

Anesthesiology
78:652-656, 1993
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The Effect of Cricoid Pressure on Preventing Gastric Insufflation in Infants and Children

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Background: The use of cricoid pressure for the possible prevention of regurgitation of gastric contents during induction of anesthesia in both adults and children has been recommended. However, equally important is the technique in possibly preventing insufflation of gas into the stomach. This study was designed to determine the efficacy of cricoid pressure application in preventing gastric gas insufflation in pediatric patients and to determine the airway pressure at which gas entered the stomach (pop-off point).

Methods: Fifty-nine patients, 2 weeks to 8 yr of age, physical status 1-4, scheduled for elective surgery, received an inhalational induction of anesthesia with halothane, N₂O, and O₂. A single observer used a stethoscope to auscultate over the upper abdomen for any air entry. In study I (without paralysis), the proximal airway pressure was slowly increased by gradually closing the pop-off valve on the anesthesia machine until gas was heard entering the stomach (pop-off point) or until the peak inspiratory pressure (PIP) reached 40 cm H₂O. Thereafter, the pressurization procedure was repeated three times, altering the application and removal of cricoid pressure. The same patients were then paralyzed (study II), and the stomach evacuated before commencing an identical pressurization sequence with and without cricoid pressure.

Results: Appropriately applied cricoid pressure was 100% effective in preventing gas insufflation into the stomach of all children up to 40 cm H₂O PIP with and without paralysis. In addition, paralysis significantly decreased the median pop-off point in any given patient.

Conclusions: Appropriate application of cricoid pressure prevents gastric gas insufflation during airway management

via mask up to 40 cm H₂O PIP in infants and children. An additional benefit of cricoid pressure occurs in paralyzed patients in whom gastric insufflation occurs at lower inflation pressures. (Key words: Anesthesia; pediatric. Anesthetic techniques: cricoid pressure. Complications: gastric distension.)

VENTILATION *via* mask is routinely performed in pediatric anesthetic practice, as well as in a variety of pediatric critical care/resuscitative settings, but is not without risk. Forcing gas into the patient's stomach increases the potential for regurgitation and, thus, pulmonary aspiration of gastric contents.¹ Gaseous distension of the stomach can also function as an extrathoracic competitor to ventilation, thereby restricting lung expansion. Additionally, obstruction of central venous return may occur, leading to a reduction in cardiac output.^{2,3} The efficacy of cricoid pressure in preventing gastric gas insufflation has been studied in adults^{4,5} and—in a preliminary, uncontrolled fashion—in healthy infants and children.^{6,7} The current study was designed to determine the airway pressures at which gastric inflation occurred in paralyzed and nonparalyzed anesthetized infants and children, with and without the application of cricoid pressure (Sellick's maneuver⁸).

Materials and Methods

Fifty-nine infants and children, 2 weeks to 8 yr of age (mean age [months] 22.8 ± 22.8 SD) with clinically assessed ASA Physical Status 1-4, scheduled for elective surgery, were enrolled in the study, after approval by this Institution's Human Subjects Committee. Written informed consent was obtained from the parents or guardians. None of the patients had any overt airway, pulmonary, or gastrointestinal pathology. Thirty-four patients (ASAPS 3-4) were children scheduled for cardiac surgery. Thirty-nine patients who needed preoperative sedation were given oral midazolam 0.5-0.75

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Received from the Department of Anesthesia, Stanford University School of Medicine, Stanford, California. Accepted for publication December 9, 1992.

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**Feld LH, Archer JH, Kreitzman TR, Brock-Utne JG. Cricoid pressure prevents gaseous distention of the stomach during manual inflation of the lungs in infants (abstract). ANESTHESIOLOGY 73: A1090, 1990.

