

Ultrasonographic evaluation of gastric content and volume: a systematic review

 César Antonio Tavares da Rocha¹
 Lia Mayumi Kubota Kamada¹
 Pedro Hilton de Andrade Filho^{1,4}
 Isabela Araujo Villaverde²
 Jacqueline Yamahata Barbosa Shiro²
 João Manoel Silva Junior^{3,4}

1. Hospital do Servidor Público Estadual de São Paulo, São Paulo, SP, Brasil.

2. Acadêmica de Medicina da Universidade Cidade de São Paulo, São Paulo, SP, Brasil.

3. Chefe do departamento de anesthesiologia do Hospital do Servidor Público Estadual de São Paulo, São Paulo, SP, Brasil.

4. Programa de Pós-Graduação em Anesthesiologia, Ciências Cirúrgicas e Medicina Perioperatória – FMUSP, São Paulo, Sp, Brasil.

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SUMMARY

OBJECTIVE: Bronchoaspiration of gastric content is associated with high morbidity and mortality, but evaluating this complication is a difficult task. However, gastric ultrasonography can safely assess gastric content and prevent bronchoaspiration. Therefore, a systematic review was performed in order to verify the efficacy of ultrasonography in the qualitative and quantitative analyses of gastric content.

METHODS: A literature review of articles published between 2009 and 2019 in the PubMed and LILACS databases was conducted using combinations of the keywords "gastric ultrasound," "gastric emptying," and "gastric content."

RESULTS: Of the 20 articles found, 19 chose the antral region as the best site for qualitative analysis of the gastric content. Regarding quantitative measurement, the most commonly used method to calculate the gastric volume in eight articles was the formula "Gastric Volume = 27 + (14.6 × ATAG) – (1.28 × Age)," in which the area of the transverse section of the gastric antrum (ATAG) could also be calculated by the largest antral diameters or by free tracing.

CONCLUSION: An efficient evaluation of the gastric content can be performed by ultrasonography of the antral region, contributing to greater safety in the clinical management of patients with increased risk for bronchoaspiration during airway management.

KEYWORDS: gastric ultrasonography, gastric content, gastric emptying

INTRODUCTION

Bronchoaspiration (BCA) of gastric content is a serious complication, and mortality increases with higher aspirated volumes or gastric content of pH <2.5.¹ Adequate gastric emptying contributes to greater safety in procedures such as orotracheal intubation and endoscopic examinations, in which the incidence of BCA varies from 0.1-19%, reaching mortality rates of 30%.²⁻⁴

Gastric content assessment is usually performed by invasive and/or high-cost techniques. Currently, the gold standard is gastric scintigraphy, which is a high-cost examination involving radiation exposure; hence, gastric ultrasonography (USG-G) is used as an alternative.⁵

Although there are reviews on the use of USG-G, none evaluated the qualitative, quantitative, and

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CORRESPONDING AUTHOR: Pedro Hilton Andrade Filho
 Rua Pedro de Toledo, 1800, Vila Clementino, SP, Brasil – 04029-000
 E-mail: pedrohaf07@gmail.com

risk analyses, and this review is the most recent. A literature review was performed to summarize the current knowledge about the assessment of gastric content by ultrasonography and measure the risk of perioperative BCA. This review aims to validate the methodology already described and evaluate its efficacy in determining the risk of complications in airway management.

