The use of lumbar spine and gastric ultrasound in perioperative obstetric anesthesia

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Neuraxial anesthesia is a gold standard anesthetic technique employed for labor analgesia and cesarean section. Spinal cord injury can occur if the needle insertion is performed above the recommended lumbar spine level. Pre-procedural lumbar spine ultrasound scanning can provide several benefits, such as increasing first attempt success rate, reducing the number of attempts, and reducing redirection of the needle.

Pulmonary aspiration during general anesthesia is a fatal complication which remains a cause of maternal mortality. Gastric content volume (GCV) is an important component related to the risk of regurgitation followed by aspiration. There is growing interest in the utility of bedside gastric ultrasound to assess GCV in non-obstetric and obstetric populations.

Introduction

Ultrasound is a familiar tool for obstetricians and allows for the non-invasive examination of pregnant women. The use of ultrasound in various situations such as a Focused Assessment with Sonography for Trauma (FAST) in the emergency department has gained popularity. During the perioperative period in obstetric anesthesia, lumbar spine and gastric ultrasound have been used to reduce the potential for serious complications such as neural injury from spinal anesthesia or aspiration pneumonia posed by the risk of a full stomach.

A large prospective observational cohort study1) found that a serious complication occurs in approximately 1:3,000 women (1:2,443–3,782) who undergo obstetric anesthesia. The most frequent complications are high neuraxial block and respiratory arrest during labor and delivery. Unrecognized spinal catheters were also among the frequently encountered complications.

Neural injury in the obstetric population can occur in 1:168,000–200,000 cases2–4) which is less than that of the non-pregnant population, for which the incidences are 1:150,000–220,000.5) In a study6) which assessed the accuracy of lumbar space identification by palpation versus MRI, anesthesiologists correctly identified the lumbar spine level in only 29% of cases. Furthermore, this study showed that the spinal cord terminated below L1 in 19% of patients, while anesthesiologists have traditionally learnt that the spinal cord terminates at L1 in adults. Other studies demonstrated that 28–58% of adult spinal cords end below L1.7–10) The combination of an inaccurate needle insertion point and low-lying cord can lead to a neurological complication due to conus medullaris injury.11,12) Epidural hematoma is another serious complication related to neuraxial blockade. Pre-eclampsia,12) thrombocytopenia, or hypertension during pregnancy could be a contributory risk factor for epidural hematoma. Anesthesiologists should avoid traumatic neuraxial procedures with multiple attempts. In this regard, the use of ultrasound can help reduce the number of attempts.13–16) Neural injury and epidural hematoma are devastating complications which significantly adversely affect a young mother’s life. Therefore, anesthesiologists must be vigilant when performing neuraxial blockade. Overall, the use of lumbar spine ultrasound can decrease the risk of serious complications by determining accurate
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Lumbar spine level, interlaminar space, midline, and depth from skin to epidural space.

Pulmonary aspiration followed by aspiration pneumonia is a fatal complication; therefore, all patients who undergo surgery requiring general anesthesia or sedation must have a negligible amount of gastric volume achieved by fasting for a certain period of time. The review article of the eighth report named Saving Mothers’ Lives in the United Kingdom Enquiries into Maternal Deaths, found that one maternal death was associated with aspiration on emergence from general anesthesia after an emergency cesarean section.

In obstetrics, pregnant women who undergo elective cesarean section are recommended to fast for six to eight hours from solid food and two hours from clear fluids. However, during an emergency cesarean section or perioperative emergency procedure, there is often not enough time for fasting, hence a significant risk for aspiration remains. In the modern practice of obstetric anesthesia, neuraxial blockade has become a gold standard anesthesia technique for cesarean section. However, neuraxial blockade is often contraindicated in pre-eclamptic women with thrombocytopenia or neurological symptoms. Emergency cesarean section often requires general anesthesia. Hence, safe general anesthesia for cesarean section remains essential. Although there are fasting guidelines which apply to the general population, some patients do not fit the general trend and are found to have a significant gastric residual volume even after following the fasting guidelines. Several factors contribute to this observation; one being that laboring women are known to have delayed gastric emptying. It is therefore crucial to confirm the gastric status of laboring patients before general anesthesia or sedation, given the risk of a full stomach, which can be seen even after fasting.

