

Effect of facemask ventilation with different ventilating volumes on gastric insufflation during anesthesia induction in patients undergoing laparoscopic cholecystectomy

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ABSTRACT

الأهداف: لمقارنة حدوث تضخم في المعدة أثناء تحرير في المرضى الذين يخضعون لاستئصال المراة بالمنظار، وذلك باستخدام تهوية قناع الوجه ب أحجام تهوية مختلفة.

المنهجية: أجريت دراسة استطلاعية لـ 54 مريضاً يخضعون لاستئصال المراة بالمنظار تحت التخدير العام خلال الفترة من يناير 2018 يونيو 2018. تهوية قناع الوجه مع وضع الحجم في 6 مل / كجم (مجموعة V6)، 8 مل / كجم (مجموعة V8) أو 10 مل / كجم (المجموعة V10) تم تطبيقه لمدة 120 ثانية (ثانية). أثناء تحرير المعدة، قياس النفخ المعدي بواسطة الموجات فوق الصوتية. وقيم النفخ المعدي باستخدام الرؤية المباشرة للتنفس الباطني. كما رصدت المعلمات الجهاز التنفسي.

النتائج: كان معدل حدوث تضخم في المعدة في المجموعة V10 أعلى بكثير من ذلك في المجموعتين V6 (11.1%) و V8 (16.7%). ومع ذلك ، فإنه لم يظهر أي فرق كبير بين المجموعتين V6 و V8. أثناء تهوية قناع الوجه لمدة 120 ثانية، حدث اتجاه تراكم ثاني أكسيد الكربون في المجموعة V6، وعرضت المجموعة V10 أدلة على التهوية المفرطة. يمكن اعتبار المجموعة V8 أفضل توازن بين انخفاض نفخ المعدة والتهوية الفعالة في الرئة.

الخلاصة: يبدو أن تهوية قناع الوجه بحجم تهوية 8 مل / كغ يظهر أكسجة مسبقة وتجنب النفخ المعدي المفرط أثناء تحرير في استئصال المراة بالمنظار.

Objectives: To compare the occurrence of gastric insufflation during anesthesia induction in patients undergoing laparoscopic cholecystectomy, using facemask ventilation with different ventilation volumes.

Methods: This is a prospective study of 54 patients undergoing laparoscopic cholecystectomy under general anesthesia between January 2018 and June 2018. Facemask ventilation with volume mode

controlled at 6 ml/kg (group V6), 8 ml/kg (group V8) or 10 ml/kg (group V10) was applied for 120 seconds (sec) during anesthesia induction. Before facemask ventilation and at 120 sec of facemask ventilation, gastric insufflation was determined by ultrasonography. Gastric insufflation was also evaluated using direct vision of laparoscopy. Respiratory parameters were monitored.

Results: The incidence of gastric insufflation in group V10 (55.6%) was significantly higher than that in groups V6 (11.1%) and V8 (16.7%). However, it showed no significant difference between groups V6 and V8. During facemask ventilation for 120 sec, carbon dioxide accumulation trend occurred in group V6, and group V10 exhibited evidence of hyper-ventilation. Group V8 might be considered the best balance between low gastric insufflation and effective lung ventilation.

Conclusion: Facemask ventilation with a ventilation volume of 8 ml/kg seems to have adequate preoxygenation and avoid excessive gastric insufflation during anesthesia induction in laparoscopic cholecystectomy.

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A good visual field is crucial for successful laparoscopic cholecystectomy. However, there is a high risk of gastric insufflation during anesthesia induction with facemask ventilation. This impair the surgical visual field, which sometimes require emptying the stomach using a gastric tube. In patients with general anesthesia, gastric insufflation can cause various complications¹⁻³ such as stomach perforation, gastric content regurgitation, nausea, vomiting, and aspiration pneumonitis, leading to increased risk of mortality.

Different ventilation modes during anesthesia induction can cause different degrees of gastric insufflation,⁴⁻⁷ but there are few reports of the relationship between gastric insufflation and volume-controlled facemask ventilation during anesthesia induction. Over the past years, some studies have found that ultrasonography can accurately assess the volume and properties of gastric contents.⁸⁻¹⁰ Bouvet et al¹¹ reported a significant correlation between antral area and gastric volume measured by ultrasonography. Therefore, we selected the antral area measured by ultrasonography to calculate gastric volume.