METHODS

A systematic review was conducted in the CENTRAL (PubMed), MEDLINE (OvidSP), and EMBASE (OvidSP) databases for articles published between 2009 and 2019. The following keywords were used in the search: “antrum” or “gastric” and “sonography;” “antrum” or “gastric” and “ultrasound;” “antrum” or “gastric” and “emptying;” and “antrum” or “gastric” and “content.” Studies involving the use of USG-G in humans were included when they contained specifications of the qualitative method of gastric content analysis (empty, clear, pasty, or solid-liquid), and/or method for quantification of gastric volume and/or volume considered as a risk for respiratory complications. Studies in animals and in special populations (pregnant women, children, obese, and diabetics) who present gastric motility different from the general population were excluded. The main purpose was to analyze the volume of gastric content (VCG) as a complication risk. In order to avoid bias in the selection of studies, two independent researchers conducted the search for the articles. After the initial selection, a discussion was held to define the most appropriate studies to be included in this review. For the articles to be considered, the following topics were observed: year of publication, the position of the patient during the examination, the portion of the stomach analyzed, existing gastric content, scanning technique, type of transducer, and type of research.

RESULTS

Selected articles

Initially, 426 articles were found, of which 20 were selected. The clinical trials included were evaluated for risk of bias, as shown in Figure 2, which resulted in a low to moderate risk in the selected articles.

The analyzed population included 1631 patients in several clinical settings such as emergency rooms (n = 39), intensive care units (n = 154), surgical

procedures (n = 921), and high digestive endoscopy procedures (n = 108), as well as healthy volunteers (n = 409).

Anatomical portion

The gastric antrum was the anatomical region of choice for gastric content evaluation in 19 studies.

FIGURE 1. FLOWCHART OF ARTICLE SELECTION

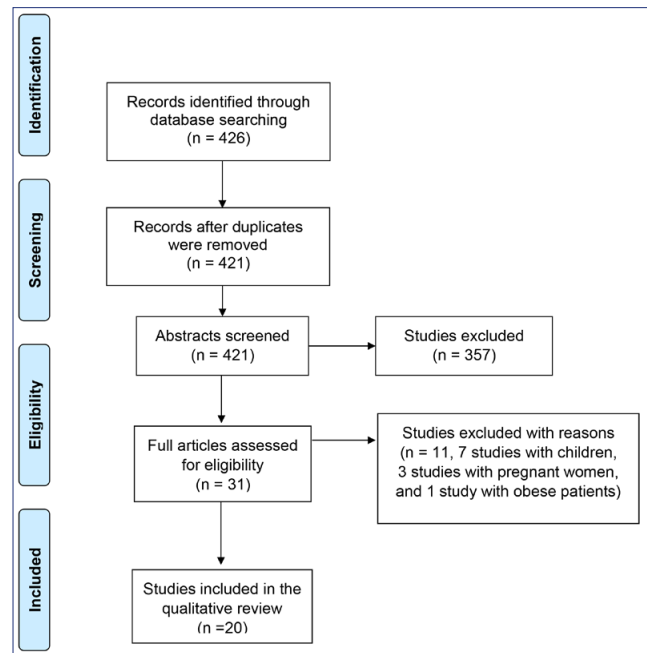


FIGURE 2. RISK OF BIAS ANALYSIS FOR CLINICAL TRIALS

Study	Risk of bias domains					Overall
	D1	D2	D3	D4	D5	
Perlas et al.5, 2009	+	+	+	-	+	+
Bouvet et al.7, 2009	+	+	+	X	-	-
Perlas et al.12, 2013	-	+	+	+	+	+
Kruisselbrink et al.13, 2014	+	+	+	+	+	+
Gomes et al.17, 2017	-	X	-	+	-	-
Kruisselbrink et al.1, 2019	+	+	+	+	+	+
Carmona et al.20, 2018	+	+	+	+	+	+
Bovet et al.22, 2019	-	+	+	-	+	+
Mazzawi et al.5, 2019	+	X	+	-	+	-
Sugita et al.23, 2019	-	X	+	-	+	-

Domains:
 D1: Bias arising from the randomization process
 D2: Bias due to deviations from intended intervention
 D3: Bias due to missing outcome data.
 D4: Bias in measurement of the outcome.
 D5: Bias in selection of the reported result.

Judgement
 High (Red X)
 Some concerns (Yellow -)
 Low (Green +)

Patient position

The patients were most commonly in the supine and right lateral decubitus (DLD) positions. Twelve studies used the DLD position, either alone or associated with the supine position.

