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Cricoid pressure impedes positioning and ventilation through the laryngeal mask airway

Purpose: *To assess the effect of cricoid pressure on the positioning of and ventilation through the laryngeal mask airway (LMA).*

Methods: *In a double-blind, randomized design, the LMA was inserted with (CP[+] group, n = 20) or without double-handed cricoid pressure (CP[−] group, n = 20). Ventilation through the LMA was assessed by measuring expiratory tidal volume and judged as adequate when a mean expiratory tidal volume of* ≥ 10 *ml·kg*$^{-1}$ *could be obtained. The LMA position was examined by fibreoscopy. The position of the mask relative to the cricoid cartilage and the cervical spine was radiologically examined (n = 10 in each group).*

Results: *Ventilation was adequate in all patients in the CP[−] group but in only five patients (25%) of the CP[+] group (P < 0.001). The glottis was visible fibreoptically below the mask aperture in all patients in the CP[−] group, but in only three patients in the CP[+] group (P < 0.001). Fibreoscopy showed that the mask was not inserted far enough in the remaining 17 patients of the CP[+] group. The reason for unsuccessful ventilation in the CP[+] group was excessive gas leakage (n = 2) and/or partial or complete airway obstruction (n = 13), which was noted fibreoptically. The radiographs showed that the tip of the mask in the CP[−] group was located below the level of the cricoid cartilage (*C_6 *or* C_7 *vertebra). The mask tip in the CP[+] group was above this level (*C_4 *or* C_5 *vertebra) (P < 0.01).*

Conclusion: *Cricoid pressure impedes positioning of and ventilation through the LMA.*

Objectif: *Vérifier l'influence de la pression cricoïdienne sur la ventilation au masque laryngé (ML) et son positionnement.*

Méthodes: *Au cours de cette étude aléatoire et en double aveugle, le LM a été inséré avec (groupe CP[+], n = 20) ou sans pression cricoïdienne manuelle (groupe CP[−], n = 20). La ventilation par masque laryngée était évaluée par la mesure du volume courant expiré et jugée suffisante lorsqu'on obtenait un volume minute expiré* ≥ 10 *ml·kg*$^{-1}$*. La position du ML était vérifiée par fibroscopie. Chez dix patients de chaque groupe, l'examen radiologique a déterminé la position du ML relativement au cartilage cricoïde et à la colonne cervicale.*

Résultats: *La ventilation a été adéquate chez tous les patients du groupe CP[−] mais chez seulement cinq (25%) du groupe CP[+] (P < 0,001). La glotte était visible par fibroscopie sous l'ouverture du masque chez tous les patients du groupe CP[−], mais chez seulement trois du groupe CP[+]. La fibroscopie a montré que le masque n'était pas inséré assez profondément chez les 17 autres patients du groupe CP[+]. Cet échec ventilatoire dans le groupe CP[+] était causé par une fuite de gaz exagérée (n = 2) ou/et par l'obstruction des voies aériennes partielle ou complète (n = 13), vérifiée par fibroscopie. Les radiographies ont révélé que la pointe du masque dans le groupe CP[−] était située sous le niveau du cartilage cricoïde (*C_6 *ou* C_7*). Dans le groupe CP[+], la pointe du masque était située à un niveau plus élevé (*C_4 *ou* C_5*, P < 0,01).*

Conclusion: *La pression cricoïdienne nuit et à la ventilation au masque laryngé et a son positionnement.*

Key words
AIRWAY: laryngeal mask;
ANAESTHETIC TECHNIQUE: cricoid pressure;
EQUIPMENT: airway, laryngeal mask.