In the present study, ultrasonography was used to detect the effect of facemask ventilation with different ventilation volumes on gastric insufflation. Our study was performed on patients undergoing laparoscopic cholecystectomy during general anesthesia induction, so as to provide reference for clinical anesthesia operation.

Methods. Prior related study was searched in PubMed using keywords such as facemask ventilation, anesthesia induction, gastric insufflation, and laparoscopic cholecystectomy. This is a prospective study of 54 patients (29 males and 25 females) undergoing elective laparoscopic cholecystectomy under general anesthesia between January 2018 and June 2018 in the Department of Anesthesia, Fuyang District First People's Hospital, Hangzhou, China. Our study was approved by the Ethics Committee of Fuyang District First People's Hospital and followed the principles of the Declaration of Helsinki. Informed consent was obtained from the patients.

The age range was 29-84 years. American Society of Anesthesiologists physical status was I-II. The exclusion criteria were gastroparesis, gastrectomy,

gastroesophageal regurgitation, upper respiratory tract infection, potentially difficult airway, allergy to muscle relaxant, hypertension, diabetes mellitus, obesity, and an unclear ultrasound image under gastric ultrasonography before anesthesia induction. The patients were randomly divided into 3 groups using a random table (n=18): Tidal volume (VT)=6 ml/kg (group V6), VT=8 ml/kg (group V8) and VT=10 ml/kg (group V10). Patients in the 3 groups were further divided into 2 subgroups, GI⁺ and GI⁻, according to the presence or absence of gastric insufflation.

Anesthesia induction. Intravenous access to an upper arm was established. Routine electrocardiography, oxygen saturation (SpO_2) and noninvasive blood pressure monitoring were performed after entering the operation room. Midazolam 0.05 mg/kg (Enhua Pharmaceuticals, Jiangsu, China) was provided intravenously. Facemask oxygen inhalation was 3 L/min. Sufentanil citrate (Renfu Pharmaceuticals, Yichang, China) 0.5 µg/kg, propofol (AstraZeneca, China) 1.8 mg/kg and rocuronium (Xianju Pharmaceuticals, Zhejiang, China) 0.6 mg/kg were intravenously administered for anesthesia induction.

An oropharyngeal airway was placed when the patient's eyelash reflex disappeared by the same anesthesiologist with 5 years of experience. A facemask suitably sized for the patient was applied to ensure full sealing. Facemask ventilation was then started for 120 seconds (sec) with a Datex Ohmeda S/5 Avance anesthetic machine (Ohmeda, USA) at oxygen flow 3 L/min, inspired oxygen concentration 100%, respiratory rate 15/min and inspiratory/expiratory ratio 1:2. The ventilation volumes were set at VT 6 ml/kg (group V6), VT 8 ml/kg (group V8), or VT 10 ml/kg (group V10).

The VT was set by a nurse and the numbers on the anesthetic machine was covered using an opaque paper. The anesthesiologists and surgeons were blinded to patient grouping.

Ultrasonography. Before facemask ventilation after anesthesia induction, and at 120 sec of facemask ventilation, a portable ultrasound locator (Acuson Sequoia 512 color Doppler ultrasonic apparatus with a 3.5 MHz ultrasonic probe) was used to scan the sagittal plane under the xiphoid process.¹¹ The section image was adjusted to include the antrum, sagittal plane of abdominal aorta, left lobe of liver, and superior mesenteric artery. The anteroposterior diameters (D1) of the antrum and superoinferior (D2) of the antrum were measured 3 times to obtain a mean value (Figure 1). The cross-sectional antral area was calculated using the formula: antral area = $\pi \times D1 \times D2 / 4$. If there was a comet-tail sign or antral area enlargement, a positive

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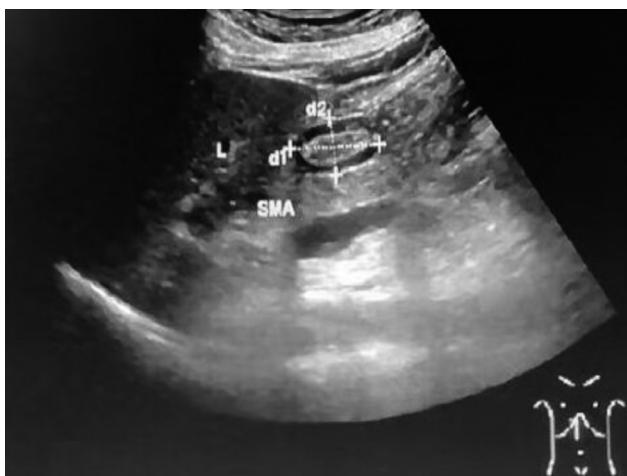