Scanning and measures

Nineteen studies recommended the use of low frequency (1-5 MHz) curvilinear transducers, and only one of them additionally used a high-frequency linear transducer (8-13 MHz).

To locate the gastric antrum, most studies recommended initiating parasagittal scanning in the left subcostal region. The probe was then slid to the right in search of the following anatomical references: the left lobe of the immediately cranial liver, used as a reference in 14 studies; the immediately posterior pancreas, used as a reference in seven studies; and the more deeply abdominal aorta, used as a reference in 10 studies. The other structures reported less frequently as anatomic references were the vena cava and superior mesenteric vein.

METHODS OF GASTRIC CONTENT ANALYSIS

Qualitative evaluation

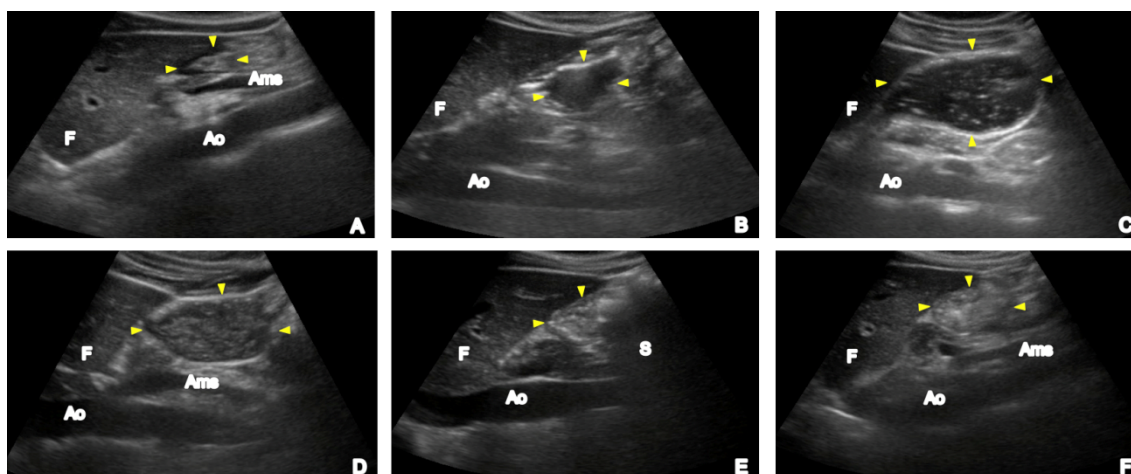
The evaluation of the type of gastric content was described in 11 articles, analyzed by differentiating between solid, liquid, and empty stomach contents.^{1,7-11,16,18-21}

The imaging findings according to gastric content were as follows:

- Empty stomach: the gastric antrum was visualized with its walls juxtaposed with a “target” or “bull’s eye” appearance (Figure 3A).^{6,11}
- Liquid content: the distance from the antrum walls and filling of hypoechoic liquid content without residues was observed (Figure 3B). Immediately after ingestion or after a gastric contraction, the liquid content mixed with the air and formed a “star-filled sky” appearance (Figure 3C). Liquids with residues (e.g. milk or juices) showed a more echogenic content (Figure 3D).^{6,11}
- Solid content: Solid food mixed with air, previous liquid, and gastric juices, formed a “frosted glass” appearance that could be accompanied by acoustic shading later (Figure 3E). After digestion, the gastric content presented a hyperechoic and more heterogeneous aspect, similar to that of hepatic parenchyma (Figure 3F).

