Real-time Detection of Gastric Insufflation Related to Facemask Pressure–controlled Ventilation Using Ultrasonography of the Antrum and Epigastric Auscultation in Nonparalyzed Patients

A Prospective, Randomized, Double-blind Study

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ABSTRACT

Background: The authors sought to determine the level of inspiratory pressure minimizing the risk of gastric insufflation while providing adequate pulmonary ventilation. The primary endpoint was the increase in incidence of gastric insufflation detected by ultrasonography of the antrum while inspiratory pressure for facemask pressure-controlled ventilation increased from 10 to 25 cm H_2O.

Methods: In this prospective, randomized, double-blind study, patients were allocated to one of the four groups (P10, P15, P20, and P25) defined by the inspiratory pressure applied during controlled-pressure ventilation: 10, 15, 20, and 25 cm H_2O. Anesthesia was induced using propofol and remifentanil; no neuromuscular-blocking agent was administered. Once loss of eyelash reflex occurred, facemask ventilation was started for a 2-min period while gastric insufflation was detected by auscultation and by real-time ultrasonography of the antrum. The cross-sectional antral area was measured using ultrasonography before and after facemask ventilation. Respiratory parameters were recorded.

Results: Sixty-seven patients were analyzed. The authors registered statistically significant increases in incidences of gastric insufflation with inspiratory pressure, from 0% (group P10) to 41% (group P25) according to auscultation, and from 19 to 59% according to ultrasonography. In groups P20 and P25, detection of gastric insufflation by ultrasonography was associated with a statistically significant increase in the antral area. Lung ventilation was insufficient for group P10.

Conclusion: Inspiratory pressure of 15 cm H_2O allowed for reduced occurrence of gastric insufflation with proper lung ventilation during induction of anesthesia with remifentanil and propofol in nonparalyzed and nonobese patients. **(ANESTHESIOLOGY 2014; 120:326-34)**

PULMONARY aspiration of gastric contents has been reported to be the first cause of mortality related to general anesthesia.[1] Predisposing factors for pulmonary aspiration include increased gastric contents, increased tendency to regurgitate, and laryngeal incompetence.[2] For patients at risk of aspiration, the rapid-sequence induction and intubation technique avoiding facemask ventilation (FMV), or with FMV with application of cricoid pressure, remain recommended.[3] However, pulmonary aspiration may also occur in patients under fasting condition and patients without any known predisposing factors.[4–6] Indeed, insufflation of air into the stomach during pulmonary ventilation in patients with apnea with an unprotected airway may be one of the

What We Already Know about This Topic

- No gastric insufflation was found for peak airway pressure of less than 20 cm H_2O during facemask ventilation by using an auscultation method with a stethoscope or microphone

What This Article Tells Us That Is New

- In 67 anesthetized and nonparalyzed adult patients with non-obstructed upper airway, real-time ultrasonography of the antrum for the detection of gastric insufflation revealed that pressure-controlled ventilation with inspiratory pressure of 15 cmH2O and zero positive end-expiratory pressure achieved lower occurrence of gastric insufflation with proper lung ventilation during anesthesia induction

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causes of pulmonary aspiration of gastric contents.[7–11] The entry of air into the stomach can bring about an increase in gastric pressure leading to regurgitation of gastric contents into the esophagus, while equally leading to possible hemodynamic and pulmonary failures.[12]

The use of pressure-controlled ventilation rather than manual or volume-controlled ventilation reduces the peak airway pressure and consequently the risk of entry of air into the stomach during FMV.[8,13] In adult patients, no gastric insufflation was found for peak airway pressure of less than 20 cm H_2O.[13–15] Therefore, it has been recommended that peak airway pressure or pop-off valve setting be limited to 20 cm H_2O to avoid occurrence of gastric insufflation during FMV.[8–11]

These data and recommendations arose from studies using an auscultation method with a stethoscope or microphone placed on the epigastric area to detect the entry of air into the stomach during ventilation. However, the reliability of auscultation to detect gastric insufflation during FMV remains uncertain, because this method was assessed using an experimental model that differs from a clinical situation.[16]

