric insufflation, in practice it is a complex manoeuvre which is difficult to perform optimally. The purpose of this review is to examine and evaluate studies on the application of (CP). It deals with anatomical and physiological considerations, techniques employed, safety and efficacy issues and the impact of CP on airway management with special mention of the laryngeal mask airway.

Source of material: Three medical databases (48 Hours, Medline, and Reference Manager Update) were searched for citations containing key words, subject headings and text entries on CP to October 1996.

Principle Findings: There have been no studies proving that CP is beneficial, yet there is evidence that it is often ineffective and that it may increase the risk of failed intubation and regurgitation. After evaluation of all available data, potential guidelines are suggested for optimal use of CP in routine and complex situations.

Conclusions: If CP is to remain standard practice during induction of anaesthesia, it must be shown to be safe and effective. Meanwhile, further understanding of its advantages and limitations, improved training in its use, and guidelines on optimal force and method of application should lead to better patient care.

Objectif : Bien qu'elle soit une méthode mécanique en apparence simple et appropriée exécutée pour protéger contre la régurgitation et l'insufflation gastrique, la compression du cricoïde (CC), en pratique, constitue une manoeuvre complexe et difficile à réaliser parfaitement. Cette revue vise l'analyse et l'évaluation des études publiées sur son usage. Elle porte sur les considérations anatomiques et physiologiques, les techniques utilisées, les problèmes de sécurité et d'efficacité et l'impact de la CC sur la gestion des voies aériennes avec une attention spéciale envers le masque laryngé.

Source : Trois bases de données médicales (*48 Hours*, *Medline* et *Reference Manager Update*) ont été scrutées au regard des citations contenant les mots clés, les titres des sujets et les entrées de texte concernant la CC jusqu'au mois d'octobre 1996.

Principales constatations : Aucune étude n'a prouvé les bienfaits de la CC, alors qu'il est démontré qu'elle est souvent inefficace et qu'elle peut augmenter l'incidence des intubations échouées et des régurgitations. Après une évaluation de toutes les données disponibles, des lignes de conduites sont suggérées en vue d'une pratique optimale de la CC dans les situations courantes et complexes.

Conclusions : Si la CC doit demeurer une manoeuvre standard pendant l'induction de l'anesthésie, il faut faire la preuve qu'elle est sûre et efficace. En attendant, une meilleure compréhension de ses avantages et de ses limitations, un enseignement amélioré et des données plus précises sur la pression exercée idéale et son mode d'utilisation devraient nous aider à fournir de meilleurs soins.

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CRICOID pressure (CP) has been described as the "linchpin of the rapid sequence induction"[1] and over the last 35 yr has become widely accepted as a standard of practice during anaesthesia[1] and, to a lesser extent, during resuscitation.[2] However, although it is, superficially, a simple and anatomically appropriate manoeuvre (Table I), there have been increasing concerns about its safety and efficacy.[3-5] There are fewer than 40 studies investigating its use and none confirming its clinical benefits. It is often ineffective (Table II), even when applied by experienced personnel,[6-8] is detrimental to overall patient safety[4,9] because it reduces lower oesophageal sphincter pressure (LOSP),[10] and there is anecdotal evidence that its application may be fatal.[11] The most important clinical limitation with CP is that it may interfere with airway management (tracheal intubation, face mask ventilation and laryngeal mask airway placement), and failure to manage the airway is a more frequent cause of morbidity/mortality than aspiration.[12]

Opinion is polarized on the effectiveness of CP in clinical practice. Some consider that it should remain the standard of care and that randomized controlled trials would be unethical.[5] Others see the dangers of continuing to mandate a clinically unproven technique and urge for re-evaluation[13] and some have even stated that CP may be unnecessary.[14] Justification for the continued use of CP is based, in part, on audit of maternal deaths which shows a reduction in aspiration-related mortality since its widespread introduction. However,