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The laryngeal mask airway (LMA) has been used as a routine airway for general anaesthesia[1,2] and as an aid in difficult airway management.[3] Although use of the LMA is generally contraindicated in patients at risk of aspiration,[4,5] there are reports of successful management of these patients using the LMA with application of cricoid pressure, when tracheal intubation and/or mask ventilation has failed.[6,7] However, it is controversial whether cricoid pressure affects the proper positioning of and ventilation through the LMA. Cricoid pressure without support of the patient's neck (single-handed cricoid pressure) did not affect successful insertion of the LMA,[8,9] while that with support of the neck by a hand (double-handed cricoid pressure) prevented successful placement of the LMA.[10,11] The main reason for this discrepancy was thought to be the difference in the method of cricoid pressure,[11] but in a recent study even the single-handed method impeded placement of the LMA.[12] This controversy compromises the role of the LMA in patients with a full stomach, in whom tracheal intubation and pulmonary ventilation are not possible.[13,14]

Fibreoscopy has been used in these studies to examine the position of the LMA,[9,11,12] but fibreoscopy through the LMA alone cannot reliably confirm its position.[15] Radiography is useful for the assessment of the LMA position relative to the larynx,[16] but there are no such reports describing LMA position during cricoid pressure. Thus, the first aim of this study was to examine the influence of cricoid pressure on the position of the LMA using lateral neck radiography and fibreoscopy.

Previous studies have reported that ventilation through the LMA was adequate when the chest expanded with satisfactory compliance,[9,11,12] but this definition is unclear. Therefore, we also measured expiratory tidal volume through the LMA during cricoid pressure to assess the adequacy of ventilation. Our study differs from previous investigations because the position of the LMA was determined precisely using radiography and fibreoscopy, and because ventilation was assessed quantitatively.

Methods

Institutional ethics committee approval and informed consent from each patient were obtained. We studied 40 adult patients with ASA physical status 1–2, undergoing general anaesthesia for elective surgery on the extremities. Patients with pharyngeal pathology, low lung compliance, increased airway resistance or morbid obesity, and those at risk of aspiration were excluded. Patients with Mallampati class III[17] or IV,[18] limited atlantooccipital extension or a short thyromental distance were also excluded.

All patients received 0.25 mg triazolam *po* two hours before induction of anaesthesia. In the operating room, patients were monitored with ECG, indirect blood pressure, pulse oximetry and a capnogram. A firm pad (8 cm in height) was placed under the patients' occiput. After preoxygenation for a few minutes, anaesthesia was induced with 3–5 $mg \cdot kg^{-1}$ thiopentone and 1–2 $\mu g \cdot kg^{-1}$ fentanyl *iv*. Neuromuscular blockade was produced with 0.1 $mg \cdot kg^{-1}$ vecuronium. The patient's lungs were ventilated with isoflurane 1–2% in oxygen via a face mask for five minutes.

Forty patients were randomized sequentially to one of two groups. In 20 patients, the LMA was inserted with application of cricoid pressure (CP[+] group), and in the other 20 patients, the LMA was inserted without cricoid pressure (CP[−] group). The size of LMA was selected according to the manufacturer's instruction.[19] We selected a #4 mask for men and either a #3 or #4 for women according to weight. After paralysis was confirmed using a nerve stimulator, cricoid pressure was applied firmly by an experienced anaesthetist with the patient's neck supported (double-handed method[20]) in the CP[+] group. No pressure was applied in the CP[−] group, but the anaesthetist's hands were placed on the patient's neck without force. The patient's neck was covered with a drape to blind the presence or absence of cricoid pressure. In both groups, the LMA was inserted using the method described in the manufacturer's manual[19] combined with the jaw-thrust manoeuvre (triple airway manoeuvre), because this manoeuvre facilitates optimal positioning of the LMA, compared with the standard method alone.[21] Briefly, after the patient's neck was flexed and the head extended (sniffing position), the LMA, adequately deflated and lubricated, was applied firmly against the hard palate and advanced into the hypopharynx with the index finger until resistance was felt. When advancing the LMA into the hypopharynx, the jaw-thrust manoeuvre was added by an another assistant. Cricoid pressure or no pressure was maintained until the completion of all examinations. The cuffs of a #3 or #4 LMA were filled with 20 or 30 ml of air, respectively.