Ultrasonographic measurement of the antral area is a well-described technique, currently used for the assessment of gastric emptying in patients with diabetes mellitus or dyspepsia, since the gastric antrum is visible in almost all subjects, irrespective of gas contents in the fundus.[17,18] Recent studies have reported that a quantitative approach through measurement of the antral area and a qualitative examination of the antrum allow for reliable assessment of gastric contents during the preoperative period.[19,20] In a preliminary study, we found that entry of air into the stomach was easily visualized by using real-time ultrasonography of the antrum, as acoustic shadows or comet-tail artifacts that appear in the gastric antrum during FMV.[21] We also recorded significant increases in the antral area after pressure-controlled ventilation for peak airway pressure above or equal to 15 cm H_2O.[21] These preliminary results questioned the accepted level of 20 cm H_2O for a peak airway pressure that avoids risk of gastric insufflation. They also suggested that ultrasonography could be of interest for the detection of gastric insufflations during FMV.

The aims of this prospective, randomized, double-blind, parallel study were: first, to determine the level of inspiratory pressure that reduces the risk of gastric insufflation during FMV while providing adequate pulmonary ventilation in anesthetized adult patients; and second, to assess the use of real-time ultrasonography of the antrum for the detection of gastric insufflation. We hypothesized that ultrasonography of the antrum allowed for the detection of a statistically significant increase in incidence of gastric insufflation while inspiratory pressure increased from 10 to 25 cm H_2O.

Materials and Methods

This trial was registered at the French National Agency for Medicines and Health Products Safety (ANSM, N°2012-A00775-38) on June 14, 2012, and was approved by an Institutional Ethics Committee (Comité de Protection des Personnes Sud-Est III, N° 2012-050B, Lyon, France). This single-site study was performed in our hospital (Édouard Herriot Hospital, Lyon, France), from November 5, 2012 to December 12, 2012. After obtaining written patient consent, patients scheduled for elective surgery (ophthalmologic, orthopedic, urologic, or ear-nose-and-throat surgery) requiring tracheal intubation were enrolled through our department. Patient inclusion criteria were: American Society of Anesthesiologists physical status 1 and 2, age up to 18 yr, body mass index less than 30 kg/m^2, and less than two from five criteria predicting difficult mask ventilation as described by Langeron *et al.*[22] Exclusion criteria were patient refusal, pregnancy, a known or predicted respiratory disease, oropharyngeal or facial pathology, and risk of aspiration.

Patients were randomized by a computer-generated list into one of the four groups defined by the applied inspiratory pressure (10, 15, 20, or 25 cm H_2O, corresponding to groups P10, P15, P20, and P25, respectively). No blocking, stratification, or other restriction were used when creating group assignments. Patients were allocated in a 1:1 ratio. Allocation concealment was ensured by the use of coded, sealed opaque envelopes.

All patients were premedicated with alprazolam 0.25 mg and hydroxyzine 1 mg/kg orally 1 h before induction of anesthesia.

A preoperative measurement of the antral area was performed by a physician (M.-L.A.) for each patient lying in the supine position on the operating table, using ultrasonography (SonoSite, Inc., Bothell, WA; S-Nerve, fitted with a 2 to 5.5 MHz probe), as previously described.[23] In brief, longitudinal (D1) and anteroposterior (D2) diameters of a single section of the gastric antrum in the sagittal plane passing through the aorta were determined, using the abdominal aorta and the left lobe of the liver as internal landmarks to obtain the same standardized scanning level consistently.[17] As the cross-section of the gastric antrum is elliptical, its area was calculated in all subjects using the following formula:

$$\text{Antral area} = \pi \times D1 \times D2 / 4$$

The measurements of the gastric antrum were obtained between antral contractions to provide a measure of the relaxed width of the antrum.