The use of ultrasound in the perioperative period for safety and efficacy has been described extensively in previous publications. 

Lumbar spine ultrasound

The neuraxial technique (epidural or spinal anesthesia) is a gold standard in obstetric anesthesia for cesarean section and labor pain. In recent years, the neuraxial technique has become more challenging due to various factors, one being an increase in obese parturients. The efficacy and reliability of lumbar spine ultrasound in several aspects of neuraxial blockade have been demonstrated.

Intercristal line by palpation vs. by ultrasound examination

The intercristal line correlates with the L4 spinous process or L4/5 interspace. Palpating a patient’s back to determine the intercristal line and interspinous levels is unreliable, especially during pregnancy due to exaggerated lumbar lordosis. Identifying the correct level is crucial to avoid unnecessary neurological injury.

Margarido et al. examined the correlation between the intercristal line as determined by palpation versus ultrasound guidance in pregnant women at term. The majority of anesthesiologists chose the level L2/3 or higher for the intercristal line. They found that the intercristal line as determined by palpation does not correspond to the intercristal line as determined by ultrasound.

Whitty et al. investigated the accuracy of palpation in identifying lumbar interspinous spaces in the postpartum period. They scanned the back in the postpartum period, and then compared the level of the epidural needle insertion point that was written on the anesthesia record to the level determined by ultrasound. They found that 32% of skin puncture levels based on palpation were in fact at least one interspace higher when later assessed by ultrasound. Only 55% of skin puncture levels by palpation were in agreement with vertebral levels, as assessed by ultrasound.

Lee et al. examined lumbar vertebral levels by ultrasound on pregnant patients and found that the spinal level of the intercristal line determined by palpation by senior anesthesiologists agreed with the level determined by ultrasound in only 14% of cases. Levels of the intercristal line determined by palpation were at L3 or L3/4 in 54% of cases, and L2/3 or higher in 27% of cases.

Identifying lumbar intervertebral spaces on obese pregnant women is often difficult. In one study, the L3/4 space identified by palpation was compared to the level determined by ultrasound on non-obese and obese pregnant patients. The L3/4 determined by palpation corresponded to the level examined by ultrasound in 53% and 49% of cases in non-obese and obese parturients, respectively.

Reducing the number of attempts (Table 1)

Ultrasound scanning has been shown to improve both the efficiency and success of neuraxial blockade for labor epidural analgesia and cesarean section. Use of
### Table 1. Efficacy of lumbar spine ultrasound assisted neuraxial blocks