A risk stratification model for the qualitative assessment of gastric content was proposed by Perlas, Davis:⁹ grade 0, empty gastric antrum in supine and DLD positions (suggesting empty stomach); grade 1, liquid content visualized only in DLD position (suggesting liquid in small quantity); and grade 2, liquid content visualized in supine and DLD positions (suggesting liquid in large quantity). It was observed that 75% of grade 1 patients had <100 mL of gastric residue, 75% of grade 2 patients had >100 mL, and 50% of grade 2 patients had >250 mL.⁹

FIGURE 3. ULTRASONOGRAPHY OF GASTRIC CONTENT IN THE RIGHT LATERAL DECUBITUS POSITION



A: empty stomach; B: stomach with liquid without residues; C: stomach with liquid and air showing “sky of stars” appearance; D: stomach with liquid with residues; E: stomach with solids showing “frosted glass” appearance and acoustic shadow; F: stomach with solid late-stage digestion.

(F = liver; Ams = upper mesenteric artery; Ao = aorta; S = posterior acoustic shadow; arrowheads = gastric antrum)

TABLE 1. TECHNICAL ANALYSIS OF THE STUDIES

Author	Study design	Population studied	Number of participants	Patient position	Stomach portion	Scanning	Quantitative Evaluation	VCG risk for BCA (mL/kg)	Semi-quantitative evaluation	Probe
Perlas, Chan ⁶	Clinical trial	Volunteers	Stage 1: 18 Phase 2: 36	Supine	A/C/F	Parasagittal	Yes	NA	NA	Curvilinear 2-5 MHz
Bouvet, Miquel ⁷	Clinical trial	Volunteers	22	Semi-sitting	Antrum	Sagittal	Yes	NA	NA	Curvilinear 2-5 MHz
Koenig, Lakticova ⁸	Observational	ICU patients	80	Supine	C/F	Sagittal and parasagittal in LAM	No	NA	NA	Curvilinear 1-5 MHz
Perlas, Davis ⁹	Observational	Surgical patients	200	Supine/DLD	Antrum	Sagittal	Yes	NA	Yes	Curvilinear 2-5 MHz
Bouvet, Mazoit ¹⁰	Observational	Surgical patients	183	Semi-sitting	Antrum	Sagittal	Yes	>0.8	NA	Curvilinear 2-5 MHz
Cubillos, Tse ¹¹	Observational	Volunteers	6	DLD	Antrum	Axial/Sagittal	No	NA	NA	Curvilinear 2-5 MHz/ linear 8-13
Perlas, Mitsakakis ¹²	Clinical trial	EDA patients	108	DLD	Antrum	Sagittal	Yes	>1.5	Yes	Curvilinear 2-5 MHz
Kruisselbrink, Arzola ¹³	Clinical Trial	Volunteers	22	Supine/DLD	Antrum	Sagittal	Yes	NA	NA	Curvilinear 2-5 MHz
Hamada, Garcon ¹⁴	Observational	ICU patients	55	Semi-sitting	Antrum	Sagittal	Yes	>0.8	NA	Curvilinear 2-5 MHz
Bisinotto, Pansani ¹⁵	Observational	Volunteers	67	Supine/DLD	Antrum	Sagittal	Yes	>1.5	NA	Curvilinear 2-5 MHz
Sharma, Gudivada ¹⁶	Observational	ICU patients (enteral nutrition)	19	Semi-sitting	Antrum	Sagittal	Yes	>500	NA	Curvilinear 2-5 MHz
Gomes, Caporossi ¹⁷	Clinical trial	Volunteers	20	DLD	Antrum	Sagittal	Yes	NA	NA	Not Informed
Bisinotto, Naves ¹⁸	Observational	Volunteers	80	Supine/DLD	A/C	Parasagittal	Yes	NA	Yes	Curvilinear 2-5 MHz
Van de Putte, Vernieuwe ¹⁹	Observational	Surgical patients	538	Supine/DLD	Antrum	Sagittal	Yes	>1.5	Yes	Curvilinear 2-5 MHz
Carmona, Almeida ²⁰	Clinical trial	Volunteers	17	DLD	Antrum	Sagittal	Yes	>0.8	NA	Curvilinear 2-6 MHz
Kruisselbrink, Gharapetian ¹	Clinical trial	Volunteers	40	Supine/DLD	Antrum	Sagittal	Yes	>1.5	Yes	Curvilinear 2-5 MHz
Okada, Toyama ²¹	Observational	Emergency patients	39	Supine	Antrum	Sagittal	Yes	>1.5	NA	Curvilinear 2-5 MHz
Bouvet, Barnoud ²²	Clinical trial	Volunteers	25	Semi-sitting at 0, 30°, and 45°, and DLD	Antrum	Sagittal	Yes	>1.5	Yes	Curvilinear 2-5,5 MHz
Mazzawi, Bartsch ⁵	Clinical trial	Volunteers	32	Sitting	Antrum	ND	Yes	NA	NA	Curvilinear 4 MHz
Sugita, Matsumoto ²³	Clinical trial	Volunteers	24	DLD	Antrum	Parasagittal	Yes	NA	NA	Curvilinear 2-5 MHz