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mg/kg, 20–30 min before induction of general anesthesia.⁹ Fifteen patients who were less than 6 months of age were not given any preoperative sedation. Anesthesia was induced using halothane 1–3% in 70% N₂O and 30% oxygen *via* either an Ohmeda Modulas II plus anesthesia circle system (Madison, WI) or a Siemens Servo 900C nonrebreathing anesthesia system (Danvers, MA). After 5 min of spontaneous ventilation *via* mask with 1–2% halothane and 70% N₂O, 30% O₂, an oral airway was inserted and an intravenous catheter placed. The size of the oral airway was based on the clinical judgment of the anesthetizing team. Size ranged from 0–2.0 over the range of patients studied. On no occasion did the patients move in response to placement of either the oral airway or the insertion of intravenous catheter. The patients were studied while both nonparalyzed (NP) (study 1) and paralyzed (P) (study 2). No relaxants were administered before the completion of study 1. Auscultation over the upper abdomen with both stethoscope and Doppler Probe (Parks 915-AL, Aloha, OR) was used to detect air entering the stomach (pop-off point). The peak inflation pressure of the circuit was measured using the manometer of the anesthesia machine. Equivalence between the Ohmeda and Siemens manometer was confirmed periodically throughout the study with a sphygmomanometer pressure gauge. All cricoid pressure applications and upper abdominal auscultations were performed by a single investigator throughout the study. Before each study sequence, the stomach was evacuated of gas using an oral gastric suction catheter (Argyle Rob-Nel Catheter 10 or 12 French, St. Louis, MO). Proper positioning of this catheter was confirmed by the visible evacuation of a gastric bubble in a distended abdomen or by seeing the catheter tip pushing out against the abdominal wall. The stomach was not evacuated within the sequence. A study sequence would commence by closing the anesthesia machine pop-off valve, thereby increasing proximal airway pressure. The end point of the study sequence was when gas was heard to enter the stomach as a “gurgle” (the gurgle was noted by the auscultating observer, or the Doppler), or the airway pressure reached 40 cm H₂O, or epigastric distention was observed. At any of these end points, the peak inspiratory pressure (PIP) was noted and the study concluded. In both studies, patients with even hospital numbers had the following cricoid pressure application/removal sequence: without, with, without, and with cricoid pressure. Patients with odd hospital numbers had the opposite sequence: with,

without, with, and without cricoid pressure. A total of four airway pressure measurements were taken and data from all four points were analyzed.

Muscle relaxants were then administered (study II) using 0.2 mg/kg doses of pancuronium or vecuronium. When no twitches were detected by the train-of-four stimulation (TOF = 0), airway pressurizations were performed four times, as with study I, using a sequence of cricoid application and removal as determined by the patients' hospital numbers.

The contribution of variables such as age, weight, sex, ASAPS, existence of congenital heart disease, preoperative midazolam sedation, or the investigator providing positive pressure ventilation were analyzed using multiple linear regression. A sign test was used to determine the significance of changes between the first and second pop-off point measurements in each sequence. Statistical significance was assumed with $P \leq 0.05$. The sign test (nonparametric) was used to construct a confidence interval for the median differences between the paired pop-off points under paralysis and nonparalysis. An exact 96% confidence interval for this median difference is (4.9).

Results

Fifty-nine infants and children were studied. Cricoid pressure was 100% effective in preventing gas insufflation into the stomach in all 59 children, both with and without paralysis, up to 40 cm H₂O PIP.

The pop-off point data generated without the influence of cricoid pressure demonstrates significant differences between the paralyzed and nonparalyzed state in any given patient (fig. 1). The paralyzed state resulted in a significantly lower pop-off point than the nonparalyzed state for any given patient. No patients in either group had pop-off points less than 16 cm H₂O. A number of patients (n = 7) in the nonparalyzed group had no detectable gas entry into the stomach at 40 cm H₂O airway pressure. These patients are identified as “censored” (Λ) in fig. 1. No statistically significant pop-off point differences were noted with regard to age, weight, sex, physical status, existence of congenital heart disease, preoperative sedation with midazolam, or the investigator providing positive pressure ventilation (n = 10).

Discussion

Acute gastric distension may occur during positive pressure mask airway management in pediatric patients,