Patients were preoxygenated according to the method described by Hamilton and Eastwood.[24] Anesthesia was induced by a physician (L.B.) using remifentanil (2 to 3 µg/kg) infused over 60 s using a programmable device, followed by a continuous infusion of 0.05 µg kg^{-1} min^{-1}, and propofol 2.5 mg/kg simultaneously administered over 45 s.[25] Halogenated anesthetic gases were not allowed during the study period. No neuromuscular-blocking drug was administered during induction of anesthesia, because muscular relaxation was not required for surgery, and because it has been previously reported that excellent intubating conditions may be

Fig. 1. Positioning of both the ultrasonography probe and the stethoscope on the epigastric area.

achieved using a combination of propofol and remifentanil without muscle relaxant.[25,26]

Once loss of eyelash reflex occurred, real-time ultrasonography of the antral area was started by the same physician who performed the preoperative measurement of the antral area (M.-L.A.), using the same landmarks. At the same time, another physician (C.A.) was starting continuous auscultation of the epigastric area to detect any occurrence of gastric insufflation while FMV was performed, as previously described. These physicians were blinded one to another as regards the detection of the entry of air into the stomach and the inspiratory pressure applied during the FMV. This ventilation was initiated once both physicians were ready to perform their observations, that is, less than 10 s after loss of eyelash reflex occurred. Figure 1 illustrates the positioning of both the ultrasonography probe and the stethoscope on the epigastric area. The ultrasonography screen was positioned so that the physician performing the auscultation could not see it.

A Guedel (Biçakcilar, Istanbul, Turkey) oropharyngeal airway was placed in all patients before placement of the facemask after eyelash reflex loss had occurred to assure adequate mouth opening. A well-fitting disposable transparent facemask (#3 or #4; Ambu® Ultraseal, Ballerup, Denmark) was placed and fixed using a two-handed jaw-thrust technique followed by head-tilt, as previously described.[14] Mechanical breath was delivered with an inspiratory-to-expiratory ratio of 1:2, at a frequency of 15 breaths/min and with 100% oxygen, by a Primus ventilator (Dräger, Lübeck, Germany). No positive end-expiratory pressure was applied. FMV was continued for 120 s, and the trachea was thereafter intubated. Airway management, insertion of the oropharyngeal airway, and placement of the facemask were performed by a single experienced investigator (L.B.). After the trachea was intubated, an ultrasonographic measurement of the antral area was once again performed.

The occurrence of gastric insufflation during FMV according to the method used (ultrasonography or auscultation) was registered. Appearance of an acoustic shadow phenomenon and/or a comet-tail artifact into the antrum defined the ultrasonographic diagnosis of entry of air into the stomach (fig. 2).[27] A typical "gurgle" or "whoosh" heard while auscultating the epigastric area with a stethoscope defined the diagnosis of gastric insufflation through the use of auscultation method.

The following noninvasive respiratory parameters (available on the anesthesia monitor) were recorded at time 30, 60, 90, and 120 s during FMV and after tracheal intubation: the saturation level of oxygen in hemoglobin determined by a noninvasive method of pulse oximetry (Spo_2, %), the end-tidal carbon dioxide concentration in the expired air ($Etco_2$, mmHg), end-tidal fractional oxygen concentration in the expired air (Eto_2, %), the minute leak volume (ml/min), peak airway measured pressure (cm H_2O), and tidal volume (Vt, ml/kg).

Statistical Analysis

The primary endpoint was the increase in incidence of gastric insufflation detected by ultrasonography of the antrum related to the increase in inspiratory pressure from 10 to 25 cm H_2O. Secondary endpoints were the estimated probabilities of both acceptable FMV and absence of gastric insufflation, the increase in antral area after FMV, and the assessment of agreement between auscultation and ultrasonography.

