THE IMPACT OF CRICOID PRESSURE ON OESOPHAGUS POSITION AND COMPRESSIBILITY IN MALAYSIAN PATIENTS: A PREVALENCE STUDY

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ABSTRACT

THE IMPACT OF CRICOID PRESSURE ON OESOPHAGUS POSITION AND COMPRESSIBILITY IN MALAYSIAN PATIENTS: A PREVALANCE STUDY

Background

Cricoid pressure (CP) is an airway manoeuvre used during rapid sequence induction to reduce the risk of pulmonary aspiration. Classically it was thought that CP was effective for this as it compressed onto the oesophagus located centrally. However, anatomical studies involving CP showed various relative oesophagus positions with variable degrees of compressibility, and ultrasound is a non-invasive tool that could be used to assess these parameters.

Purpose:

To determine the sonographic prevalence of relative position of oesophagus to cricoid cartilage in patients undergoing general anaesthesia; and to assess the qualitative impact of CP on change of oesophagus position and its compressibility.

Methods

A prospective, cross-sectional study was performed on patients would undergo general anaesthesia for elective surgery in single tertiary centre in Malaysia. Written consent obtained from all eligible patients. Prior to induction of general anaesthesia, baseline ultrasound scan of the neck to assess the position of oesophagus relative to cricoid cartilage was done and designated as either: central, partially lateral, or completely lateral. Scan was repeated post general anaesthesia and pre CP. Then CP force of 30N was applied on cricoid cartilage. Patientôs sonogram was assigned to one of three groups: directly behind the trachea (ñcentralò), partially behind trachea (ñpartialò), or completely lateral to the trachea (ñlateralò). Oesophagus was assumed ñcentralò (and

compressible) if scan did not detect oesophagus; ñpartialò, if the entire tubular structure of the oesophagus located behind cricoid cartilage was not visualised (lateral borders of cricoid cartilage and the oesophagus overlapped); and ñcentralò, if there lateral border of the two structures overlapped. The position and compressibility of oesophagus were recorded. Two investigators with fixed roles were involved in obtaining the data, whereby one applied CP and the other performed the ultrasound scan of the neck. Chi square test, McNemar or Fisher exact was performed for statistical analysis (Ŭ= 0.05).

Results

There were 50 patients recruited. Results pre vs post general anaesthesia were as follow: 44% (vs 34%) patients with central oesophagus, 42% (vs 44%) were partial and 14% (vs 22%) lateral. The effect of general anaesthesia on oesophagus placement was significant ($p = 0.046$). There is no change in oesophagus position pre and post CP. There was higher prevalence (54%) of oesophagus occlusion with CP in the central and partial groups ($p < 0.001$). No oesophagus occlusion seen in lateral group.

Conclusions

There was more non-centrally located oesophagus compared to central oesophagus. Anaesthesia effect has an association with further displacing the oesophagus. Oesophagus occlusion was less likely if it is deviated from cricoid cartilage.

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-Aaron Wilson

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CHAPTER 1 : INTRODUCTION

Sellick first described cricoid pressure (CP) in 1961, which it was described as, ñtemporary occlusion of the upper end of the oesophagus by backward pressure of the cricoid cartilage against the bodies of the cervical vertebrae [1].ò Since then it has been adopted by clinicians worldwide to decrease the risk of pulmonary aspiration during rapid sequence intubation [2][3].

Ultrasound is a non-invasive imaging tool that is increasingly becoming more portable therefore more accessible to more healthcare practitioners. There is a growing amount of publications [4] on point-of-care ultrasound in the area of airway assessment and management.

The objective of this study is by using ultrasound, to qualitatively evaluate the incidence of positions of oesophagus relative to trachea, and assess the impact of general anaesthesia and cricoid pressure on this distribution and the oesophagus compressibility. We hypothesise that there were more laterally located oesophagus. General anaesthesia and cricoid pressure could displace it further laterally. Laterally located oesophagus was less likely to be occluded by cricoid pressure.