DLD: right lateral decubitus; EDA: upper-digestive endoscopy; A: antrum; C: body; F: gastric fundus; ND: not described; NA: not evaluated; LAM: middle axillary line; VCG: volume of gastric content; BCA: bronchoaspiration; ICU: intensive care unit.

Quantitative Evaluation

Eighteen studies correlated the measurement of the area of the transverse section of the gastric antrum (ATAG) and the VCG. The ATAG measurement was calculated in two ways: measurement of the area by free tracing including the serous layer; and the technique used in 16 studies involving the anteroposterior (AP) and craniocaudal (CC) diameter measurements, measured from serous to serous by the formula: $ATAG = (CC \times AP \times \pi) / 4$.²⁴

A comparative study between these ATAG measurement techniques showed a small difference in the predicted VCG value of up to 20 mL in 96% of cases.¹³

Another study developed a mathematical model capable of estimating the VCG according to the measurement of ATAG in the DLD position using the age of the patient as the only covariable in the formula: $VCG (mL) = 27 + (14.6 \times ATAG) - (1.28 \times \text{age})$. This mathematical model was used by eight of the studies analyzed.^{6,12} Okada Toyama,²¹ using computed tomography as the

USG-G control group, showed that ATAG measurements $>3.01 \text{ cm}^2$ in the supine position were indicative of either gastric content $>1.5 \text{ mL/kg}$ or presence of solid content, with a sensitivity of 85% and specificity of 53%.

Combined assessment and correlation with bronchoaspiration risk

High-risk predictors for BCA include the presence of solid residues in any amount or large liquid content, defined as VCG $>1.5 \text{ mL/kg}$ in six analyzed studies.^{10,12}

The main fasting management protocol and risk classification for BCA proposed by Van de Putte and Perlas²⁵ advocate scanning in the supine and DLD positions and classifying BCA risk according to the USG-G findings as follows:

- Low risk: Empty antrum
- High risk: Solid waste
- Presence of liquid waste calculated by ATAG: After calculation, correlate the ATAG measurement with the VCG according to the formula: $\text{VCG (mL)} = 27 + 14.6 \times \text{ATAG (cm}^2) - 1.28 \times \text{age (years)}$. If VCG is $>1.5 \text{ mL/kg}$, it is considered high risk for BCA, and if $<1.5 \text{ mL/kg}$, it is considered low risk.

DISCUSSION

This review found several studies using USG-G for qualitative and quantitative assessments of gastric content. Regarding the methodology, most of the articles opted for the analysis of the antral region, which has a better relationship with the measurement of gastric content and volume. Although a small divergence occurred in the image acquisition of the gastric antrum, all studies preferred sagittal/parasagittal scanning.

The antral ultrasound visualization is complicated by the presence of air and the depth of the anatomical structures, with the curvilinear transducer of low frequency (2-5 MHz) being the best to perform the exam.