Our preliminary study showed that gastric insufflation as detected by ultrasonography occurred in 18% (2 of 11 patients) to 83% (10 of 12 patients) of patients for the different levels of peak airway pressure, varying from 10 to 25 cm H_2O during FMV.[21] On the basis of these results, the sample

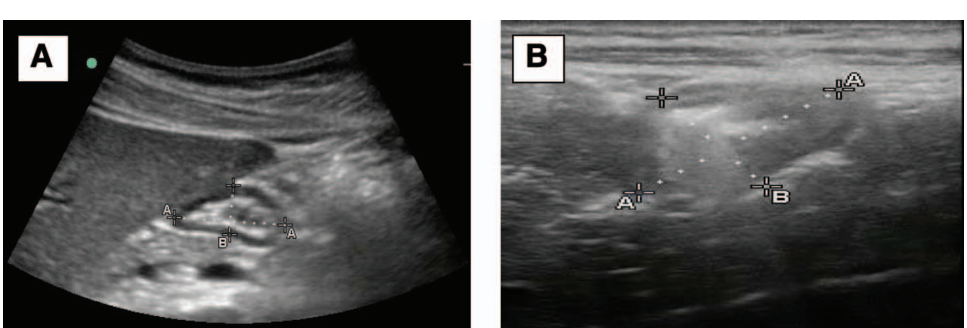

Fig. 2. Example of gastric ultrasonographic images. (*A*) Before facemask ventilation. (*B*) After gastric insufflation with typical aspect of comets tail artifact.

size for this dose–effect study was calculated using a Cochran–Armitage test for the trend in proportions.[28] Considering that inspiratory pressures equal to 10, 15, 20, and 25 cm H_2O would produce proportions of gastric insufflation of 20, 40, 60, and 80%, respectively, a total sample of 68 patients (17 per group) results in 90% power in detecting a linear trend, using a two-sided Z test with continuity correction and a significance level of 0.05 (PASS® 8.0.05; NCSS, LCC, Kaysville, UT).

Demographics (age, sex, weight, height, body mass index, and the number of criteria that predicts difficult mask ventilation) were investigated with a descriptive analysis using the Statistical Package for Social Science version 16.0 (SPSS®, Chicago, IL).

Incidence of gastric insufflation in the four groups was analyzed by a two-tailed chi-square test for trend. Other incidence data were analyzed by a chi-square test. Agreement between both methods to assess the occurrence of gastric insufflation during FMV was tested by calculating the κ coefficient.[29]

Comparisons of the measurements of the antral area before and after FMV were carried out by means of Wilcoxon matched-pair tests. These analyses were performed into each group, and if any, into the following subgroups: subgroups P10GI+, P15GI+, P20GI+, and P25GI+, made up of the patients from the corresponding groups P10, P15, P20, and P25 for whom gastric insufflation was detected by real-time ultrasonography of the gastric antrum; and subgroups P10GI−, P15GI−, P20GI−, and P25GI−, made up of the patients from corresponding groups P10, P15, P20, and P25 for whom no gastric insufflation was detected by real-time ultrasonography of the antrum. The Benjamini–Hochberg step-up procedure was applied for multiple hypothesis testing correction.[30]

Repeated measurements of the respiratory values were analyzed by two-way ANOVA, followed by a Bonferroni *post hoc* test as appropriate, using the Statistica® version 6.0 computer software package (Statsoft, Tulsa, OK). The 95% Bonferroni-corrected CIs were calculated using Minitab® 16.2.3 Statistical Software (Minitab Inc., State College, PA).

The probability of acceptable ventilation, as defined by tidal volume greater than 6 ml/kg and less than 10 ml/kg at each time during the study period,[31] and the probability of an absence of gastric insufflation were both estimated in each group with an exact 95% CI with continuity correction (mid-*P* exact CI), using R® version 2.15.2 (the R Foundation for Statistical Computing, Vienna University of Technology, Vienna, Austria). For each test, a *P* value of less than 0.05 was considered as statistically significant.

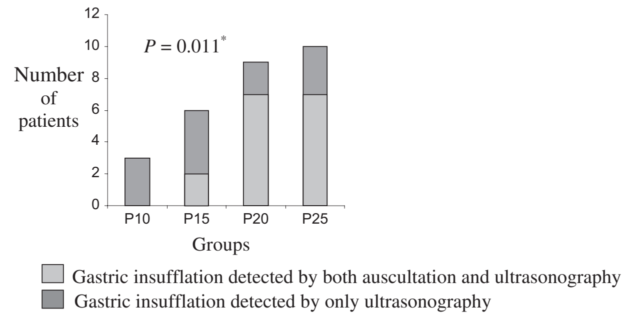

Fig. 3. Detection of gastric insufflation in the four groups according to the method used. All cases detected by auscultation were also detected by ultrasonography. **P* value is given for chi-square tests for trend performed for auscultation and for ultrasonography.