CHAPTER 2: LITERATURE REVIEW

Historically, CP was thought to exert its effectiveness in preventing pulmonary aspiration was via direct compression of the oesophageal lumen, which was directly posterior to the cricoid cartilage. It has been hypothesised that a ñ30 Newton force should provide a pressure around 200 mm Hg under the 10 cm^2 area of the lamina of the cricoid cartilageò [5]. It was found that CP could prevent regurgitation of gastric content at intraoesophageal pressures of up to 100 cm H_2O [6][7](although intraoesophageal pressure rarely exceeds 25 mm Hg)[8][9]. CP could also prevent gastric insufflation during face mask ventilation up to peak airway pressure of 20 cm H_2O [10]. Oesophagus occlusion is also achieved with CP of 30N onto the laterally located oesophagus [5], even though it receives less force than midline areas [11]

However, pulmonary aspiration still occurred in patients despite application of CP [11]. Furthermore, CP may induce airway obstruction; cause difficulty in mask ventilation or inserting endotracheal tube; distort fibreoptic visualisation of vocal cords; and even cause oesophageal rupture [11][12]. This left many practitioners questioning its safety and effectiveness [11].

Therefore there had been many [13] [14][15] [16][17][23] imaging studies to assess the impact of CP on the oesophagus. The study designs include performing CP on exclusively awake patients; on anaesthesised patients, with or without administration of muscle relaxants; and applied CP force between 10-40N. Imaging modalities that were employed included magnetic resonant imaging (MRI), computed tomography, and ultrasound of the neck. More invasive methods such as video laryngoscopy and fibreoptic evaluation of the glottis have been described. Assessment of the oesophagus compression and displacement, qualitative and quantitatively were performed, and various reference anatomic points have been used to assess (relative) oesophageal displacement.

These studies showed various prevalence differences between individuals. In ultrasound study by Kei et al [13] on 50 awake, healthy patients, carbonated drinks were given to patients to enhance the sonographic views of the oesophagus lying directly behind cricoid cartilage. They demonstrated that prior to application of CP, 20% oesophagus was central, 60% partially lateral and 20% completely lateral. Post CP, the distribution of oesophagus positions was as follow: 4% (central), 26% (partial), 70% (lateral). There was no successful oesophagus occlusion post CP in this study.

In MRI study of the neck by Smith et al [14], in 22 awake healthy volunteers that received CP up to 30N, they found that 53% oesophagus was in lateral position and number increased to 91% post CP. Centrally located oesophagus prevalence changed from 47% to 9%, pre and post CP respectively. Similar MRI study in 16 awake patients, performed by Boet et al [15], found that all incomplete oesophageal occlusion (62.5%) was associated with lateral deviation. Meanwhile the remaining 6 centrally located oesophagus had complete oesophageal occlusion.

Rice et al [16] also performed a MRI neck study on 24 awake healthy volunteers, and they concluded that up to 83% patients had central oesophagus, and 17% were lateral. They found that they the degree of oesophageal occlusion is independent of its location. Interestingly, they concluded that it was the hypopharynx and not the oesophagus that was compressed during CP, providing an alternative explanation to the effectiveness of CP in preventing pulmonary aspiration despite low prevalence of central oesophageal and occlusion success.

Zeidan et al [17] used videolaryngoscope to assess oesophagus occlusion in 79 anaesthesised and paralysed patients. An unsuccessful insertion of a nasogastric tube was interpreted as effective CP due to the evidence of an occluded oesophagus by CP. Oesophagus was midline in 32% of the subjects, and 58% lateral. They noted 95% success rate of occlusion with CP, and that was independent of the position of the oesophagus relative to glottis.

There is lack of publications on this area of research especially for anaesthesised and paralysed patients. Many papers were produced from the Western hemisphere, therefore it will be interesting to compare and contrast the impact of CP on prevalence of oesophagus position and occlusion - under general anaesthesia - at different geographical settings.

CHAPTER 3: METHODOLOGY

This prospective observational study was approved by the University of Malaya Research Ethics Committee and registered with National Medical Research Register (Research ID: 45835; NMRR ID: NMRR-19-666-45835). We recruited healthy adults, American Society of Anesthesiologists (ASA) Class I-II, that would undergo general anaesthesia for elective surgery. Written consent was obtained from all participants. They were excluded if had have either one of the followings: undergoing neck surgery, undergoing emergent surgery, pregnant, age under 18 years old, had abnormal neck structures, previous neck or facial surgery, previous radiation to the neck, and had features of difficult airway.