TABLE I Evidence supporting the use of cricoid pressure

Setting	*Reference*	*Mode of CP*	*Head position*	*Evidence*
Clinical	22,54,55	SHCP/children	Magill	SHCP prevents gastric insufflation in children
	8	CY/adults (intubated)	Magill/ tonsillectomy	40 N force increased UOSP to >38 mmHg
	5,9	Unknown	Unknown	95% at risk patients did not aspirate when CP applied
	20	SHCP/high risk adults	Unknown	reflux occurred in 3/26 when CP released after intubation
	27	SHCP/adults	Unknown	CP prevented gastric inflation.
Cadaver: human, few hours old	23	SHCP/children	Tonsillectomy	No reflux up to 100 cm H_2O. When CP released, fluid in pharynx.
	30	CY/adults	Unsupported Magill	30 N force prevented reflux up to 40 mm Hg UOSP
	52	SHCP/adults	unknown	Prevented reflux up to 50 cm H_2O UOSP
Cadaver: animal, fresh	52	SHC	unknown	Prevented reflux up to 50 cm H_2O UOSP

CP = cricoid pressure. SHCP = single handed cricoid pressure. DHCP = double handed cricoid pressure. CY = cricoid yoke. UOSP = upper oesophageal sphincter pressure

TABLE II Evidence against usefulness of cricoid pressure

Setting	*Reference*	*CP Mode*	*Head position*	*Evidence*
Clinical	6–8	Various	Various	CP is unreliably applied in the clinical setting
Physiological	1	CY	Unknown	CP reduces lower oesophageal sphincter tone and barrier pressure
	26,27,37,60	Various	Unknown	CP impedes airway patency
Clinical: audit	CEMDEW* CP used from 1964 onwards	Unknown	Unknown	Reduced deaths from aspiration – balanced byincreased deaths from failed intubation, overall death rate unchanged
	5,9	Unknown	Unknown	9/12 patients with post op CXR evidence of aspiration had CP applied on induction
	87,92	Not applicable	Not applicable	Low incidence of aspiration when CP not/rarely used
Clinical: case reports	35	?SHCP	Unknown	2 cases death from acid aspiration despite CP. Pre sodium citrate
	27	?SHCP	Unknown	1 elderly patient in study, CP allowed gastric insufflation, but caused laryngeal obstruction
	90	?DHCP	?Magill, ?Magill + head support	2 cases (1 died, CP applied prior to induction, caused hiccough and aspiration) pharynx filled with fluid despite CP.

*Confidential Enquiry into Maternal Deaths in England and Wales 1952–1987

the influence of newer pharmacological agents and increased use of regional anaesthesia is unknown. Furthermore, over the same period, there has been an equivalent increase in the number of deaths from failed airway management.[15] A recent survey of failed tracheal intubation in a teaching maternity unit reported an increase in incidence from 1:300 in 1984 to 1:250 in 1994.[16] There is a remarkable lack of information available about CP. Basic issues such as the optimum mode and force required in a given clinical situation are unproven. It is also not widely appreciated that most perioperative aspirations occur at times unrelated to anaesthesia.[17] General knowledge of anaesthetists and their assistants is also lacking – one study reported that only 52% of anaesthetists were able to describe the technique precisely.[18] There are no guidelines on the correct action to be taken when the application of CP is anatomically difficult (as in obesity, or where a neck collar is present), or potentially dangerous as in laryngeal trauma and cervical pathology.

This review sets out to examine critically the studies on CP. It deals with the anatomical considerations and the techniques employed, safety and efficacy issues and the impact of CP on airway management with special emphasis on the laryngeal mask airway. Guidelines are suggested for its use in routine and complex situations.

History

Cricoid pressure was first publicized by Monro in the 1770s as a means of preventing gastric distension during inflation of the lungs of persons "drowned and seemingly dead,"[19] and it was recognized that pressure should be applied so that laryngeal patency would remain uninterrupted. Reference to pressure on the larynx was also mentioned by Hunter[19] in 1776 as a means of preventing insufflation of the stomach during inflation of the lungs by bellows. He warned that the pressure be conducted "with judgement" so that the larynx and trachea remain patent. There was no further mention of CP until 1961 when Sellick reintroduced it as a means of preventing the consequences of vomiting or regurgitation at induction of anaesthesia.[20] In his original description he suggested that correct application of CP would prevent gastric distension during bag and mask ventilation. Ruben *et al.*, in the same year, investigated the effect of flexion and extension of the neck on the probability of gastric insufflation during bag and mask ventilation.[21] Independently, they described the benefit of "forceful pressure on the anterior surface of the neck, against the thyroid and cricoid cartilages." They reported that gastric inflation was unlikely to occur provided inflation pressures of 15–20 cm H_2O were not exceeded. Most of the early research was conducted by

Sellick[20,22] and Salem,[22-25] but workers such as Lawes[7,26-28] and Vanner[8,29,30] have made important contributions to our understanding in the last 10 yr.