Results

Sixty-eight patients were included. For one patient from group P10, the antrum could not be visualized before and during FMV. The analysis was based on the remaining 67 data sets. There were no missing data for analysis. Demographics are presented in table 1.

The incidence of gastric insufflation significantly increased with inspiratory pressure, ranging from 0% (0 of 16) in group P10 to 41% (7 of 17) in group P25 according to epigastric auscultation, and from 19% (3 of 16) in group P10 to 59% (10 of 17) in group P25 according to the real-time ultrasonographic method (fig. 3).

Auscultation did not allow for detection of gastric insufflation that was not found through use of ultrasonography in any of the patients (fig. 3). The κ coefficient was 0.61 (95%

Table 1. Baseline Characteristics

	P10 (n = 16)	P15 (n = 17)	P20 (n = 17)	P25 (n = 17)
Age, yr	41 ± 19	56 ± 19	51 ± 17	49 ± 16
Sex ratio, M/F	10/6	8/9	5/12	7/10
Weight, kg	71 ± 12	65 ± 16	68 ± 11	66 ± 10
Height, cm	169 ± 11	168 ± 11	167 ± 9	168 ± 8
BMI, kg/m^2	24 ± 2	22 ± 3	24 ± 3	23 ± 3
ASA status, I/II	11/5	8/9	10/7	10/7
Criteria for difficult mask ventilation				
0	7	6	8	8
1	7	7	6	5
2	2	4	3	4

Data are expressed as mean ± SD or n.

ASA = American Society of Anesthesiologists; BMI = body mass index; F = female; M = male.

Table 2. Measured Antral Cross-sectional Area before and after Facemask Ventilation

	Antral Area before Facemask Ventilation (mm^2)	Antral Area after Facemask Ventilation (mm^2)	Adjusted *P* Value†
Group P10			
P10GI– (n = 13)	320 (285–345)	316 (277–445)	0.458
P10GI+ (n = 3)	310 (259–318)	417 (378–477)	0.147
Total* (n = 16)	314 (277–345)	371 (279–466)	0.135
Group P15			
P15GI– (n = 11)	280 (260–536)	357 (300–408)	0.48
P15GI+ (n = 6)	329 (298–431)	450 (331–521)	0.067
Total* (n = 17)	298 (277–432)	380 (310–434)	0.094
Group P20			
P20GI– (n = 8)	331 (264–364)	424 (321–514)	0.072
P20GI+ (n = 8)	290 (250–297)	615 (509–953)	0.036
Total* (n = 16)	291 (256–360)	509 (371–665)	0.001
Group P25			
P25GI– (n = 7)	305 (244–366)	383 (256–421)	0.372
P25GI+ (n = 7)	293 (195–310)	450 (410–662)	0.032
Total* (n = 14)	305 (202–318)	416 (342–511)	0.012

Data are expressed as median (interquartile range).

* Total number of patients for whom the measurement of antral area could be performed before and after facemask ventilation. † Adjusted *P* values according to the Benjamini–Hochberg procedure for multiple testing correction.[30]

GI– = gastric insufflation not detected by real-time ultrasonography; GI+ = gastric insufflation detected by real-time ultrasonography.

CI, 0.41–0.90), corresponding to good agreement between both methods.[32]

The antral cross-sectional area could be measured for all 67 patients before induction of anesthesia. However, after tracheal intubation, measurement of the antral area could not be performed for three patients from group P25 and for one patient from group P20, because the antral posterior wall could not be visualized due to the presence of a large amount of gas in the stomach. There were statistically significant increases in the values of the antral cross-sectional area before and after FMV in groups P20 and P25, without any statistically significant increase in groups P10 and P15. The antral area statistically significantly increased in subgroups P20GI+ and P25GI+, whereas it did not statistically significantly increase in subgroups P10GI–, P10GI+, P15GI–, P15GI+, P20GI–, and P25GI– (table 2).