Figure 1 - Gastric ultrasonographic image during induction of anesthesia. The anteroposterior diameter (D1) and the superoinferior diameter (D2) of the antrum were measured. L - liver, SMA - superior mesenteric artery.

gastric insufflation was recorded.¹¹ After the first ultrasonic measurement, the position of the ultrasonic probe was marked, and the measurements were repeated before facemask ventilation after anesthesia induction and at 120 sec of facemask ventilation at the mark. Endotracheal intubation began at 120 sec of facemask ventilation. Sevoflurane 3% was used to maintain anesthesia during surgery.

Intraoperative evaluation. After sterilizing and laying towel, the surgeon performed laparoscopic cholecystectomy with 3 ports. After placing the laparoscope in the abdominal cavity, the degree of gastric distension was evaluated by the surgeon with a gastric distension score: grade one, the stomach was unfilled, there was no tension within it and the lesser curvature did not enter into the gallbladder area; grade 2, the stomach was filled a little, there was low tension within it and the lesser curvature partly entered into the gallbladder area; grade 3, the stomach was moderately filled, there was high tension within it, the lesser curvature covered completely the gallbladder area, but the surgical visual field could be exposed with a laparoscopic brace for difficult completion of the surgery; grade 4, the stomach was extremely distended, there was extremely high tension within it, the lesser curvature covered completely the whole gallbladder area, it was difficult to expose the surgical visual field with a laparoscopic brace, and it was necessary to place a gastric tube to expel gas and reveal the surgical visual field before the surgery could be completed. In our study as we defined grade one or 2 of gastric distension was an excellent exposure of the hepatobiliary triangle.

The pressure of carbon dioxide pneumoperitoneum was maintained at 11-17 mmHg.

Respiratory parameters. Oxygen saturation was recorded at 30 sec, real-time peak inspiratory pressure (PIP) was recorded at 60 sec, end-tidal carbon dioxide partial pressure (PetCO_2) was recorded at 90 sec, and end-tidal oxygen concentration (ETO_2) was recorded at 120 sec of facemask ventilation.

Statistical analysis. In our pre-trial, a 12 ml/kg (group V12) and 14 ml/kg (group V14) were included and 10 adult patients in each group were pre-tested. The incidences of gastric insufflation in each group were 10% (group V6), 20% (group V8), 40% (group V10), 40% (group V12), and 60% (group V14). According to the Cochran-Armitage trend test, the patients in each group were set up with the same configuration. With an effectiveness of 0.9, the continuous correction of bilateral Z test was performed, resulting in 16 patients for each group (accurate test efficiency 0.91). Assuming a drop-out rate of 10%, there should be 18 patients for each group. The average PIP in group V12 was 22 cm H_2O (1 cm $\text{H}_2\text{O}=0.098$ kPa) during anesthesia induction, which was much higher than 15 cm H_2O ¹¹ when low gastric insufflation rate and effective pulmonary ventilation were both possible. The mean PIP in group V14 was 25 cm H_2O with a higher gastric insufflation rate, so neither group was included in our study. Therefore, the total sample of the remaining 3 groups were 54 patients with 18 patients in each group.

Quantitative data were expressed as mean and standard deviation. The ANOVA test was used for multi-group comparison followed by the least significant difference (LSD) test for pairwise comparison. The paired t-test was used for intra-group comparison. Comparison of PetCO_2 , ETO_2 and PIP at 30 sec, 60 sec, 90 sec, and 120 sec of facemask ventilation in the 3 groups were made using the 2-way ANOVA test. Qualitative data were expressed by constituent ratio or rate and analyzed using the Chi-square test was used for comparison between groups. The rank sum test was used for comparison between groups for grade of treatment. All statistical analyses were performed using the Statistical Package for Social Sciences version 21.0 (IBM Corp, Armonk, NY, USA). A $p<0.05$ was considered statistically significant.