Anatomy

The cricoid cartilage (CC) is shaped like a signet ring, horizontal inferiorly, with the narrow part of the ring (arch) anteriorly. Behind this it deepens progressively so that its upper margin passes deep to the thyroid cartilage and forms a vertical lamina posteriorly, between the free posterior margins of the laminae of the thyroid cartilage. The superior surface of the lamina of the cricoid is surmounted by the two arytenoid cartilages, one on each side at the inferior margin of the laryngeal orifice. Here, the mucous membrane of the posterior wall of the larynx becomes continuous with that of the anterior wall of the pharynx and extends into the oesophagus. The arch of the CC is attached anteriorly to the thyroid cartilage by the crico-thyroid ligament. Each side of the cricothyroid gap is filled by the cricothyroid muscle, and the inferior horn of the thyroid cartilage descends to articulate with the lateral surface of the cricoid cartilage. Inferiorly, the cricoid is attached to the first tracheal ring by the cricotracheal ligament. The oesophagus begins at the lower border of the CC, the opening of which is guarded by the cricopharyngeus muscle. The adult and the paediatric CC differ only in size, the backward inclination of the plate-like posterior lamina at the superior aspect and a higher position.

There have been no radiological studies assessing the effect of CP on neck anatomy. Contrast CT scanning of one patient showed that when CP was applied, the two convex structures of the CC and cervical vertebral body were pressed together, but only part of the oesophageal lumen could be obliterated.[29] There was also slight lateral movement of the CC which allowed the rest of the lumen to be pressed against the longus colli muscle on that side of the vertebral body. A nasogastric tube was present and was squeezed sideways to occupy the part of the lumen that was not so effectively compressed.

Cricoid pressure is a force and is generally measured in Newtons (9.81 N = 1 kg = 2.2 lb).

Mode of application

Head and neck position

Sellick suggested positioning the patient without a pillow "as in the position for tonsillectomy" with cricoid force applied over the C5 vertebra.[20] The intention was to increase the concavity of the cervical spine, to stretch the oesophagus and to prevent lateral displacement of the oesophagus. However, the "tonsillar position" often worsens the view at laryngoscopy[31] and there is no difference in the efficacy of CP >15N with/without a pillow.[8] The ideal intubating position with a pillow beneath the occiput, as originally described by Magill, has been recommended for tracheal intubation with CP applied.[32] The upper oesophagus is then compressed against the C6 vertebra. However, flexion of the neck at the atlanto-occipital joint caused by CP must be avoided as this may make intubation more difficult.[33]

Timing of application

Reduction in upper oesophageal sphincter pressure (UOSP) commences before loss of consciousness,[34] therefore Sellick suggested that CP should be applied to the awake patient simultaneously with the injection of the induction agent.[20] However, this causes pain, and may also trigger vomiting and coughing. Using a cricoid yoke, CP could not be applied in awake volunteers without considerable pain or coughing.[26] Vomiting with CP applied has resulted in death from aspiration[35] and ruptured oesophagus.[11] Sellick subsequently suggested that unconsciousness, muscle relaxation and CP should occur synchronously to prevent oesophageal rupture.[36] However, when increments of cricoid force were applied to 22 conscious volunteers, difficulty in breathing, particularly in inspiration, occurred in half of the subjects who tolerated 40 N of cricoid force. Two subjects experienced complete airway obstruction. Most subjects could tolerate 20 N of CP applied for 20 sec.[37] Based on this and evidence from cadaver studies that 20 N will not rupture the oesophagus during retching,[30] Vanner has suggested that a pressure of 20 N should be applied until loss of consciousness at which point the pressure should be increased to 30 N.[15]

Single handed cricoid pressure

Single handed cricoid pressure (SHCP) involves placing the thumb and middle finger on either side of the cricoid cartilage and the index finger above, thereby preventing lateral movement of the cricoid.[20] The normal intubating position is commonly adhered to. In a blinded crossover study in 120 patients, the laryngoscopic view was better with SHCP and with the head in the Magill position than with double handed cricoid pressure.[38]