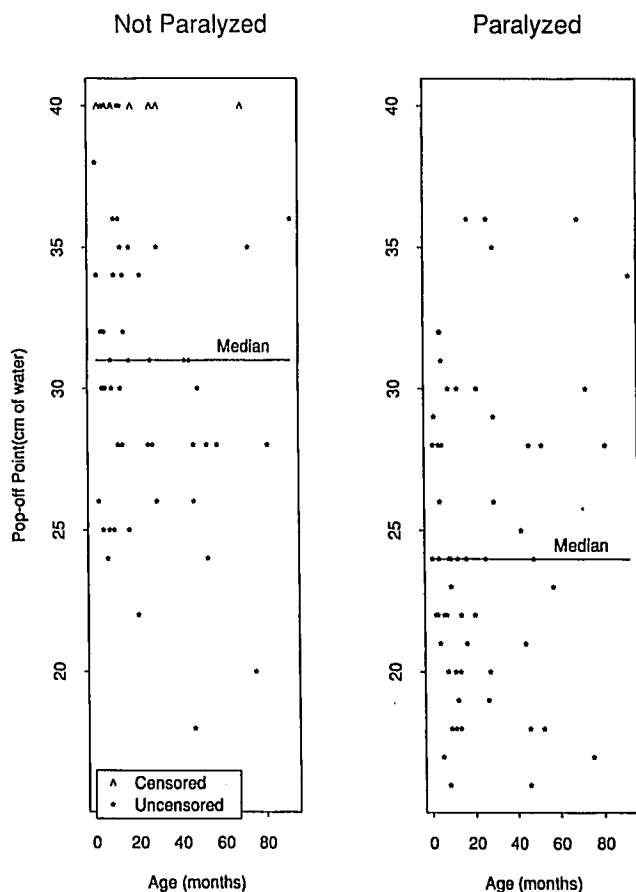


Fig. 1. Shown are the pop-off points (cm H₂O) as related to age in the nonparalyzed and paralyzed state. "Censored" (Δ) data points in the nonparalyzed group represent those patients in whom no gastric gas insufflation was detected at 40 cm H₂O airway pressure.

and it is the opinion of many that this is a common phenomenon.^{3,6} Potential complications of this gastric gas insufflation include cardiorespiratory compromise² and increased risk of pulmonary aspiration.¹ In this study, we have shown that the application of cricoid pressure is 100% effective in preventing gas insufflation of the stomach in both nonparalyzed and paralyzed infants and children with normal airway anatomy and function up to a PIP of 40 cm H₂O. Our results are consistent with those of other adult^{4,5} and pediatric studies.^{6,7} In the routine management of pediatric patients in the operating room, one can often induce gastric distension. Our study suggests that cricoid pressure may be effective in preventing gastric distension in these circumstances, especially if other maneuvers for preventing gastric distension are ineffective (changed head position, artificial airway insertion, or lower PIPs).

Although not evaluated in this study, truly difficult pediatric airway management situations associated with partial airway obstruction caused by airway pathology and/or deformity are common causes of gastric distension during mask ventilation.³ It is possible that these patients may benefit from early placement of cricoid pressure. This is especially true because the only adverse effect observed in the pediatric population has been transient tracheal obstruction due to inappropriate application, and only one complication has been reported in an 81-yr-old patient.¹⁰ Therefore, a risk/benefit analysis would seem to strongly support the routine application of cricoid pressure. If no benefit or a deleterious effect is seen, the technique could be abandoned as quickly as it was instituted.

The concept of "appropriate" cricoid pressure deserves comment. It is well known that pediatric tracheas are less rigid than those of adults, and are thus more easily compressed by conditions such as extreme hyperextension of the neck and inappropriate cricoid pressure (*i.e.*, pressure not applied to the cricoid cartilage).³ In fact, complete airway obstruction is easily accomplished in very young infants under the influence of excessive or malpositioned cricoid pressure. In this study, the single investigator applying cricoid pressure in every subject appreciated how easily incorrect cricoid pressure can obstruct the airway of a young infant. With minimal experimentation, before the study commenced, "appropriate" cricoid pressure was established. This pressure, as described by Sellick in 1961,⁸ consists of firm pressure applied to the cricoid cartilage, but not so firm as to obstruct the trachea in a clinically notable way. The amount of pressure applied certainly varied from application to application and was probably less in the younger patients, but the clinical outcome was consistent. The lungs of every patient in whom firm cricoid pressure was applied could be readily ventilated without the introduction of gas into the stomach.

With our recommendation to utilize cricoid pressure in the abovementioned settings comes some responsibility to teach its correct application. In the previous paragraph, "appropriate" cricoid pressure is described. A key point is that appropriately firm and positioned cricoid pressure never increased airway resistance in a clinically notable way. Inappropriate applications would increase airway resistance. If cricoid pressure is applied and no gas enters the lungs with mask ventilation, or if airway resistance is increased, the cricoid pressure should be lessened and/or its position changed. Airway pressure increases should be avoided.

