Laboratory Report

Cricoid pressure decreases lower oesophageal sphincter tone in anaesthetized pigs

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Purpose: Previous studies have shown a decrease of lower oesophageal sphincter (LOS) tone during stimulation of the upper oesophageal sphincter. Therefore, we hypothesized that during anaesthesia, cricoid pressure could result in a decrease in LOS pressure.

Methods: The LOS and oesophageal barrier pressures (BrP = LOSP minus gastric pressure) were obtained in 11 anaesthetized pigs with intraabdominal pressure of 15 mmHg using a manometric method (perfused catheters) before and during firm application of cricoid pressure. Reflux was assessed with concomitant recording of the lower oesophageal pH.

Results: Cricoid pressure decreased LOSP from 31.0 ± 14.5 mmHg to 26.1 ± 12.7 mmHg ($P < 0.001$) leading to a 35% reduction of oesophageal barrier pressure (9 ± 10.3 mmHg vs 13.7 ± 12.4 mmHg; $P < 0.001$). No episodes of reflux were recorded.

Conclusions: This study shows that cricoid pressure decreases LOS tone in anaesthetized pigs. Although no gastro-oesophageal reflux was recorded, this study suggests that, if cricoid pressure does not completely occlude the oesophagus, the decrease of oesophageal barrier pressure induced could favour the appearance of pulmonary aspiration.

Key words:

ANAESTHETIC TECHNIQUES: cricoid pressure;
COMPLICATIONS: aspiration, regurgitation;
GASTROINTESTINAL TRACT: lower oesophageal sphincter.

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Objectif: La stimulation du sphincter supérieur de l'oesophage (SSO) entraîne une diminution du tonus du sphincter inférieur de l'oesophage (SIO). Le but de cette étude a été d'évaluer les effets de la pression cricoïdienne (manoeuvre de Sellick) sur la pression du SIO.

Méthode: Chez 11 porcs anesthésiés à pression intraabdominale élevée (pneumopéritoine de 15 mmHg), la pression du sphincter inférieur de l'oesophage (PSIO) et la pression de barrière (BrP = PSIO moins pression gastrique) ont été enregistrées par une méthode manométrique (catheter perfusé), avant et pendant l'application de la manoeuvre de Sellick (pression cricoïdienne en regard du SSO). La survenue d'un reflux a été évaluée par la surveillance en continu du pH de l'oesophage inférieur.

Résultats: La pression cricoïdienne diminuait la PSIO de 31.0 ± 14.5 mmHg à 26.1 ± 12.7 mmHg ($P < 0.001$) entraînant une réduction de 35 % de la pression de barrière : 9 ± 10.3 mmHg versus 13.7 ± 12.4 mmHg; $P < 0.001$. Aucun reflux n'a été enregistré pendant la pression cricoïdienne.

Conclusions: Cette étude montre que la pression cricoïdienne entraîne une baisse de la pression du SIO et de la pression de barrière chez le porc anesthésié. Malgré qu'aucun reflux n'ait été enregistré, ces résultats suggèrent qu'une incompétence du SIO avec risque d'inhalation pulmonaire peut survenir si la lumière oesophagienne n'est pas complètement obturée par la compression cricoïdienne.

Most oesophageal regurgitation occurs when an increase in gastric pressure is associated with a relaxation of the lower oesophageal sphincter (LOS).¹⁻³ In 1961, Sellick recommended the application of firm cricoid pressure during induction of anaesthesia to avoid pulmonary aspiration.⁴ However, regurgitation and pulmonary aspiration of gastric contents have been reported during cricoid pressure.^{5,6} Factors which decrease lower oesophageal sphincter pressure (LOSP) also decrease

the efficacy of oesophageal barrier pressure (BrP = LOSP minus gastric pressure), leading to oesophageal reflux.² Previous studies have shown a decrease of LOS tone during swallowing⁷ or during insertion of the laryngeal mask airway.⁸ These studies suggest that stimulation of the upper oesophageal sphincter decreases LOS pressure. Therefore, we hypothesized, that during anaesthesia, cricoid pressure could result in a decrease in BrP. This hypothesis was tested in anaesthetized pigs.