For all patients, the measured peak airway pressure tallied to inspiratory pressure applied by the ventilator according to the protocol. The saturation level of oxygen in hemoglobin was greater than 99% in each group, at each time, without any difference among the groups. End-tidal fractional oxygen concentration was statistically significantly decreased in group P10 compared with all other groups at time postintubation, with a mean value of less than 80% (fig. 4), whereas the end-tidal carbon dioxide concentration in the expired air was statistically significantly increased in group P10 *versus* group P25 at time postintubation, with a mean value equal to 37 mmHg (95% CI, 34–40) *versus* 26 mmHg (95% CI, 23–29), respectively. Tidal volume statistically significantly increased over time, and there was a statistically significant difference among the four groups as regards the tidal volume, corresponding to a statistically significant increased tidal volume in group P25 in comparison with all other groups at each time (fig. 5). The mean tidal volume was less than 6 ml/kg at each time in group P10 during FMV and was statistically significantly increased at time postintubation *versus* time 30 s into this group. Mean tidal volume ranged between 8 and 12 ml/kg in groups P15 and P20, and was greater than 14 ml/kg in group P25 in the same period (fig. 5). Neither inadequate

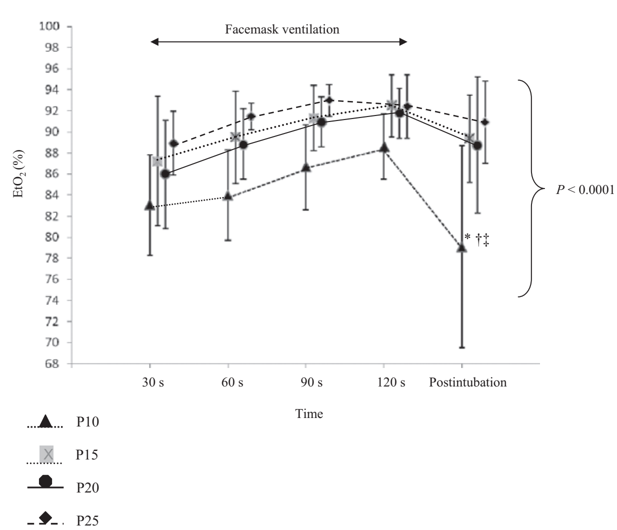

Fig. 4. Variation of end-tidal fractional oxygen concentration in the expired air during facemask ventilation and after tracheal intubation. *Vertical bars* denote 95% Bonferroni-corrected CIs. **P* < 0.0001 between group P10 at time postintubation and all other groups at each time. †*P* < 0.0001 between time postintubation and time 90 and 120 s into group P10. ‡*P* = 0.03 between time postintubation and time 60 s into group P10.

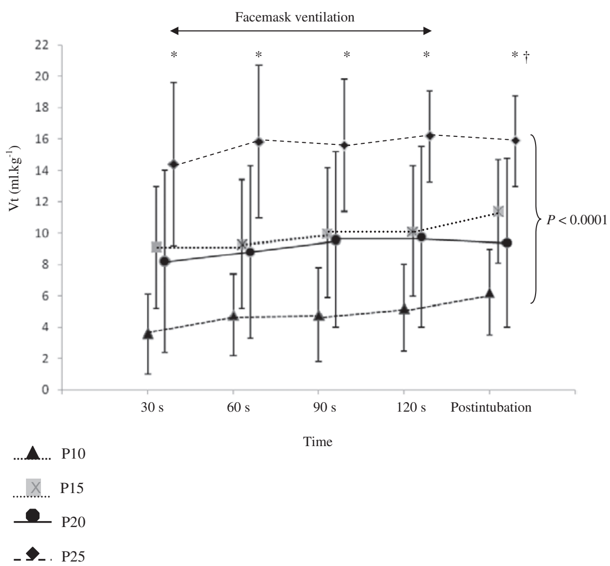

Fig. 5. Mean tidal volume during facemask ventilation and after tracheal intubation. *Vertical bars* denote 95% Bonferroni-corrected CIs. *P < 0.001 between group P25 and other groups and †P = 0.04 into group P10 between postintubation time and time 30 s.

mask ventilation nor leaks of air were recorded for any patient during FMV.