Two investigators participated in the study, each assigned to a fixed role throughout the study. First operator would be responsible to identify cricoid ring pre-induction of anaesthesia, and later post- induction applying CP with the force of approximately 30 Newton, with the cricoid ring held between thumb and middle finger of the dominant hand (right).

This forced was standardized for each patient by having the investigator practiced with Newton force meter prior to study. The second operator performed the pre- and post- induction of ultrasound scans and its interpretations. The first operator was blinded to ultrasonography outcomes during application of CP, with the ultrasound screen obscured from him.

In operating room, standard anaesthesia monitoring (as per Association of Anaesthetist of Great Britain and Ireland guidelines) were applied. Patient was put in supine position, with slightly extended head (in ñsniffingò position). High-flow oxygen 10L/min was applied and after end tidal oxygen level (EtO_2) > 80% achieved, anaesthesia was induced with intravenous bolus of fentanyl 2mcg/kg body weight, IV propofol 3-4mg/ kg , and IV rocuronium 1mg/ kg. Upon loss of consciousness, CP was applied by the first operator. The ultrasonographic position of and compressibility of the oesophagus were recorded by the second operator and next would signal to the first operator to release CP to mark the end of the study. The study took about 30-60 seconds to completed post anaesthesia. It would be terminated prematurely and patient would be excluded from the study if patient developed bradycardia or desaturation. Basic demographic data including age and gender were recorded for each participant.

Sonosite Micromaxx® ultrasound machine (Fujifilm Sonosite, Inc. USA) was used with linear probe (frequency 5-13 MHz). Prior to induction of anaesthesia, neck scan was performed by the ultrasonographer to determine the baseline anatomic relationship of the oesophagus relative to the trachea (at the level of cricoid ring). The ultrasound probe was placed horizontally to the cricoid ring. Three scan views namely midline, left midline and right midline obtained were in an attempt to locate the oesophagus. The structure detected was further assessed with colour and doppler scan modes to rule out vascular structure. Based on this, patients were assigned to one of the following 3 groups: directly behind the trachea (ñcentralò) partially behind trachea (ñpartialò), or completely lateral to the trachea (ñlateralò). The oesophagus position was deemed directly behind the trachea, if it was not seen in any of the scan views. The oesophagus was considered ñpartialò if the entire tubular structure of the oesophagus located behind cricoid cartilage was not visualised. In other words, ultrasonographically, the lateral borders of cricoid cartilage and the oesophagus ñoverlappedò. Hence the oesophagus was considered ñlateralò if there was no overlap between the oesophagus and cricoid cartilage (Figure 1)