Results. There was no significant difference in the general data between the 3 groups ($p>0.05$, Table 1). No patients were excluded due to unclear imaging of the antral area by ultrasonography either before facemask ventilation after induction or at 120 sec of

mask ventilation. In no patient relevant air leak during facemask ventilation was found. No gastric distension was found visually by the surgeons in patients without gastric insufflation assessed by ultrasonography. The number of patients (0, 2, and 4) with gastric insufflation visually found by the surgeons, correlated with gastric distension measured by ultrasonography in groups V6, V8 and V10. However, no patient required gastrointestinal decompression for excessive gastric distension. Gastric distension during surgery were graded as grade one in 18 patients in group V6, grade one in 16 patients and grade 2 in 2 patients in group V8, grade one in 14 patients, and grade 2 in 4 patients in group V10. The excellent and good rates were 100%. During anesthesia induction, SpO_2 was equal to or greater than 99% in all 3 groups.

The incidence of gastric insufflation in group V10 was significantly higher than that in groups V6 and V8; but the difference between groups V6 and V8 was not statistically significant (Table 2). Compared with the antral area before facemask ventilation after anesthesia induction, the antral area in groups V6 and group V8 at 120 sec of facemask ventilation was not significantly changed, but the antral area in group V10 at 120 sec of facemask ventilation was significantly increased. The antral area of the GI⁺ subgroup in group V10 at 120 sec of facemask ventilation was significantly higher than that before facemask ventilation after anesthesia induction, while that of the GI⁺ and GI⁻ subgroups in the groups V6 and V8 and that of the GI⁻ subgroup in group V10 were not significantly changed compared with that before facemask ventilation after anesthesia induction (Table 3).

End-tidal carbon dioxide partial pressure was higher in group V6 than that in groups V8 and V10 and lower in group V10 than that in group V8 at 30 sec, 60 sec, 90 sec and 120 sec of facemask ventilation. End-tidal carbon dioxide partial pressure was higher in group V6 and lower in group V10 at 60 sec, 90 sec and 120 sec compared with 30 sec, higher in group V6 and lower in group V10 at 90 sec and 120 sec compared with 60 sec, and higher in group V6 and lower in group V10 at 120 sec compared with 90 sec. End-tidal oxygen concentration was lower in group V6 than that in the V8 and V10 group and higher in group V10 than that in group V8 at 30 sec, 60 sec, 90 sec, and 120 sec. End-tidal oxygen concentration was higher in 3 groups at 60 sec, 90 sec and 120 sec compared with 30 sec, higher in 3 groups at 90 sec, and 120 sec compared with 60 sec, and higher in 3 groups at 120 sec compared with 90 sec. Peak inspiratory pressure was lower in group V6

Table 1 - Comparison of general data between the 3 groups.

Group	n	Age, year	Male	Female	BMI, kg/m ²
V6	18	45.4±9.3	12	6	22.4±2.5
V8	18	44.9±10.0	9	9	23.0±1.2
V10	18	42.7±8.7	8	10	21.0±1.7
p-value		0.636		0.38	0.148

Data are expressed as mean ± standard deviation or frequencies.
V6 - facemask ventilation with volume mode controlled at 6 ml/kg,
V8 - facemask ventilation with volume mode controlled at 8 ml/kg,
V10 - facemask ventilation with volume mode controlled at 10 ml/kg,
BMI - body mass index

Table 2 - Comparison of incidences of gastric insufflation during anesthesia induction between the 3 groups.

Group	n	Gastric insufflation n (%)	P-value
V6	18	2 (11.1)	0.005
V8	18	3 (16.7)	
V10	18	10 (55.6) [†]	

Data are expressed as percentages or frequencies. V6 - facemask ventilation with volume mode controlled at 6 ml/kg, V8 - facemask ventilation with volume mode controlled at 8 ml/kg, V10 - facemask ventilation with volume mode controlled at 10 ml/kg
* - p<0.05 versus group V6, † - p<0.05 versus group V8

than that in the V8 and V10 group and was higher in group V10 than that in group V8 at 30 sec, 60 sec, 90 sec, and 120 sec (Table 4).

Discussion. Our study found that facemask ventilation with a ventilation volume of 10 ml/kg had a significantly higher incidence of gastric insufflation than 6 or 8 ml/kg during induction of anesthesia in laparoscopic cholecystectomy. Facemask ventilation with a ventilation volume of 8 ml/kg seems to have generally better respiratory parameters during the 120 sec of anesthesia induction than the other 2 ventilation volumes.