For each level of peak airway pressure, probabilities of insufficient, too high, and acceptable ventilation and probability of absence of gastric insufflation are shown in table 3. For peak airway pressure of 15 cm H_2O, the probability of acceptable ventilation was the highest, whereas probability of absence of gastric insufflation was 65%.

Discussion

By using the epigastric auscultation method, several authors have previously described that the incidence of gastric insufflations increased with inspiratory pressure during unprotected airway ventilation, with a threshold of 20 cm H_2O above which the risk of insufflation became statistically significant.[9–11] The rates of gastric insufflation detected by auscultation in these previous studies were appreciably less than those recorded in our study. The difference in our results could in part be attributed to our study design, because we wished to reproduce actual clinical anesthetic conditions. Therefore, no equilibration time was applied, so chest wall compliance was probably not optimal at the beginning of the FMV, increasing the risk of entry of air into the stomach.[8–10] In the same way, patients were ventilated for a 2-min period leading to a potentially increased rate of detected gastric gas insufflation, because the number of breaths during FMV can noticeably affect the detection of gastric insufflation by auscultation.[16] Finally, the two-handed mask-hold technique used in our study contributed to avoiding leaks of air to the atmosphere,[14] and probably to increasing the frequency of gastric insufflation.[7,10]

Although the highest probability of absence of gastric insufflation was achieved in group P10, one may not consider inspiratory pressure of 10 cm H_2O for the FMV, because it also provided the highest rate of insufficient ventilation that was associated with a statistically significant decrease in the end-tidal fractional oxygen concentration in group P10. Indeed, in clinical practice, FMV is required after loss of consciousness and before tracheal intubation for elective patients, to carry on adequate oxygenation of the patient while waiting for optimal laryngoscopic and tracheal intubation conditions at the effect-site peak concentrations of the drugs. As inspiratory pressure of 15 cm H_2O provided less gastric insufflation with similar rate of insufficient ventilation than pressure of 20 cm H_2O, one can conclude that 15 cm H_2O provided the best balance between the probability of sufficient pulmonary ventilation and the probability of absence of gastric insufflation.

In our study, no neuromuscular-blocking drug was administered during the study period although the occurrence of gastric insufflation during FMV was previously assessed in paralyzed patients.[8–10] The depolarizing muscle relaxant succinylcholine and the nondepolarizing muscle relaxants have different pharmacological actions on muscles, leading to differences concerning both the improvement of FMV and the risk of gastric insufflation. Succinylcholine transiently improved FMV, especially at the time of fasciculations, by reopening of the airway during pharyngeal muscle contractions, while, furthermore, increasing the lower esophageal sphincter pressure.[33] Therefore, the

Table 3. Probability (95% CI) of Absence of Gastric Insufflation and Probability of Acceptable Facemask Ventilation According to the Applied Peak Airway Pressure

	Probability of No Gastric Insufflation (%)				
Peak Airway Pressure (cm H_2O)	According to Auscultation	According to Real-time US	Probability of Hypoventilation (%)	Probability of Too High Tidal Volume (%)	Probability of Acceptable Ventilation (%)
10	100 (83–100)	81 (57–95)	75 (50–91)	7 (1–27)	19 (5–43)
15	88 (66–98)	65 (41–84)	12 (2–34)	24 (8–47)	65 (41–84)
20	59 (35–80)	47 (25–70)	6 (0–26)	59 (35–80)	35 (16–60)
25	59 (35–80)	41 (20–65)	0 (0–16)	100 (84–100)	0 (0–16)

US = ultrasonography.