In all patients, the lungs were ventilated manually through the LMA. Expiratory tidal volumes at a peak airway pressure of 2 kPa were measured over 10 breaths using a Wright respirometer. Ventilation was judged to be adequate when mean expiratory tidal volume of ≥ 10 $ml \cdot kg^{-1}$ could be obtained.

After assessment of ventilation, the position of the mask was examined in all patients using a fibreoptic bronchoscope, which was passed through the shaft of the LMA and placed at the mask aperture bars. The view of the larynx was scored as follows: (1) the glottis was completely visible below the aperture of the mask; (2) the glottis was visible below the mask aperture, but slightly obscured by the tip of the epiglottis; (3) the glottis could not be seen below the mask aperture and the epiglottis and/or the tongue was visible. When the glottis could not be seen through the mask aperture (3), the position of the mask was judged to be more proximal, and the fibrescope was advanced below the epiglottis to examine whether the glottis was open or obstructed.

In the first 10 patients of each group, a lateral neck radiograph was obtained after insertion of the LMA, using a mobile *x*-ray apparatus (Toshiba, Tokyo) at 62–65 kV and 12–15 mAs, depending on the patient's build, and with 100 cm focal film distance. Radiography was prepared during mask ventilation, before insertion of the LMA, and taken quickly after fibreoptic examination.

Only one attempt at insertion of the LMA was allowed. If ventilation through the LMA was not adequate or the glottis could not be seen through the aperture of the mask, the patient's trachea was intubated. If arterial haemoglobin oxygen saturation (SpO_2) decreased to <95%, the procedure was abandoned, appropriate treatment given and the patient was excluded from the study.

Data and statistical analysis

The success rate of adequate ventilation and the fibreoptic view of the glottis were compared between the groups with the Chi-square test. The position of the tip of the mask was radiologically examined in relation to the cricoid cartilage and the cervical spine, and compared between the two groups using the Fisher's exact test or Mann-Whitney U test, respectively. $P < 0.05$ was considered as significant.

Results

Patient's age, height, weight and sex distribution were similar in the two groups (Table I). Patient characteristics were also similar in the two groups which underwent the radiological studies. During the procedure, no patient experienced haemoglobin oxygen desaturation ($SpO_2 < 95\%$) or hypercapnea ($P_{ET}CO_2 > 50$ mmHg).

Assessment of ventilation

Ventilation was judged to be adequate in all patients in the CP[−] group and in five patients (25%) of the CP[+] group (Figure 1) ($P < 0.001$). In seven patients of the CP(+) group, mean expiratory tidal volume ranged from 1.5 $ml \cdot kg^{-1}$ to 6.7 $ml \cdot kg^{-1}$, and ventilation was judged to be inadequate. In two of these patients, the reason for inadequate ventilation was excessive gas leakage since the leak occurred at airway pressure of 0.5–0.7 kPa. In the remaining eight patients of the CP(+) group, the lungs could not be ventilated at 2 kPa airway pressure.

TABLE I Demographic characteristics

	CP [−] group	*CP [+] group*
n	20	20
Age (yr)	50.3 ± 19.3	56.6 ± 17.9
Height (cm)	160.1 ± 11.7	158.4 ± 11.1
Weight (kg)	57.1 ± 9.5	55.4 ± 11.8
Sex (M/F)	11/9	12/8
Radiological study		
n	10	10
Age (yr)	45.1 ± 18.7	49.9 ± 17.7
Height (cm)	161.6 ± 13.7	160.8 ± 10.7
Weight (kg)	57.7 ± 9.7	60.4 ± 10.1
Sex (M/F)	6/4	6/4

Mean ± SD.