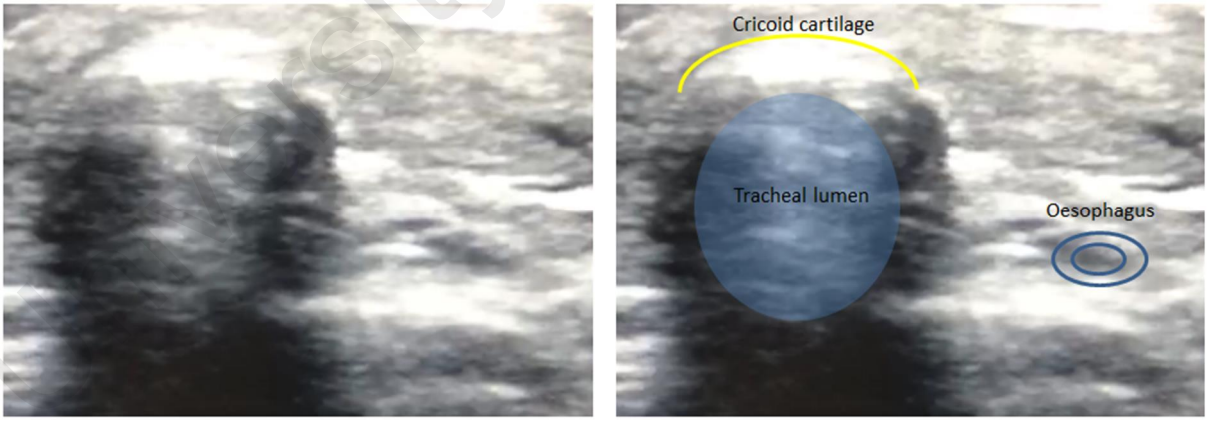

Figure 1: Sonogram of a ñlateralò oesophagus in sagittal axis - there was no overlapping of the lateral borders of the oesophagus and cricoid cartilage. The tracheal lumen shaded in blue represented by hypoechoic appearance (the ñcomet tailò artifacts) of trachea when the ultrasound probe was placed at anterior surface neck at the level of the cricoid cartilage.

Statistical Analysis

Based on a recent ultrasound study, the sample sample was determined using McNemar test. One study found thirty four out of 39 patients (80%) oesophagus were compressed laterally [22] while 15% of blind cricoid pressure group in another 50 subject study achieved oesophageal occlusion [13]. With confidence interval of 95%, Ŭ=0.05, 1-ɓ = 0.8, the calculated sample needed to prove the significance of ultrasound guidance in oesophageal occlusion is calculated to be 23 subjects. In view of current population study prevalence of central oesophagus of 50% [18], the number of recruitment will need to be at 46 subjects, so that we can get at least 23 patients for McNemar test. Estimating 10% dropped out rate, the final recruitment number was 51.

We tested the effect of (pre and post) anaesthesia on the position of oesophagus with McNemar test. Chi Square test or Fisher Exact Test was used to analyse other the categorical variables. Specifically we tested the effect of cricoid to the success rate of oesophageal compression post induction of anaesthesia, post CP. Result of $p < 0.05$ was considered significant. All data was analysed with IBM ® SPSS Statistics 21.0

CHAPTER 4: RESULTS

Fifty patients were recruited to this study, with nil dropped out. There was no incidence of bradycardia, hypotension or desaturation during this study.

Age range was between 19 -79 years old, with mean age of 46.8 . There is female preponderance - 32 subjects (64%) , male , 18 (36%). The demographic data was independent of oesophagus position and compressibility ($p < 0.001$).

Table 1: Relative position of oesophagus pre- versus post general anaesthesia (GA); Number in proportion (%)

Position of oesophagus relative to trachea	Pre GA (n=50)	Post GA (n=50)
Central	22 (44%)	17 (34%)
Partial	21 (42%)	22 (44%)
Lateral	7 (14%)	11 (22%)

Based on Table 1, there were 22/50 (44%) patients with central oesophagus, while 28/50 (56%) were either partially or completely lateral oesophagus. There was evidence of association between anaesthesia and the position of oesophagus , X^2 (df 4, N= 50) = 63.75, $p < 0.001$.