During general anesthesia induction, apart from hand-controlled ventilation, pressure-controlled and volume-controlled ventilation are the most commonly used ventilation modes.^{12,13} In our study, volume-controlled ventilation mode was used. Laparoscopic cholecystectomy is technically sensitive to the degree of gastric insufflation; thus, its prevention is critically important. In our study, higher ventilation volume was associated with higher PIP value, which reached 17 cmH₂O with the ventilation volume of 10 ml/kg. The corresponding incidence of gastric insufflation was high as assessed by antral ultrasonography. However, the volume of insufflation did not adversely affect the

Table 3 - Comparison of the antral area before and after facemask ventilation in the 3 groups.

Group	n	Antral area before facemask ventilation, mm ²	Antral area after facemask ventilation, mm ²	P-value
V6	18	394.5 ± 55.6	421.8 ± 48.5	0.140
GI ⁺	2	387.5 ± 13.1	409.8 ± 52.9	0.716
GI ⁻	16	395.4 ± 59.0	423.3 ± 49.6	0.172
V8	18	401.8 ± 43.7	425.2 ± 43.9	0.130
GI ⁺	3	381.6 ± 25.0	436.6 ± 41.0	0.273
GI ⁻	15	405.8 ± 46.1	422.9 ± 45.5	0.308
V10	18	417.9 ± 46.8	503.9 ± 112.1	0.001
GI ⁺	10	429.1 ± 44.3	573.6 ± 97.3	<0.001
GI ⁻	8	404.0 ± 48.9	416.8 ± 52.3	0.441

Data are expressed as mean±standard deviation. V6 - facemask ventilation with volume mode controlled at 6 ml/kg, V8 - facemask ventilation with volume mode controlled at 8 ml/kg, V10 - facemask ventilation with volume mode controlled at 10 ml/kg,
GI⁺ - with gastric insufflation, GI⁻ - without gastric insufflation

Table 4 - Comparison of end-tidal carbon dioxide partial pressure, end-tidal oxygen concentration, and peak inspiratory pressure at 30sec, 60sec, 90sec, and 120 sec of facemask ventilation in the 3 groups.

Variables	Group	n	Facemask ventilation 30 sec	Facemask ventilation 60 sec	Facemask ventilation 90 sec	Facemask ventilation 120 sec
PetCO ₂ , mmHg	V6	18	36.5±1.3*	38.7±1.4 [§]	40.7±1.6 ^{§**}	42.4±1.8 ^{*§**††}
	V8	18	35.0±1.4	35.4±1.6	35.2±1.4	35.5±1.6
	V10	18	34.0±1.3 [‡]	32.4±1.8 ^{‡§}	30.4±1.8 ^{‡§**}	28.4±1.8 ^{‡§**††}
p-value [†]			<0.001	<0.001	<0.001	<0.001
ETO ₂ , mmHg	V6	18	78.3±1.6*	80.3±1.6 [§]	82.4±1.7 ^{§**}	84.2±1.7 ^{*§**††}
	V8	18	84.2±1.3	86.2±1.5 [§]	88.1±1.6 ^{§**}	90.1±1.7 ^{*§**††}
	V10	18	86.3±1.2 [‡]	88.4±1.2 ^{‡§}	90.4 ± 1.2 ^{‡§**}	92.4±1.2 ^{‡§**††}
p-value [†]			<0.001	<0.001	<0.001	<0.001
PIP, cmH ₂ O	V6	18	11.9±0.9*	12.2±0.7*	11.9±0.7*	12.2±0.8*
	V8	18	15.2±0.8	15.2±0.8	15.3±0.8	14.9±1.0
	V10	18	17.0±0.5 [‡]	17.0±0.9 [‡]	17.3±0.8 [‡]	17.3±0.9 [‡]
p-value [†]			<0.001	<0.001	<0.001	<0.001

Data are expressed as mean±standard deviation. V6 - facemask ventilation with volume mode controlled at 6 ml/kg, V8 - facemask ventilation with volume mode controlled at 8 ml/kg, V10 - facemask ventilation with volume mode controlled at 10 ml/kg, PETCO₂ - end-tidal carbon dioxide partial pressure. ETO₂ - end-tidal oxygen concentration, PIP - peak inspiratory pressure. †Comparison between the 3 groups at one specific time point. *p<0.05 versus (vs) groups V8 and V10, ‡p<0.05 vs group V8, § - p<0.05 vs 30 sec, **p<0.05 vs 60 sec, ††p<0.05 vs 90 sec

operation. In a previous study,¹¹ the average ventilation volume was approximately 8 ml/kg when the PIP value was 15 cmH₂O, which was consistent with the average PIP value of 15 cmH₂O in group V8 in our study.