| Study       | Study design            | Study population                        | N  | Objectives                                      | Outcomes                                                                 |
|-------------|-------------------------|------------------------------------------|----|------------------------------------------------|--------------------------------------------------------------------------|
| Grau[^13^]  | Randomised controlled   | Labor epidural Abnormal anatomical conditions | 72 | Number of puncture attempts (n)                 | 1.5 ± 0.9 vs. 2.6 ± 1.4, *p < 0.001*                                     |
|             |                         |                                          |    | Number of puncture sites (n)                    | 1.3 ± 0.6 vs. 1.5 ± 0.7, *p < 0.05*                                      |
|             |                         |                                          |    | Catheter advancement attempts (n)              | 1.1 ± 0.6 vs. 1.3 ± 0.6, *p < 0.003*                                      |
| Grau[^14^]  | Randomised controlled   | CSE for CD                               | 80 | Success in first attempt                        | 75% vs. 20%, *p < 0.001*                                                 |
|             |                         |                                          |    | Number of puncture attempts (n)                 | 1.3 ± 0.5 vs. 2.1 ± 0.9, *p < 0.001*                                     |
| Grau[^15^]  | Randomised controlled   | CSE for CD                               | 30 | Success in first attempt                        | 70% vs. 40%, *p < 0.03*                                                  |
|             |                         |                                          |    | First level success in first attempt            | 90% vs. 50%, *p < 0.036*                                                 |
| Grau[^16^]  | Randomised prospective  | Labor epidural                           | 300| Puncture attempts (n)                           | 1.4 ± 0.7 vs. 2.2 ± 1.1, *p < 0.013*                                     |
|             |                         |                                          |    | Necessary puncture levels (n)                   | 1.2 ± 0.4 vs. 1.3 ± 0.6, *p < 0.029*                                     |
|             |                         |                                          |    | Complete analgesia                              | 98% vs. 92%, *p < 0.03*                                                  |
|             |                         |                                          |    | Maximum VAS pain score                          | 0.8 ± 1.5 vs. 1.3 ± 2.1, *p < 0.006*                                     |
|             |                         |                                          |    | Side effect                                      | 20% vs. 34%, *p < 0.011*                                                 |
| Arzola[^31^]| Prospective observational cohort | Labor epidural Transverse approach       | 61 | Success in first attempt                        | 92%                                                                      |
|             |                         |                                          |    | No need to redirect the needle                  | 74%                                                                      |
| Balki[^32^]| Prospective observational cohort | Labor epidural Obese parturients (BMI 33–86 kg/m^2) | 46 | Success in first attempt                        | 76%                                                                      |
| Sahin[^33^]| Randomised controlled   | Spinal anesthesia for CD Lean (BMI < 30 kg/m^2) | 50 | Success in first attempt                        | 92% vs. 72%, *p < 0.001*                                                 |
|             |                         |                                          |    | No need to redirect the needle                  | 40% vs. 28%, 0.001                                                      |
|             |                         |                                          |    | Duration of the procedure (sec)                 | 23 vs. 45, 0.031                                                        |
|             |                         |                                          |    | Spinal anesthesia for CD Obese (BMI ≥ 30 kg/m^2) |                                                                           |
|             |                         |                                          |    | Success in first attempt                        | 92% vs. 44%, *p < 0.001                                                 |
|             |                         |                                          |    | No need to redirect the needle                  | 32% vs. 28%, 0.001                                                      |
|             |                         |                                          |    | Duration of the procedure (sec)                 | 22 vs. 52, 0.031                                                        |
| Chin[^34^]  | Randomised controlled   | CSE for CD                               | 215| Success in first attempt                        | 64% vs. 38%, 0.001                                                      |

CSE, Combined Spinal and Epidural; CD, Cesarean Delivery.
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ultrasonography has been shown to increase the success of first attempts and reduce the number of attempts as well as the numbers of puncture sites and spinal needle manipulations. In addition, ultrasonography also reduces the number of catheter advancement attempts and necessary puncture levels.\(^\text{33–46}\) One study\(^\text{37}\) observed that the success rate of first attempts was 92% when pre-puncture lumbar spine ultrasound was used and there was no need of needle redirection in 74% of patients (BMI range, 22–42). Another study\(^\text{32}\) confirmed the success rate of first attempts to be as high as 76%, even in obese parturients (BMI range, 30–79). In addition, one study\(^\text{16}\) \(n=300\) found a reduction in maximum VAS pain scores and side effects in cases where pre-procedural ultrasound scanning was performed.