Cricoid pressure application with the left hand from the left side may avoid interference with laryngoscope insertion.[39] However, this places both assistant and anaesthetist in an unfamiliar environment. A further method is to place the palm of the hand on the sternum and apply pressure to the CC using only the

index and middle finger.[40] This technique aims to improve the laryngoscopic view by reducing the risk of excessive CP causing distortion of the larynx, avoids collision with the laryngoscope blade and facilitates the displacement of large breasts. In children, SHCP may be performed with the middle or little finger of the hand holding the mask while the neck is kept extended.[22]

Double handed cricoid pressure (bimanual)

Double handed cricoid pressure (DHCP) comprises counterpressure with a hand beneath the cervical vertebra to support the neck.[41] It is usually performed without a pillow and with one hand under the hyperextended neck and the other applying CP. The aim is to support the hyperextended arch of the vertebral column so that when CP is applied both the laryngoscopic view and the effectiveness of CP are maintained. The use of the tonsillar position means that the three axes (oral, pharyngeal and laryngeal) are not aligned for optimal laryngoscopic view.[32] Variations of DHCP are to place the left hand behind the patient's head[42] or to hold the extended head[43] to maintain the Magill intubating position. Crawford described the use of a 'contra-cricoid' cuboid aid (a firm pillow 27 cm × 10 cm × 5 cm) to facilitate stable extension of the neck.[44] Double handed CP may be more suitable than SHCP if there is cervical spine pathology since it will allow support for the cervical spine architecture.[45] However, Crowley[41] urges caution as the head must be moved on the neck to perform the manoeuvre correctly.

Cricoid yoke

A yoke was first described by Lawes *et al.* to decrease the incidence of improperly applied CP.[26] This consisted of a pair of stainless-steel wings with intrinsic elasticity. The device was applied to the CC via a moulded sponge cushion, and gently depressed against the patient. When the designated force had been applied, a circuit on a perspex platform was activated by means of a contact breaker causing a light to come on. The advantages of the yoke are that it removes hands from the laryngoscope field, maintains a constant pressure that may be adjusted pre-application and is easily learned. The yoke enabled individuals with no previous experience in the application of CP to achieve similar results to those obtained by experienced anaesthetic staff. Consistency of applied cricoid force was improved in all.[7] However, in 57 obstetric patients, adequate or good intubating conditions were only obtained in 93% at 44 N using the yoke *vs* 100% in the SHCP group.[26] Lateral displacement and sagittal laryngeal compression were the most common forms of distortion. Reducing applied pressure overcame the distortion. Patients in whom distortion was least were those with a short fat neck and large breasts, who are often associated with difficulty in manually locating the CC.

The pressor response to tracheal intubation in 40 patients following a rapid sequence induction was the same with or without CP via a yoke.[46]

Regurgitation

Physiology

Gastric pressures are normally <7 mmHg and lower oesophageal sphincter pressure (LOSP) is 15–25 mmHg higher. During spontaneous gastro-oesophageal reflux or vomiting, intragastric pressure (IGP) equals oesophageal pressure (OP) with the creation of a common cavity.[47] Maximum IGP in the starved human in the supine position is 25 mmHg and increases to 35 mmHg when distended.[48] Succinylcholine fasciculations increase IGP by a further 40 mmHg.[49] Vomiting may lead to IGP >45 mmHg.[50] The aim of CP is to enhance the 'second line of defence' or upper oesophageal sphincter pressure (UOSP) and thus withstand the additional pressure. Resting LOSP in awake patients is approximately 38 mmHg.[51] General anaesthesia reduces LOSP to 7–14 mmHg, depending upon the degree of muscle relaxation.[8]

The application of CP exposes patients to regurgitation. Tournadre *et al.* investigated the effects of CP on LOSP in eight awake volunteers with 40 N CP in the supine position.[10] The CP resulted in a large decrease in LOSP and barrier pressure while IGP remained unchanged.

Cricoid force

The cricoid force required to prevent regurgitation depends on the OP and the efficacy with which the force is transmitted to the oesophageal lumen. Vanner and Pryle calculated that a 30 N force applied to the CC should provide a pressure of >200 mmHg below the 10 cm^2 area of the lamina of the average adult cartilage. In practice, however, 30 N provides UOSP of only 40 mmHg.[29]

Salem *et al.* distended the oesophagus' of cadavers with saline to 75 mmHg and found that 'firm' CP prevented regurgitation.[23] Fanning found that the pressures varied from 27–70 mmHg before leak occurred.[52] In infant[23] and adult[24] cadavers with and without nasogastric tubes, CP was effective to OPs of 75 mmHg. Cricoid force was not measured in these studies.