value of peak airway pressure providing acceptable FMV in most of patients should be decreased after the administration of succinlycholine, leading to a probable strong decrease in the rate of gastric insufflation. Nondepolarizing muscle relaxants also improved the FMV whereas, however, impairing pharyngeal muscle function and decreasing the resting tone in the upper esophageal sphincter muscle.[34–36] Except pancuronium, these drugs had not statistically significant effect on both lower esophageal sphincter and barrier pressure.[37–39] Compared with noncurarized patients, the use of nondepolarizing muscle relaxant may probably decrease the value of peak airway pressure providing acceptable FMV in most of patients, leading to reduced occurrence of gastric insufflation, although probably in a less important manner than after administration of succinylcholine. Therefore, the recommended airway pressure may probably differ between patients who received a neuromuscular-blocking agent and those who did not. This should be assessed in further studies.

Besides, our results do not apply to obese patients for whom positive end-expiratory pressure should be applied,[40] allowing us to assume that the value of inspiratory pressure providing both acceptable FMV and low rate of gastric insufflation may be different from 15 cm H_2O. Other factors may affect the value of the optimal inspiratory pressure, such as impaired respiratory function or presence of more than two criteria predicting difficult mask ventilation. At last, our results apply only to elective patients as the ultrasonographic detection of gastric insufflations for low inspiratory pressures until then it was considered that there was no danger for gastric insufflation confirms that, for patients at risk of aspiration, ventilation should be avoided before intubation, or should be performed with application of cricoid pressure during ventilation.[3]

Ultrasonographic examination of the antrum allowed for detection of gastric insufflation, with a good agreement with the auscultation method. Air is classically considered as a problem for the ultrasonography technique, as sound waves do not travel well through it, thus creating a shadow. However, in certain circumstances, detection of gas is required and ultrasonography has proved that it was useful for the diagnosis of pneumoperitoneum,[41] as well as that it was useful for detecting air injected through a nasogastric tube into the stomach.[27] In the current study, real-time detection of entry of air into the stomach through ultrasonography of the antrum was easy and was not prevented by the normal presence of air into the fundus. Besides, ultrasonographic measurement of antral area may provide interesting semi-quantitative data as regards the entry of air into the stomach during FMV. Indeed, the statistically significant increase in the antral area recorded in subgroups P20GI+ and P25GI+ for whom gastric insufflation was detected by real-time ultrasonography but not in subgroups for whom gastric insufflation was not detected by real-time ultrasonography (P10GI−, P15GI−, P20GI−, and P25GI−), let us to suppose that entry of air may have clinically significant effect upon the gastric wall through an increase in gastric pressure and could lead to clinical consequences for inspiratory pressure of 20 cm H_2O or greater.

Unfortunately, the assessment of the performance of both auscultation and real-time ultrasonography could not be performed because of the too small groups of patients. Brimacombe *et al.*[16] have reported that sensitivity of auscultation for detecting air entering the stomach through a gastric tube was 91% and specificity was only 79%, whereas it was reported, in eight patients, that sensitivity and specificity of ultrasonographic detection of gastric insufflation were both equal to 100%.[27] A false-positive rate related to auscultation may be due to normal gastric motility, whereas gastric motility is easily visualized and therefore not confused with entry of air into the stomach when using ultrasonography. As the results of this study allow us to conclude that real-time ultrasonography of the antrum could be useful for the detection of entry of air into the stomach during FMV, further studies comprising larger number of patients are now required to more precisely assess the performance of this new method.

The performing of real-time ultrasonography and ultrasonographic measurements of the antral area by a single operator constituted a limitation of this study. It would have been preferable for both of these methods to have been performed by two different physicians being blinded one to another. However, it would be concretely hard to achieve, because of the excessive number of investigators it would require around the patient.

In conclusion, peak airway pressure of 15 cm H_2O provided a probability of occurrence of gastric insufflation of 35% according to real-time ultrasonography while providing the highest probability of acceptable FMV. This pressure level should be used in nonobese and noncurarized patients during pressure-controlled FMV. Furthermore, real-time ultrasonography of the antrum allowed for detection of gastric insufflation with high sensitivity; particularly, it detected entry of air into the stomach for low inspiratory pressures applied during pressure-controlled FMV.

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Competing Interests

The authors declare no competing interests.

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