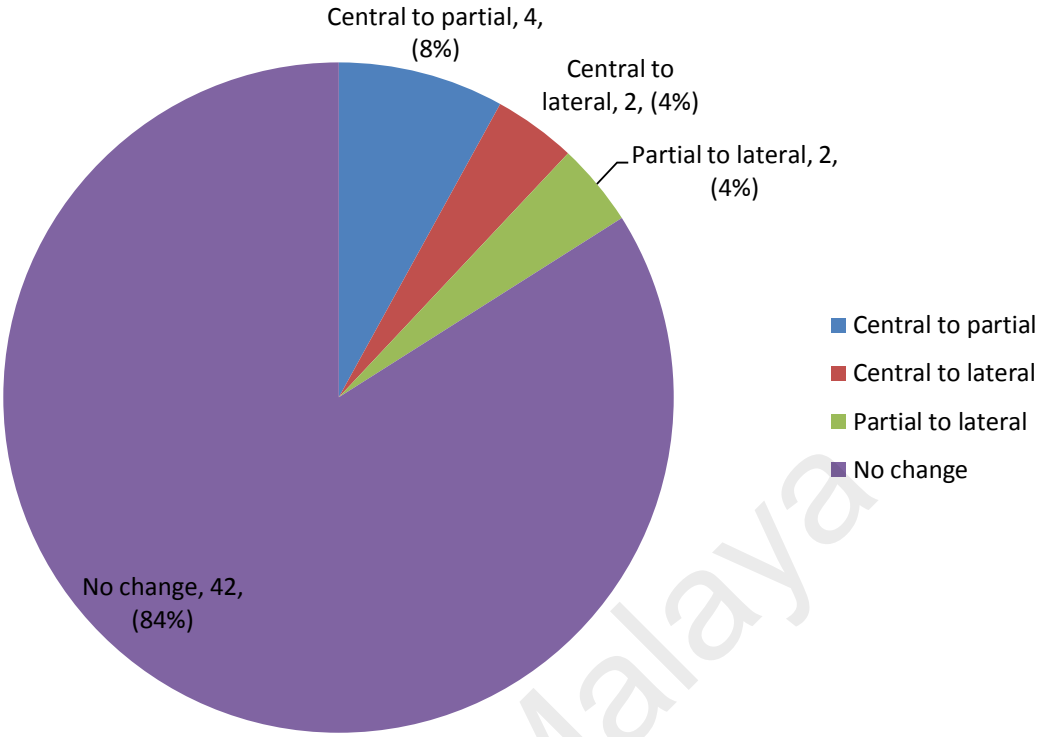

Figure 2: Pie Chart Distribution of The Change to Oesophagus Position post general anaesthesia

Based on Figure 2, there were 8/50 (16%) patients that had significant oesophageal displacement post general anaesthesia (prior to application of CP) p = 0.046 . There was no ñreverseò oesophageal displacement ,i.e towards central position post CP (from pre CP partial/lateral views to post CP central/partial views) seen in this study. Majority (4 patients) were displacement from central to partial view, 1 was from oesophageal to lateral view; meanwhile the remaining 2 had a change from initially partial view to lateral view. There was no change in oesophagus position pre and post CP.

Table 2: Occlusion of oesophagus (post CP) results according the relative position of the oesophagus. Number in proportion (%)

Position of oesophagus relative to trachea	Oesophagus Compressed	
	Yes	No
Central	17 (34%)	0 (0 %)
Partial	10 (20%)	12 (24%)
Lateral	0 (0%)	11 (22%)
Total	27 (54%)	23 (46%)

Based on Table 2, the more central the oesophagus the more likely the oesophagus will be occluded by cricoid pressure X^2 (df 1, N= 50) = 5.357 ,$p < 0.001$. If the central oesophagus was presumed so, 27/50 (54%) oesophagus were occluded, while 23/50 (46%) were not. Even if the central oesophagus views were excluded, the occlusion success was significantly higher in partial than the lateral group (p=0.040).

Only 1 of 8 displaced oesophagus (Central to partial position) had oesophageal occlusion. There was statistically significant association oesophageal occlusion if the cricoid pressure is still applied on the displaced oesophagus from central position (p = 0. 001). However if an already partial oesophageal was displaced further laterally the oesophageal occlusion was not statistically significant (p = 0.533)

CHAPTER 5: DISCUSSION

Our study demonstrated that there was 44% centrally located oesophagus, 42% partial and 14% laterally located oesophagus. There is a lower incidence of central oesophagus (34%) after patient underwent anaesthesia, and higher incidence of non-central oesophagus (partial 44%, lateral %). This took into account 16% of our patients had a change in the relative position of post general anaesthesia, and that CP did not affect the position.

Our results regarding demographic data concurred with other studies, whereby oesophagus position and compressibility are independent of age and gender. Other studies also have demonstrated that this outcome was independent of neck circumference, height, weight, body mass index and ASA classification.

Ultrasonographic study finding by Kei et al [13] (compared to our data) showed post application of CP, their prevalence of oesophagus relative to cricoid cartilage was: 4% (vs 34%) central, 26% (vs 44%) partial, 70% (22%) lateral. There were also 50 patients recruited in this study, with high prevalence of non-central oesophagus. Our study differ their whereby the patients were awake, and only 10N of CP force was applied therefore suboptimal occlusion occurred. There was no statistical analysis performed on the data, therefore it was difficult to draw further conclusions from the study.