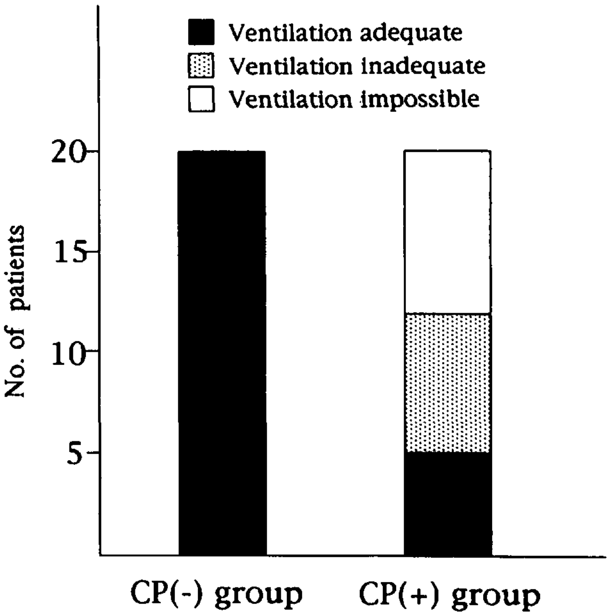

FIGURE 1 Success rate of adequate ventilation through the LMA. Ventilation was judged to be adequate in all patients in the CP[−] group and in five patients of the CP[+] group since mean expiratory tidal volume of ≥10 $ml \cdot kg^{-1}$ could be obtained through the LMA at a peak airway pressure of 2 kPa ($P < 0.001$). In seven patients of the CP(+) group, expiratory tidal volume ranged from 1.5 $ml \cdot kg^{-1}$ to 6.7 $ml \cdot kg^{-1}$, and ventilation was judged to be inadequate. In eight patients of the CP(+) group, the lungs could not be ventilated.

Fibreoptic findings

The glottis was seen just below the mask aperture (Score 1 or 2) in all patients in the CP[−] group, but in only three in the CP[+] group ($P < 0.001$, Table II). In the remaining 17 patients of the CP[+] group the mask was judged not to be positioned deeply enough, since the glottis was not visible through the grille of the mask, and the epiglottis and/or the tongue could be seen (Score

TABLE II Fibreoptic view of larynx through LMA

	CP [−] group	CP [+] group		
	Adequate	Adequate	Inadequate	Impossible
Ventilation	20	5	7	8
Score 1	13			
Score 2	7	2	1*	
Score 3				
– Glottis open		3	1*	
– Glottis partially obstructed by arytenoids			5	
– Glottis completely obstructed by arytenoids				4
– Mask aperture completely obstructed by tongue				4

Numbers of patients shown.
*Ventilation inadequate, excess leak.

3). After the fibrescope was advanced beyond the epiglottis, the glottis was confirmed to be open in the three patients in whom ventilation was adequate. In the five of six Score 3 patients in whom ventilation was inadequate, the arytenoid cartilages, pressed anteriorly by the inflated cuff, partially obstructed the glottis. In the eight patients in whom the lungs could not be ventilated through the LMA, the airway was completely obstructed by the base of the tongue at the mask aperture (four patients) or by the arytenoid cartilages compressed anteriorly by the inflated cuff at the level of the glottis (four patients). Accordingly, in 18 patients of the CP[+] group, the trachea was intubated for surgery.

Radiological findings
The radiographs demonstrated that the tip of the mask in the CP[−] group was located at the level of the 6th or 7th cervical vertebra, while that in the CP[+] group was positioned at the 4th or 5th cervical vertebral ($P < 0.001$, Figure 2, Table III). The cricoid cartilage could be identified in five patients of the CP[−] group and in four patients of the CP[+] group. In these patients, the mask was positioned below the level of the cricoid cartilage in all patients in the CP[−] group, but in none in the CP[+] group ($P < 0.01$).

Discussion

Radiography and fibreoscopy were used to examine the precise position of the LMA during cricoid pressure, and ventilation was quantified by measuring expired tidal volume. We found that double-handed cricoid pressure impeded proper positioning of, and ventilation through the LMA.