The supine position followed by the DLD position seems favorable to measure the volume and classify the risk, since DLD not only allows better visualization of the antrum in its lower portion and a better correlation with ATAG as compared to the supine position but also provides greater sensitivity and specificity in the examination.^{11,22}

The method of quantitative evaluation regarding the measurement technique and its accuracy, reliability, and reproducibility is still debatable. The measurement of ATAG through free tracing, though technically easier, still requires further studies for its validation,

because it has only been used in two studies. ATAG measurement should be performed by involving the entire serous layer of the stomach and outside periods of peristaltic contractions. For greater accuracy of the test, it is recommended to use the mean of three ATAG measurements in clinical practice, since the mean of multiple measurements to calculate VCG has a good correlation with gastric scintigraphy measurements.²⁶

Thus, USG-G could be an efficient method for airway management in cases of uncertain fasting, risk factors for gastric emptying delay, or unreliable history (cognitive dysfunction, delirium).¹⁴

This systematic review had the limitation of analyzing studies of different designs performed in controlled environments, single centers, and with homogeneous populations. Moreover, the number of selected articles may have been insufficient, despite the estimated time for the study to be conducted over 10 years. Therefore, studies with a larger scope are necessary to generalize these recommendations in other populations.

CONCLUSION

The bedside use of USG-G has been consolidated in clinical practice. Currently, the USG-G of the antral region is the most practical, non-invasive, and easy imaging method to characterize gastric content and volume.

Author's Contribution

César Antonio Tavares Da Rocha – conceptualization and design of the study, search and analysis of articles, writing of the original manuscript, elaboration and revision of the graphic components (tables and figures); Lia Mayumi Kubota Kamada – study design, search and analysis of articles, writing of the original manuscript, elaboration and revision of graphic components (tables and figures); Pedro Hilton de Andrade Filho – study design, review of the selected articles, elaboration and review of graphic components (tables and figures), review of the original manuscript, and writing of the final manuscript; Isabela Araujo Villaverde and Jacqueline Yamahata Barbosa Shiro – review of the selected articles, preparation and review of graphic components (tables and figures), writing of the original manuscript; João Manoel da Silva Junior – conceptualization and design of the study, revision and orientation of methodology, revision of graphic components (tables and figures), revision of the original and final manuscripts.

RESUMO

OBJETIVO: A broncoaspiração do conteúdo gástrico associa-se à alta morbimortalidade, porém a avaliação desta complicação é tarefa difícil. Por outro lado, a ultrassonografia gástrica avalia o conteúdo gástrico com segurança, podendo evitar a broncoaspiração. Portanto, foi realizada revisão sistemática com objetivo de verificar a aplicabilidade da ultrassonografia na análise qualitativa e quantitativa do conteúdo gástrico.

MÉTODOS: Revisão de literatura de artigos publicados entre 2009 e 2019 nas bases de dados PubMed e LILACS usando combinações das palavras chave: "Gastric ultrasound", "gastric emptying" e "gastric content".

RESULTADOS: Foram encontrados 20 artigos. A região antral foi escolhida em 19 artigos como melhor local do ponto de vista qualitativo para analisar o conteúdo gástrico. A respeito da mensuração quantitativa, o método mais utilizado para cálculo do volume gástrico, escolhido em 8 artigos, foi através da fórmula $\text{Volume gástrico} = 27 + (14,6 \times \text{ATAG}) - (1,28 \times \text{Idade})$, em que a Área da Secção Transversal do Antro Gástrico (ATAG) pode ser igualmente calculada pelos maiores diâmetros antrais ou pelo seu traçado livre.

CONCLUSÃO: A ultrassonografia da região antral permite boa avaliação do conteúdo gástrico, trazendo maior segurança ao manejo clínico de pacientes com risco aumentado para broncoaspiração no manejo da via aérea.

PALAVRAS CHAVE: Ultrassonografia gástrica, conteúdo gástrico, esvaziamento gástrico.

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