Our study showed predominance of partial/complete latearal displacement of the oesophaugus. This was similar to a study done by Smith et al [18], whereby they retrospectively reviewed oesophagus anatomy on cervical computed tomography scans images of 51 patients. Lateral oesophageal displacement was seen in 49% of the images, with 64% of displacement occurred ñbeyond the lateral border of cricoidò, and the proportion increased to 90% after application of CP. However these patients were not anaesthesised (and paralysed), therefore it was uncertain that whether similar result would still be achieved. We noted displacement of the oesophagus post general anaesthesia, and no further displacement occurred upon application of CP.

Another study by Zeidan et al [19] in 79 anaesthesised and paralysed patients, whereby they used video laryngoscope and studied the relative position of oesophagus and trachea, and assessed the patency of oesophagus post CP (indirectly by the success attempt of nasogastric tube insertion). They found 68% oesophagus was displaced

laterally (57% leftside, 11% rightside); and 32% were centrally located. We noted that the position of oesophagus did not change with CP and this was similar to our result. However, it was unknown whether a change in oesophagus position post general anaesthesia had occurred prior to application of CP.

The limitation of this study was we could not confirm that a sonographically central located oesophagus was compressible, despite presuming so in this study. This may be due to air in trachea obscuring the structures posterior to it [24]. Ultrasound may not be the gold-standard imaging modality to observe structures obscured by air in the trachea.

Furthermore, our study assigned the trachea as a static reference point for the relative position of the oesophagus, and that reference points differ in other studies. Zeidan et al [19] assigned this reference point to the glottis (imaging with videolaryngoscope), whereby arbitrary ñvertical line was drawn from the middle of the posterior border of the glottis. If the line crossed the middle third of the esophageal entrance, it was considered in a midline position, whereas if the line crossed to the right or to the left of the middle third of the esophageal entrance, it was considered in a left lateral or right lateral positionò. All their centrally (and non-centrally) located oesophagus patients had 100% success rate of oesophageal occlusion.

In MRI neck studies by Smith et al [14], on the hand, assigned the position and displacement of oesophagus relative to midline part of vertebral body. Statistically insignificant result for the mean difference of the distance of the transverse distance between cricoid and oesophagus (pre and post CP) was noted, suggesting that the border of a ñlaterallyò displaced oesophagus would still have overlapped with the cricoid cartilage. Reduction of mean diameter of oesophagus pre and post CP was not statistically significant, suggesting that CP was not effective. Similar finding was found in study by Rice et al [16]

Hence, based on the images and published in these reports and the designated arbitrary lines, the lateral borders of the cricoid and oesophagus still overlapped in all positions. Presuming our sonogram would have obtained similar images of structural arrangement, potentially all those images would be interpreted as centrally located oesophagus, and erroneously presumed that the oesophagus was compressible.

However, the need for oesophageal compression in order for CP to be effective was challenged, and even deemed to be ñirrelevantò by Rice et al [16]. They concluded

that it was the hypopharynx (containing cricopharyngeus muscle) and not the oesophagus that lies posterior to cricoid cartilage that was compressed by CP. It was thought that cricoid cartilage and postcricoid hypopharnyx move as a unit (CP unit) due to attachment of the cricopharyngeus muscle on both sides of the larynx. Therefore, the position of the oesophagus was irrelevant to efficacy of CP [20].

In conjunction with this data and their outcome, Zeidan et al concluded that ñthe compression of the postcricoid hypopharynx occurred regardless of the position of the cricoid cartilage (midline or lateral) relative to the vertebral bodyò [19]. There were recent novel techniques described to occlude the oesophagus effectively, namely the paratracheal [21] and paralaryngeal pressure [22]. Currently at our institution, we also embarked on novel technique combining cricoid pressure and paralyngeal pressure and assessing its efficacy in oesophageal occlusion.

There was inadequate evidence of correlating sonogram of the trachea and oesophagus with other imaging modalities (e.g ultrasound versus MRI versus video laryngoscope). Future studies are needed to look into imaging correlation of CP on oesophagus displacement and compression, comparing with different types imaging modalities.

CHAPTER 6: CONCLUSION

Our study showed that there were more oesophagus located lateral to cricoid cartilage (44% partial lateral, 22% complete lateral) than centrally located 34% (central) and that anaesthesia effect has an association with further displacing oesophagus. Oesophageal occlusion was less likely if it is more deviated from cricoid cartilage.

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