The efficacy of CP has been assessed in two studies of anaesthetised patients whilst applying known levels

of cricoid force. In 24 adult patients at risk of regurgitation, 44 N cricoid force were required to prevent regurgitation in most in the tonsillectomy position, but there was a wide scatter and only 16 were paralysed.[43] In 24 paralysed intubated patients in both standard and tonsillectomy positions, a cricoid force of 40 N increased OP to > 38 mmHg.[8]

Based on these studies, 44 N has become widely accepted as the 'gold standard' for the prevention of regurgitation. However, information from a cadaver study showing that 30 N prevented regurgitation from an OP of 42 mmHg, and the anatomical studies above, have suggest that 30 N is adequate and this should reduce the risk of oesophageal rupture.[8,30]

Gastric insufflation

During face mask ventilation (FMV), gas may be forced into the stomach leading to gastric insufflation. This increases the potential for regurgitation, reduces the efficacy of ventilation, and predisposes to visceral rupture and decrease in cardiac output.

In the absence of CP, the lungs of 20 paralysed patients could be ventilated 'gently' with peak inspiratory pressures (PIP) of 16.5 cmH_2O without gastric insufflation.[27] With PIPs of 31.2 cmH_2O there was a 50% incidence of gastric insufflation which was prevented when CP was applied even to a PIP of 60 cmH_2O. In two patients, CP occluded the laryngeal inlet as well as the oesophagus. In a third, obstruction of the larynx occurred and gas also entered the stomach.[53] Studies in children have confirmed that CP prevents gastric insufflation without interfering with ventilation to PIPs of 25–40 cmH_2O.[22,54,55] Once the oesophagus has been opened by high inflation pressures, subsequent gastric insufflation pressures are lowered.[56] Provided PIP never exceeds 35 cmH_2O, resuscitation using a bag and mask should not lead to gastric insufflation.[56] Cricoid pressure applied during FMV prior to laparoscopic cholecystectomy prevents gastric insufflation.[57]

Nasogastric tube

Sellick suggested that the presence of a nasogastric (NG) tube increased risk of regurgitation by tripping both the upper and lower oesophageal sphincters and also by interfering with oesophageal compression during the application of CP.[20] However, experimentally, the reverse appears to be true. Using a 4 mm diameter manometry catheter, reflux only occurred during spontaneous ventilation when LOSP decreased to equal IGP.[47] Gastro-oesophageal scintiscanning[58] and dye studies[59] have shown that reflux past the LOS is the same with or without an NG tube. The efficacy of CP may even be increased by the presence of an oesophageal tube occupying the proportion of the oesophageal lumen not obliterated by CP.[29,30]

Plastic NG tubes remain patent during applied CP[23] but latex tubes are easily occluded. A plastic NG tube should be left open to atmospheric pressure to vent liquid or gas and, therefore, limit increases in gastric pressure during induction.[24]

Impact on airway management

The most limiting feature of CP is that it causes anatomical distortion of the upper airway making airway management more difficult. Problems arise due to interference with laryngoscope blade placement, pharyngeal compression, distortion/malalignment of the larynx/trachea, and activation of upper airway reflexes. Furthermore, external laryngeal pressure to improve the view of the larynx may not be performed concurrently with CP.

When increments of cricoid force were applied to 22 conscious volunteers, difficulty in breathing, particularly on inspiration, occurred in half of the subjects.[37] Two experienced complete airway obstruction at 45 N. Application of manual CP caused airway obstruction in 3/20 patients undergoing FMV.[27] Cricoid pressure caused a considerable decrease in mean expired tidal volume and an increase in PIP in 50 patients with complete airway occlusion occurring in 11%.[60] Laryngoscopy makes little difference to the efficacy of CP.[8]

There are minimal data quantifying the additional risk of CP in terms of failed airway management. In obstetrics, failed intubation is reported at 1:300[61] to 1:500[62] cases, but the number related to CP is unknown. In 18,500 patients, intubation difficulty was found in 1.8%, whereas emergency cases were associated with an incidence of 8.6%, with the influence of CP unknown.[63] From 2000 critical incident reports, 2/80 failed intubations were related to 'inexpert' CP distorting the view of the larynx.[64] A survey of 5802 Caesarean sections (LSCS) performed under general anaesthesia gave an increasing incidence of failed intubation despite a policy allowing partial release of CP and shift to the right for Cormack and Lehane Grade 4 views.[16] However, most of the failed intubations were reported as a Grade 3 view.