Sahin et al.\(^\text{33}\) compared the number of puncture attempts, spinal procedure time, and the success rate in the ultrasound group and control group between lean (BMI < 30) and obese (BMI ≥ 30) parturients. Furthermore, a recent randomized control study\(^\text{34}\) examined the first needle pass success rate with ultrasound pre-procedure scan. Their results were consistent with previous studies with regard to a lower number of puncture attempts,\(^\text{33}\) fewer puncture levels,\(^\text{33}\) a higher success rate in the first needle pass,\(^\text{33,34}\) lower rate of needle redirection,\(^\text{33}\) and shorter duration of the procedure\(^\text{33}\) in the ultrasound group. A systematic review and meta-analysis of ultrasound use for lumbar puncture and epidural catheterization\(^\text{35}\) concluded that ultrasound imaging reduced the risk of failed procedures (odds ratio, 0.21; \(P<0.001\)) and traumatic procedures (odds ratio, 0.27; \(P=0.005\)).

Interestingly, according to one study, ease of palpation of the iliac crest, BMI, and seniority of the anesthesiologists did not influence the odds of first-pass success.\(^\text{34}\) In that study, only half of the anesthesiologists (50.7%) were able to identify the intervertebral level correctly.\(^\text{34}\) Furthermore, major misidentification of the intervertebral level by two or more spaces was found in 10.7% of cases, and the best needle insertion point was marked at or above the L1–L2 interspace in 12.1% of cases (26/215; 21 at L1–2, 4 at T12–L1, 1 at T11–12).\(^\text{34}\) This is a worrisome finding given the increased risk for developing neurological complications.

**Accuracy of skin depth to epidural space**

Arzola et al.\(^\text{31}\) studied the correlation between the actual distance from the skin to the epidural space, as measured by loss of resistance (LOR) and the distance measured by ultrasound. They collected parturients (BMI < 35) who requested labor epidural anesthesia. There was a nearly perfect agreement between the depth determined by the LOR and ultrasound. A good success level was also achieved for the insertion point determined by ultrasound, and a very good correlation was found between the depth measured by ultrasound and the actual depth determined by the LOR technique. Balki et al.\(^\text{32}\) examined the correlation between an estimated depth by ultrasound and the actual depth determined by the needle from the skin to the epidural space in obese parturients (median BMI, 40; range, 30–79). Although the accuracy of the epidural depth determined by ultrasound was not as strong as that of parturients with a BMI < 35,\(^\text{31}\) they were still able to show a strong correlation between the distance estimated by ultrasound and the actual depth determined by needle distance in obese parturients.

**Learning curves**

Lumbar spine ultrasound scanning is easy to perform, and within the skill set of most anesthesiologists. In order to acquire this technique, at least 30–40 appropriate training sessions (e.g., reading materials, workshop with live model, supervised ultrasound scanning) are required.\(^\text{36,37}\)

**Technique**

The commonly described ultrasound technique allows operators to obtain the following information.

1. Correct level of lumbar spine
2. Best interspace and insertion point
3. Best angle of needle insertion
4. Depth from skin to epidural space
5. Recognition of anatomical abnormalities (e.g., scoliosis)

**Scanning points**

A curvilinear array ultrasound probe is used.

i. Generally, the ligamentum flavum, epidural space, and posterior dura matter can be seen as one structure (posterior component) on an ultrasound scan. The anterior dura mater, posterior longitudinal ligament, and vertebral body also can be seen as one structure (anterior component).

ii. Two images to remember: 1) Longitudinal view and 2) Transverse view.

iii. Four steps to follow to determine 1) the level of the lumbar spine, 2) the midline, 3) the interspinous space and the most appropriate angle, and 4) the depth from skin to epidural space.

**Useful websites for learning the lumbar spine ultrasound scanning technique**

http://pie.med.utoronto.ca/OBAnesthesia/OBAnesthesia_content/OBA_spinalUltrasound.html

http://www.pie.med.utoronto.ca/VSpine/index.htm
**Gastric Ultrasound**

**Rationale for using gastric ultrasound in parturients**

In obstetric anesthesia, being aware of the status of gastric contents is important for clinical management of patients in several clinical circumstances. In this regard, real-time ultrasound evaluation can assist in improving patient safety. Since gastric content volume (GCV) is a significant factor associated with the occurrence of pulmonary aspiration, it would be advantageous to determine GCV before the induction of general anesthesia. There reportedly is a favorable connection between the antral cross-sectional area (CSA) with gastric volume in various situations including healthy volunteers, pregnant patients, and patients undergoing either an elective or emergent procedure. A summary of reviewed articles can be found in Table 2.