When in the correct position, the LMA provides an air-tight seal around the larynx, that permits positive pressure ventilation. An expiratory tidal volume of 10 $ml \cdot kg^{-1}$ is usually obtained by manual ventilation without excessive leakage at peak airway pressure of <2 kPa.[2,21] In our study when cricoid pressure was not applied, ventilation through the LMA was always adequate without a large leak. The mask was always properly positioned in the hypopharynx, since the glottis was always seen through the fibrescope just below the mask aperture. In contrast, when cricoid pressure was applied, the success rate of adequate ventilation was decreased to 25%. Even in patients in whom ventilation was adequate, fibreoscopy showed that occasionally the mask was not positioned correctly.

In 75% of the patients in whom cricoid pressure was applied, ventilation was inadequate or impossible through the LMA at a peak airway pressure of 2 kPa. The reason for unsuccessful ventilation was excessive leakage and/or airway obstruction. Fibreoscopy showed when the LMA was inserted with cricoid pressure it was not positioned deeply enough, so that the effectiveness of the seal around the larynx was not complete, and the arytenoid cartilages, pressed anteriorly by the inflated cuff, distorted the glottis and obstructed it. When the cuff of the correctly positioned mask is inflated, the thyroid, arytenoid and cricoid cartilages are pressed anteriorly, and the tissues overlying the larynx bulge slightly.[16] However, cricoid pressure prevents this characteristic bulging of the laryngeal tissue, so that the inflated cuff, positioned more proximally than usual, compresses only the arytenoid cartilages anteriorly, which leads to partial or complete airway obstruction. When the mask was positioned further proximally, the aperture was obstructed completely by the tongue.

Our radiological findings confirmed that when cricoid pressure was applied, the LMA was not positioned deeply enough, as shown by fibreoscopy. When the LMA is in the correct position, the distal part of the mask lies in the hypopharynx and the tip of the cuff is at the level of the sixth or seventh cervical vertebra.[22] In the radiological study, when cricoid pressure was not applied, the mask was found in this position and the tip