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Of course, familiarity with the anatomy of the larynx and trachea is essential in all age groups for the success of this technique.

Each patient was assigned one of two cricoid application sequences based on the parity of the patient's hospital number. Therefore, there was no bias from the investigators. However, the individual applying cricoid pressure was also the auscultator; therefore, this individual was not blinded. This represents a study design flaw that could introduce bias in the results.

We did not know how sensitive auscultation would be as an indicator of gas insufflation into the stomach. Therefore, we included *silent* epigastric distention as an endpoint for airway pressurization in case gas entered but was not heard. On no occasion did this occur. It also was conceivable that relatively small amounts of gas could enter the stomach without visible distention, but this also did not occur. At the end of each cricoid pressure application sequence, the stomach would be evacuated, and on no occasion when "gur-gles" were absent from the prior sequence was gas subsequently recovered from the stomach. Therefore, we felt that auscultation was a very sensitive indicator of gastric gas insufflation.

However, the first 15 patients were examined using both the Doppler and the stethoscope as the auscultory method. In every case, the gas entry was detected *via* the stethoscope at the same time as the Doppler. In 5 of 15 subjects using the Doppler, it was virtually impossible to distinguish insufflation of gas *versus* background noise. Hence, the Doppler was eliminated from the remainder of this study and all gas insufflation data presented in this paper was generated using the stethoscope.

When not applying cricoid pressure, the pop-off point, in going from the nonparalyzed to the paralyzed state, clearly decreased. However, the range over which pop-off occurred was wide (fig. 1). Because no patient's pop-off point was less than 16 cm H₂O (NP or P groups), it would seem reasonable to conclude that PIPs \leq 15 cm H₂O are less likely to induce gastric distension. Our results are consistent with those of another study;¹¹ however, this study was done in adults.

Paralysis decreases the median pop-off point; thus, neuromuscular blockade and, *perhaps*, even "functional paralysis" (*i.e.*, cardiac arrest) may increase the risk for gastric distension. The mechanism for this phenomenon probably lies with the function of both the upper and lower esophageal sphincters (UES and LES). Ruben *et al.*¹¹ noted that the minimum gastric insuffla-

tion pressure lies between 15 and 20 cm H₂O (measurement taken just above the LES). If the measurement is made in the pharynx above the UES (cricopharyngeal sphincter), higher pressure is required, indicating either a higher tone in this sphincter or an overall increased tone in the UES-LES resistor series. Because the cricopharyngeus muscle is partly striated,^{12,13} it is possible that paralysis may selectively diminish UES tone, thus allowing a greater gas pressure to be exerted on the LES. This hypothesis is consistent with our results. Another theory equally consistent with our data is that paralysis increases abdominal/gastric compliance. It is likely that both processes contribute to the potential for gaseous distention. The exact mechanism is the subject of future studies.

This study did not detect any decrease in pop-off threshold in patients having received preoperative oral midazolam compared with patients who did not receive midazolam. Because intravenous diazepam does lower LES tone,^{14,15} the lack of influence of midazolam on LES pressure¹⁶ must be considered to have an advantage over diazepam, considering that acid aspiration during induction of general anesthesia remains a cause of morbidity and mortality. It is important to note that the results with intravenous midazolam¹⁶ are not necessarily representative of the situation when the drug is given orally.

Although clinicians may believe that gastric distension is more common in young infants, we observed that the pop-off point threshold did not differ with age. If the clinical observation is correct, it is likely the results of other factors, such as ventilation techniques and magnitude of PIP, account for the perceived differences between young infants and older patients.

In conclusion, appropriate application of cricoid pressure is a potentially valuable maneuver during airway management *via* mask in infants and children to prevent gastric gas insufflation. This maneuver would seem to be even more valuable in paralyzed infants and children due to the lower PIP at which gastric insufflation occurs. A mask PIP \leq 15 cm H₂O seems to minimize the potential for gastric gas insufflation.

The authors wish to thank Dr. L.E. Moses, Professor of Statistics, and Douglas J. Haney, Postgraduate Student of Statistics, Stanford University, California, for their valuable time and expertise.

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