Complete airway obstruction may result from the application of CP. One patient with undiagnosed laryngeal injury required emergency surgical airway intervention following CP.[65] In another case, a hypertrophied lingual thyroid occluded the glottic opening when CP was applied. Obstruction may have been related to the mass causing epiglottic downfolding over the laryngeal inlet and combined with tilting forward of the larynx with applied CP,[66] or to posterior displacement of the tumour, epiglottis, and larynx.[67]

Cricoid pressure and the Laryngeal Mask Airway

The laryngeal mask airway (LMA) has a role both as a ventilatory device and as an airway intubator following failed tracheal intubation in the patient at risk of aspiration.[68] When placed correctly the tip of the mask should sit in the hypopharynx at a variable depth behind the cricoid cartilage. By obliterating the oesophageal lumen and compressing neck structures, CP may impede insertion of the LMA. Once the LMA is in situ, CP may impair maintenance of a clear airway and tracheal intubation through the LMA.

LMA insertion

Two studies showed that the LMA can usually be inserted when SHCP is applied (Table III).[69,70] However, studies using a yoke gave success rates of only 3/22 patients.[71] Gabbott and Sasada demonstrated that placement was successful in 70% within two 10 sec attempts using CP with manual in-line neck stabilisation (MIT).[72] It is possible that the differing findings are related to:

1. The mode of application of CP: the yoke or DHCP appears to make LMA insertion more difficult than SHCP.[73] This may be related to incomplete compression of the retro laryngeal tissues by SHCP.
2. Head and neck extension may make insertion more difficult.[74]
3. The degree of force applied to the CC compared with that used to place the LMA.
4. Inexperience or poor technique in LMA insertion.
5. Failure to deflate mask tip smoothly before insertion.

TABLE III Ease of placement of the LMA with applied cricoid pressure in vivo

	CP	*Control (no CP)*	*Cricoid mode*
Heath and Allagain[97]	50/50	S	
Brimacombe[69]	34/40	37/4	S
Ansermino and Blogg[98]	3/2	19/2	C
Brimacombe *et al.*[70]	45/50*	49/5	SH
Asai *et al.*[77]	10/20	19/2	DH
Asai *et al.*[71]	3/2	22/2	C
Gabbott and Sasada[72]	14/40 (29/40)**	33/4	SH + MIT
Total	159/242 (67%)	179/194 (94%)	

SH = single handed, DH = double handed, CY = cricoid yoke, SH + MIT = single handed plus manual-in-line traction

* Simulated failed intubation

** Improved at second attempt

Efficacy of cricoid pressure

The presence of the LMA does not compromise CP.[75,76] In 50 patients, the incidence of gastric insufflation was reduced at PIP of 30 cmH_20 when CP was applied at 30 N with the LMA in situ.[76] This study also showed that a correctly placed LMA is not dislodged by CP, but that it may impede ventilation, particularly if the neck is unsupported.

Effect of CP on intubation via the LMA

Application of CP produces deterioration in the fibreoptic view through the LMA aperture bars which ranges from slight[69,70] to gross[71,72,77] distortion. This may be related to anterior tipping of the laryngeal inlet when CP is applied.[69] During blind placement of a gum elastic bougie with applied CP and MIT,[78] the bougie entered the trachea in 22.5%, the oesophagus in 52.5% and either the vallecula, hypopharynx or arytenoid cartilages in the remainder. These results were similar to those obtained without CP and MIT. It is possible that by tilting the CC cranially during the application of CP, this effect may be partially counteracted.[79] Difficulty may also rarely be related to CP causing mechanical closure of the cords.[80] The distorted view of the cords lowers significantly the success rate for fibreoptic intubation through the LMA,[81] particularly if CP has also impeded its insertion, causing it to lie at an inadequate depth in the hypopharynx.