In the present study, the antral area in group V10 at 120 sec of facemask ventilation was significantly higher than that at 30 sec, which was mainly caused by the significant increase in the antral area in the GI⁺ subgroup of group V10. We speculated that facemask ventilation with a large ventilation volume was the direct cause of gastric insufflation in our patients during anesthesia induction. However, this ventilation volume did not cause severe gastric distension; therefore, gastric tube placement for decompression was unnecessary. The

main reason for this was the oropharyngeal airway used in our study.¹⁴ A second reason was that the induction time of anesthesia was only 120 sec. In this short period of time, gastric insufflation might not cause gastric distension and impair the visual field.

Ventilation of the patients during anesthesia induction was assessed using ETO₂, PetCO₂, and PIP. In our study, the first 30 sec of facemask ventilation was the ventilation balance time eliminating the effect of initial facemask ventilation on chest wall compliance. In terms of gas exchange, although none of the patients in group V6 had a reduction in SpO₂ during anesthesia induction, the PetCO₂ value in group V6 at 120 sec of facemask ventilation was significantly higher than that at

the other time points. Therefore, the ventilation volume of 6 ml/kg had a tendency of hypoventilation. End-tidal carbon dioxide partial pressure in group V10 was 28 mmHg at 120 sec of facemask ventilation, indicating hyperventilation. Peak inspiratory pressure at each time point in group V10 was also higher than that in the other 2 groups; thus, the incidence of gastric insufflation was higher in this group. In terms of oxygen supply and nitrogen removal, ETO_2 was increased in all 3 groups, but ETO_2 in group V6 was lower during the whole facemask ventilation (approximately 84 at 120 sec), indicating that its oxygen reserve was poor. Group V8 might be considered the best balance between low gastric insufflation rate and effective lung ventilation.

It has been reported that a ventilation volume less than 6 ml/kg for general anesthesia resulted in hypoventilation;^{3,15} therefore, the low limit of ventilation volume was set at 6 ml/kg. Gastric insufflation greater than 5 ml can be evaluated using a stethoscope placed on the epigastric area.^{8,9,11} This method is highly subjective, and its reliability is uncertain when the air enters the stomach at a slower rate. Therefore, we used ultrasonography and direct vision of laparoscopy for the first time to assess gastric insufflation. There were more patients with gastric insufflation determined by ultrasonography than that determined by direct vision. There may be several possible reasons for this discrepancy. First, the determination of gastric insufflation was at different times for ultrasonography and direct vision. Second, the intraabdominal pressure was increased, and gastrointestinal peristalsis was proceeded during carbon dioxide pneumoperitoneum, which may have promoted the entry of gastric contents to the duodenum. Third, ultrasonography may be more sensitive in detecting gastric insufflation than direct vision under laparoscopy.

Rocuronium is a non-depolarizing muscular relaxant and was used during anesthesia induction in our study. It can reduce the tension of the proximal esophageal sphincter and pharyngeal musculature; thus, facilitating facemask ventilation, but also increase the incidence of gastric insufflation.^{10,14,16} In order to prevent airway resistance caused by glossotorsis and to decrease air entry into the stomach during facemask ventilation, an oropharyngeal airway was placed before commencing facemask ventilation in our study.

Study limitations. First, the sample size was relatively small. Second, the ultrasonography was not performed by a professional ultrasonographer, which might result in data error. Third, this is a single-center study.

In conclusion, facemask ventilation with a ventilation volume of 8 ml/kg rather than 6 or 10 ml/kg seems to

have adequate preoxygenation and a lower incidence of gastric insufflation during anesthesia induction in laparoscopic cholecystectomy. Further investigation with a larger sample size and other surgeries is needed for better optimization of facemask ventilation.

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Statistics

Excerpts from the Uniform Requirements for Manuscripts Submitted to Biomedical Journals updated November 2003.
Available from www.icmje.org

Describe statistical methods with enough detail to enable a knowledgeable reader with access to the original data to verify the reported results. When possible, quantify findings and present them with appropriate indicators of measurement error or uncertainty (such as confidence intervals). Avoid relying solely on statistical hypothesis testing, such as the use of *P* values, which fails to convey important information about effect size. References for the design of the study and statistical methods should be to standard works when possible (with pages stated). Define statistical terms, abbreviations, and most symbols. Specify the computer software used.