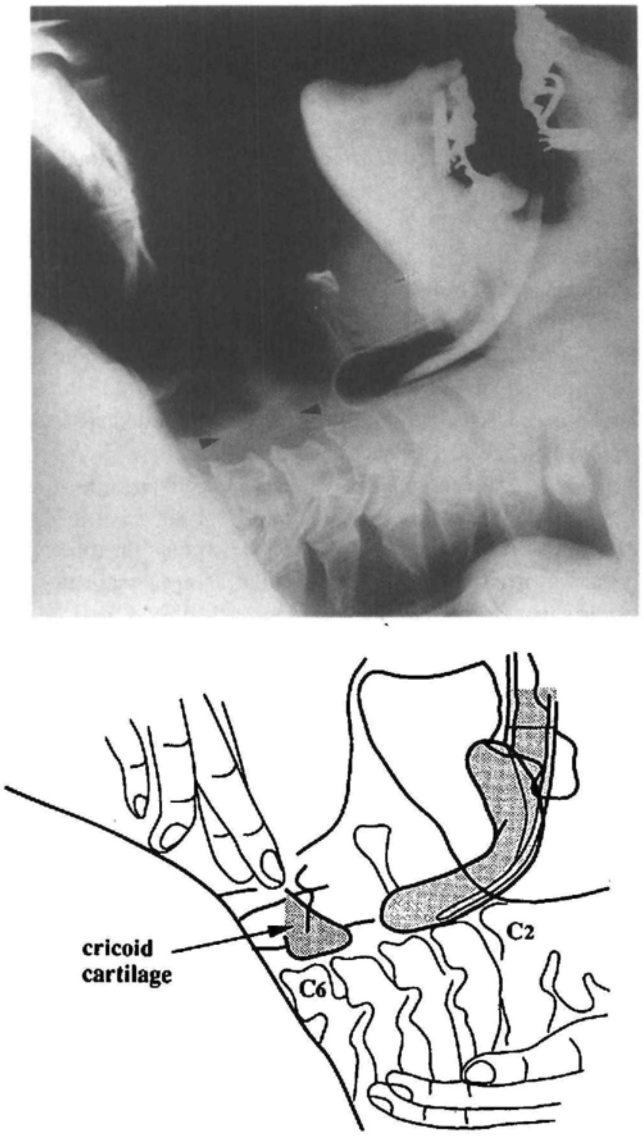

FIGURE 2 Lateral neck radiograph and diagram showing the position of the LMA during cricoid pressure. The cricoid cartilage (arrows), pressed by double handed technique, did not allow further passage of the LMA. Inflation of the cuff induced an upward movement of the LMA, and the tip of the mask was finally placed above the level of the cricoid cartilage (C_4 vertebral level in this patient). Since the mask aperture was obstructed by the base of the tongue, ventilation was impossible in this patient.

of the mask was located below the level of the cricoid cartilage, which lies at the 6th cervical vertebral body in adults.[23] In contrast, when cricoid pressure was applied, the mask was positioned in the oropharynx. The tip of the cuff was positioned at the level of the 4th or 5th cervical vertebra and above the level of the cricoid cartilage. Therefore, cricoid cartilage pressure might prevent further passage of the mask during insertion. Inflation of

TABLE III Position of tip of mask by lateral neck radiograph

	CP [−] group (n = 10)	*CP [+] group (n = 10)*
Vertebral level		
C_4	0	6
C_5	0	4
C_6	4	0
C_7	6	0

the cuff induced upward movement of the LMA, so that the mask was finally placed more proximally than usual.

In previous studies Heath *et al.*[8] and Brimacombe *et al.*[9] reported that single-handed cricoid pressure did not affect successful placement of the LMA, while in the studies reported by Ansermino *et al.*[10] and by Asai *et al.*,[11] double-handed cricoid pressure interfered with correct insertion of the LMA. Our findings are consistent with those of Ansermino *et al.* and Asai *et al.*, but contrary to those by Brimacombe *et al.* and Heath *et al.* We do not agree that the discrepancy is due to the difference in the methods of cricoid pressure,[11] because our radiographs indicate that the cricoid cartilage pressure prevented the LMA from advancing further. Despite the difference in cricoid pressure technique , if the standard head position for insertion of the LMA is maintained, the neck is flexed and the head extended (sniffing position), the position of the cricoid cartilage should not change. We used double-handed cricoid pressure, with support of the patient's neck, to maintain this standard position.[20] Therefore, pressure on the cricoid cartilage by either method might impede successful placement of the LMA.

Another possible explanation for the discrepancy among studies is the difference in the force of cricoid pressure applied.[11,12] If the force used to advance the LMA is greater than that applied in cricoid pressure, the tip of the mask may pass below the cricoid cartilage, which may permit adequate ventilation. Brimacombe *et al.* showed that the glottis could be visualized fibreoptically in many cases even during application of cricoid pressure,[9] suggesting that the LMA was positioned deeper. In the recent study reported by Asai *et al.*, even single-handed cricoid pressure impeded placement of the LMA when sufficient force was applied.[12]

These findings indicate that cricoid pressure should not be used during insertion of the LMA. In some patients, adequate ventilation can be obtained through the LMA during cricoid pressure. However, the mask is more likely to become dislodged and may not provide a secure airway, since the LMA is not placed correctly and the tip of the mask may be wedged only behind the arytenoid cartilages.[24] We agree with Ansermino *et al.* and Asai *et al.* that it may be safer not to use the LMA in patients at risk of aspiration in whom conventional mask ventilation is possible.[10,11] In the worst case, in which neither mask ventilation nor tracheal intubation is possible, the LMA with transient release of cricoid pressure may save the patient's life. In addition, subsequent tracheal intubation through the LMA can protect against aspiration.

In summary, we have demonstrated that application of cricoid pressure prevents both correct positioning of the LMA and ventilation through it.

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