Methods

After obtaining approval from our Institutional Animal Care Committee, 11 pigs (22–25 kg) were studied. Ketamine 8 mg·kg⁻¹ *im* was given for premedication after a 12-hr fast. Anaesthesia was induced with propofol 5 mg·kg⁻¹, sufentanil 3 µg·kg⁻¹ and pancuronium 0.1 mg·kg⁻¹ *iv*. After tracheal intubation, the lungs were ventilated mechanically to maintain normocapnia at baseline (Engström Eliza capnograph). All animals received propofol 10 mg·kg⁻¹·hr⁻¹ during the course of the study. Carbon dioxide was insufflated through a Veress needle placed through a 2-cm abdominal midline incision. Intra-abdominal pressure was maintained at 15 mmHg pressure (Wolf, Knittlingen, Germany).

Lower oesophageal sphincter, gastric (GP) and intraperitoneal pressures (IPP) were measured with the pig in the supine position. The method for LOSP measurements has been previously published.^{9,10} The LOS was detected by a pull-through manoeuvre using polyethylene catheters connected to pressure transducers (Bentley Trantec, Irvine, CA). Catheters were constantly perfused with water by a low-compliance infusion pump at 1 ml·min⁻¹ (SC 2000 pump, Sky Electronics). Before each investigation, transducers were calibrated in a water column (0–50 cm H₂O) and were zeroed to the mid-chest position. Pressures were recorded using a multiple channel recording system (Kontron medical) after induction (T₁), before (T₂) and during 30 sec of firm application of cricoid pressure at an intraabdominal pressure of 15 mmHg (T₃).

Oesophageal pH was continuously measured throughout the study using a glass electrode (Ecoscur pH recorder-Tacussel). The electrode was calibrated before each set of measurements with standardized solutions of buffer at pH 3 and 7. The electrode was advanced until gastric pH was recorded before it was withdrawn to the gastro-oesophageal junction, identified by a sudden increase in pH. The final position of the electrode was 5 cm above the junction. Regurgitation of gastric content was defined as decrease in oesophageal pH to 4 or less.¹¹

For all calculations, the INSTAT computer software package (Graph Pad Software, San Diego, CA) was

FIGURE 1 Lower oesophageal sphincter pressure (LOSP) and barrier pressure (BrP = LOSP minus gastric pressure) in pigs during anaesthesia. At T₁, T₂ and T₃, intraperitoneal pressure was maintained at 15 mmHg. T₁ = after induction; T₂ = before application of cricoid pressure; T₃ = during application of cricoid pressure. Values are mean ± SD (mmHg); (n = 11). *P < 0.001 vs LOSP at T₁. **P < 0.001 vs LOSP at T₂. ***P < 0.001 vs BrP at T₂.

used. Statistical significance was determined using a paired Wilcoxon test. P < 0.05 was considered statistically significant.

Results

Following induction of anaesthesia, lower oesophageal sphincter pressure was 16.4 ± 7.8 mmHg, BrP was 12.5 ± 8.5 mmHg (Figure 1). At 15 mmHg intraperitoneal pressure, the oesophageal barrier pressure was not different from baseline values (13.7 ± 12.8 mmHg vs 12.5 ± 8.5 mmHg) while LOSP increased from 12.5 ± 8.5 mmHg to 31.0 ± 14.5 mmHg; P < 0.001). Application of cricoid pressure resulted in a concomitant decrease in LOSP (26.1 ± 12.7 vs 31.0 ± 14.5 mmHg; P < 0.001) and in a 35% reduction of oesophageal barrier pressure (9 ± 10.3 mmHg vs 13.7 ± 12.8 mmHg; P < 0.001; Figure 1). This decrease in BrP was present in all pigs (Figure 2). No episodes of reflux were recorded before or during cricoid pressure.

Discussion

The present study demonstrates that, in pigs, cricoid pressure (Sellick's manoeuvre) reduces oesophageal barrier pressure by 35% when raised intraabdominal pressure is present.