Cardiopulmonary resuscitation

Patients requiring cardiopulmonary resuscitation (CPR) are commonly at risk of aspiration and gastric distension during vigorous FMV and may benefit from the use of CP.[82] Aspiration of gastric contents *per se* is known to have an important negative impact on an individual's chance of survival from cardio-respiratory arrest.[28] It has been suggested that CP should be taught to all rescue personnel to minimise the risk of aspiration and/or gastric insufflation.[3,83] However, intubation difficulty and lack of availability of a third person may limit the usefulness of CP.

Rare Complications

Cricoid pressure may predispose to oesophageal rupture if high OP develops during application. One death occurred in an elderly patient associated with CP and concurrent haematemesis.[11] Sellick suggested that oesophageal rupture would not occur if unconsciousness, muscle relaxation and CP occurred synchronously.[36] Vanner and Pryle investigated the relationship between CP, OP and rupture in 10 cadavers with or without an NG tube.[30] Rupture of the oesophagus occurred in two at oesophageal pressures

of 40 mmHg and one at 30 mmHg. Vomiting is an active reflex and, as CP cannot be tolerated at pressures >20 N, this may be one reason why oesophageal rupture is of such low incidence.[84] It has been suggested that the presence of an NG tube may weaken the oesophagus and predispose it to rupture.[11]

Current Practice and Outcome

Studies have shown that only 50% of anaesthetists and paramedics apply a force >38–46 N during CP.[6–8] A survey of clinical practice reported that only 78% of anaesthetists used CP, and some used less force in women than in men. Of those surveyed, 10% had witnessed regurgitation with CP applied and >50% with inadvertent release of CP.[6] A survey of paediatric practice revealed that only 50% of anaesthetists applied CP when anaesthetising infants for pyloromyotomy depending on the extent and timing of training and whether induction was intravenous or inhalational.[85] A survey of obstetric anaesthesia practice in British Colombia showed a failure to follow CP as safe practice in many community hospitals.[86]

There is no proof that the introduction of CP into clinical practice has improved patient outcome. A prospective study of clinical outcome noted that 9/12 patients thought to be at risk of aspiration experienced pulmonary infiltrates despite the use of CP during intubation.[4,5,9] A survey from France, where CP is rarely used, showed a lower rate for aspiration than did other large surveys.[87] Two cases of fatal aspiration syndrome occurred despite antacids and CP.[35] There were 13 aspiration related deaths in the 1972–75 maternal mortality report.[88] In seven, CP was not applied and in five it was applied incorrectly.[89] One report documented a patient in whom CP prior to induction led to hiccough with subsequent aspiration and death, a second patient who had a pharynx full of fluid with CP applied correctly, and, a third in whom the view of the vocal cords was obscured.[90]

Recommendations

The following are based on evaluation of data currently available on necessary cricoid force, action to be taken when an NG tube is in place, LMA placement in the presence of CP, and situations where care should be taken and CP reduced, or released, if a potentially detrimental effect on the patient is suspected.

Rapid sequence induction

If an NG tube is present before induction of anaesthesia, the stomach should be emptied, the nasogastric tube withdrawn to mid-oesophagus (30 cm from the nares in adults) and the oesophagus also emptied. The tube should be left open to atmosphere to limit any rise in OP during induction of anaesthesia.[30]

After pre-oxygenation, CP with a force of approximately 20 N (see Training)[91] should be applied to the awake patient with the head and neck in the optimal intubating position. Retching is unlikely but, if it does occur, CP should be maintained as oesophageal rupture is unlikely at this force. With loss of consciousness the force should be increased to 30 N and continued until tracheal intubation and cuff inflation are complete. Cricoid forces of 40 N or over should not be used as compression of the airway and difficulty with tracheal intubation can occur. The force may be increased to 40 N if regurgitation occurs, but should be reduced to 20 N if vomiting occurs. If a Grade 3 or 4 laryngoscopic view is seen, CP should be eased to 20 N for a few seconds under direct vision and with suction ready for a repeat attempt at intubation. If airway management is still unsuccessful, CP should be released altogether. Similarly, if face mask or LMA ventilation is difficult, an improved airway may be obtained with a trial relaxation of CP. In this situation, care should be taken to maintain PIP <20 cmH_2O to reduce the risk of gastric insufflation. It is not necessary to maintain CP until the patient is in the lateral position in the event of airway management failure.

Laryngeal mask airway

If a yoke or DHCP is used, the safest method is to release CP transiently during LMA insertion. If SHCP and, probably, also SHCP with MIT is used, insertion should be first attempted with CP applied if the oxygen saturation (SpO_2) is adequate (>95%). If failure of placement occurs, CP should be transiently and partially released for the second attempt. It is essential, before each attempt, to deflate the mask tip to form a smooth, thin leading edge so that the tip will enter the space behind the CC for correct insertion.

If SpO_2 is low (<95%), the initial insertion should be attempted with CP transiently released as oxygenation is a priority compared to the risk of aspiration. There were no aspirations in 224 patients undergoing elective and emergency LSCS with the LMA and no CP.[92] Vanner has suggested that CP be released under direct vision and the LMA inserted with the laryngoscope to save time if the SpO_2 was low or if the first blind insertion attempt fails.[93] Placement of the LMA was readily achieved following insertion of an oesophageal tube.[94] This suggests that the LMA may be used to provide rapid and effective oxygenation if the tracheal tube is unintentionally placed in the oesophagus. Drainage of regurgitated material may

also be facilitated by passage of a tracheal tube into the upper oesophagus following LMA placement.

If the LMA has been successfully inserted without CP, the person hand ventilating the lungs can also apply CP. If application of CP impedes ventilation the pressure should be released.[76] Alternatively, application of anterior neck pressure once the LMA has been inserted in increasing leak pressure may reduce risk of gastric insufflation during manual ventilation.

Difficult situations

There are some situations where care should be taken with CP even if the patient is at risk of aspiration (Table IV), particularly laryngeal trauma and active vomiting. It is not known whether DHCP, which possibly supports the cervical spine and so may reduce likelihood of damage to the cord, is safer than SHCP (with cervical collar or MIT) which may provide better laryngeal views.[45] In some situations access to the CC may be difficult or impossible due to neck pathology or morphology. When the CC is difficult to palpate, a yoke may be useful. A series of 73 patients with cervical spine injuries in whom oral tracheal intubation followed rapid sequence induction with SHCP, and whose necks were support with a collar and manual in line traction (MIT), suffered no neurological sequelae.[95]

TABLE IV Categories of patients at risk from inappropriately applied CP

Patient group at risk	*Reason*
The elderly	Risk of oesophageal rupture, co-occlusion of oesophagus and larynx or laryngeal obstruction without occlusion of the oesophagus.[27]
Children	Greater incidence of mechanical airway obstruction with CP.[55]
Pregnancy	Develop the highest IGPs thereby requiring more effective upper oesophageal counterpressure – at the same time are the most at risk of difficult intubation.
Laryngeal or cervical spine trauma, patients on high dose steroids	Fractured larynx[99] or spinal cord injury,[11] may require emergency surgical intervention following application of CP.[65]
Patients with predicted difficult airways	Airway management may be made impossible by the inexpert application of CP.
Inability to palpate the CC	Inadequate CP, may press on other part of larynx, worsen laryngoscopic view.
Sharp foreign body present in post-cricoid region or proximal trachea[100]	Theoretical – sharp foreign bodies placed in the post-cricoid region of cadavers caused no visible damage to the naked eye following application of CP 101.

CP = cricoid pressure. SHCP = single handed cricoid pressure. DHCP = double handed cricoid pressure. CY = cricoid yoke. UOSP = upper oesophageal sphincter pressure

Training

The application of CP is operator dependent and training is important for optimal use. Training should include use of a mannikin and anaesthetised humans. Modified 'teaching heads' improved performance from 38% to 94% success[96] and improved efficacy of application of 20 N and 30–40 N CP.[91] Operating room weighing scales may also be used to improve the accuracy of applied force. Once initial training is complete frequent practice on mannikins and weighing scales will allow the quality of the applied CP for to remain constant. The force required to produce pain over the bridge of the nose provides approximately 40 N.[7]

Conclusions

Current knowledge of CP is limited and further studies are required to prove its safety and effectiveness. However, current data indicate that the optimal method in terms of safety of providing CP, in most situations, is SHCP and firm neck support from a non collapsible intubating pillow to maintain the head in the ideal intubating position. The yoke may be more suitable for inexperienced personnel and in obese patients. There should be provision within the failed intubation drill for graded relaxation of applied pressure and re-assessment of the airway. Finally, there should be regular and ongoing training of CP skills using modified intubation trainers or weighing scales so that expert assistance can be relied on at any rapid sequence induction.

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