During obstetric anaesthesia or emergency surgery in patients with a full stomach, the high intraabdominal pressure favours regurgitation.¹ The most effective method of preventing aspiration in such situations is to

FIGURE 2 Typical recording of the lower oesophageal sphincter pressure in one anaesthetized pig with 15 mmHg of intraperitoneal pressure before and during cricoid pressure and after its release. Phasic nature of the pressure tracing corresponds to respiratory cycles.

avoid general anaesthesia. However, many surgical procedures are not amenable to regional anaesthesia and general anaesthesia is often necessary. In these patients, rapid-sequence induction of anaesthesia and cricoid pressure are advocated. The initial description of cricoid pressure was given in 1961 by Sellick.⁴ In 1970, Fanning¹² indicated that, in cadaveric specimens, cricoid pressure could prevent regurgitation from oesophageal pressures of at least 50 cm H₂O (37 mmHg). Considering that gastric pressures are generally <50 cm H₂O, it was concluded that cricoid compression was effective in preventing regurgitation.

The major finding of our study was the reduction of the LOS tone in response to cricoid pressure. The LOS is capable of a rapid adaptative response to increases in gastric pressures, as has been previously reported during fasciculations seen after succinylcholine¹⁰ or during peritoneal insufflation during laparoscopy.¹³ In this study, a 15 mmHg intraperitoneal pressure resulted in a two fold increase in LOS tone, leading to an oesophageal barrier identical to basal values. During application of cricoid pressure, LOS tone decreased: as IPP was constant, the oesophageal barrier was <9 mmHg. An increased risk of regurgitation during anaesthesia has often been inferred solely from a decrease of BrP^{8,10} or from an oesophageal pH of <4. Despite a decrease in BrP in our study, no reflux was observed. This could be explained by the short observation time (30 sec) and because the pylorus was not occluded. In addition, previous studies performed in ambulatory patients showed that there is a considerable overlap in BrP of subjects with and without reflux.^{9,14} Although it is well established that there is a relationship between decrease in LOSP and reflux,¹⁵ it is not possible to

define BrP or LOSP values below which reflux will occur. Any decrease in BrP during anaesthesia would be expected to increase the risk of regurgitation and this is particularly true in situations with high or increased gastric pressures.

The mechanism of the observed decrease in LOS tone during cricoid pressure is unknown but the rapidity of the response suggests a neural mechanism. Innervation of the upper and lower oesophageal sphincters is predominantly through the same nerve, the vagus nerve.^{16,17} By this way, stimulation of the upper oesophageal sphincter, as during swallowing, initiates relaxation at the LOS.⁷ During anaesthesia, oesophageal reflux is more frequent during ventilation using the laryngeal mask airway (LMA) than during face mask ventilation.¹⁸ stimulation of the upper oesophageal sphincter by the inflated LMA cuff has been advocated by Rabey *et al.* to open the LOS,⁸ a phenomenon quite similar to what we observed with cricoid pressure.

The protocol used in our study did not fully mimic clinical conditions where cricoid pressure is usually employed and interpretation of the results requires acknowledgement of some of its limitations. First, cricoid pressure was undertaken after tracheal intubation. However, one assumes that the pressure induced by the cuff did not modify the results because the low pressure inside the cuff would not be transmitted to the oesophagus. On the other hand, firm pressure applied on a trachea containing a tube will be well transmitted to the oesophagus. In addition, LOS tone was measured some time after intubation to enable us to obtain stable LOS measurements. A second limitation might be a difference in LOS structure between humans and pigs. There are differences in the distribution of striated and smooth fibers among species such as dogs, cats and humans.¹⁶ The current study was pursued using the porcine sphincter. It has physiological and morphological properties common to humans and responds to various stimuli in a way comparable with the human LOS.^{16,19,20} Third, the force applied on the cricoid was not quantified. Nevertheless, within the confines of the current study, a decrease in LOS tone was always elicited by cricoid pressure.

If applicable to humans, the current study suggests that cricoid pressure decreases LOS tone and BrP. This effect is particularly prominent when LOS tone is initially high. Our results have implication for the clinical practice of anaesthesia: if the same phenomenon occurs while the oesophageal lumen is not fully obstructed by the cricoid pressure, pulmonary aspiration could occur.

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