The incidence of pulmonary aspiration in parturients is higher than that of the general population, which has been reported to be at least twice that of the general surgical population. In 1946, acid aspiration was first described by Mendelson, who found that patient mortality was related to the aspiration of solid food remaining in the stomach for several hours after the last oral intake. They reported 66 cases of pulmonary aspiration in which more than half of the cases had prolonged operative interventions and greater depth of anesthesia. In approximately two-thirds of recorded cases, the aspirated material was found to be liquid, compared to only five cases of solid material.

**Gastric contents and gastric emptying**

One study looked at the nature of gastric contents in a qualitative ultrasound assessment and used gastric ultrasound to estimate stomach contents in pregnant women. Gastric ultrasound revealed solid food within the stomach of nearly two-thirds of their study population. They concluded that there was a delay in stomach emptying for many hours after the onset of labor. In addition, the investigators decided to modify the standard position of pregnant women to right lateral decubitus, with the head of the bed elevated to 45 degrees. The practice of bed-elevation during gastric ultrasound has been followed in studies conducted afterwards.

The theory that gastric mobility and stomach emptying are impaired by pregnancy and labor has been questioned recently with current knowledge suggesting and even encouraging clear fluid ingestion during labor, to improve maternal comfort and satisfaction. Wong et al. primarily measured clear fluids in obese and non-obese pregnant women, concluding that there was normal emptying of gastric contents during pregnancy. In a crossover study in 2002, they assessed gastric emptying of clear fluids in comparison with emptying after an overnight fast in pregnant women at term. They measured the half-time to gastric emptying and serial plasma acetaminophen concentrations, and found no delay in gastric emptying in healthy, term, non-obese, non-laboring pregnant women after ingestion of 300 ml of water compared with that after an overnight fast.

In another crossover study, Wong et al. compared gastric emptying in obese, term pregnant women using both serial gastric ultrasound examinations and acetaminophen absorption. They showed that gastric emptying T1/2 in obese, term pregnant volunteers did not differ after oral intake of 300 ml water compared with that after 50 ml water (23 ± 11 min vs. 32 ± 15 min). On this basis, they suggested that all women, regardless of BMI, could drink clear liquids until two hours before a planned surgery without increasing the risk of aspiration, morbidity, and mortality.

Barboni et al. conducted a prospective case-control study to assess the rate of gastric emptying in the third trimester of pregnancy, with ultrasonographic measurements taken after a standardized meal. They found delayed gastric emptying after meal intake and determined the point at which women at term pregnancy should be considered to have a “full stomach”. Their results were in agreement with practice guidelines that suggested allowing only small volumes of clear liquids during labor. However, no ultrasound examination was carried out in their study beyond six hours. Notably, the method they followed was different from that of a study conducted by Arzola et al., who evaluated only pregnant patients with an empty stomach, or those who had only taken clear liquids or solid foods such as a small muffin and coffee with cream or milk. Other cohort studies have followed the current fasting guidelines (six to eight hours for solids and two hours for clear fluids), but their study populations did not include term pregnant women with solid gastric contents before elective cesarean delivery.

Several mathematical models have been used to assess different patient positions and clinical scenarios. A study by Bouvet used the antral cross-sectional area with cut-off values measured in a 45° semi-recumbent position. CSAs > 3.4 cm² and > 3.8 cm² were reported in non-pregnant and pregnant patients, respectively, and these values correlated with a gastric volume > 0.8 ml kg⁻¹. This was defined as a ‘risk stomach’. Moreover, they found a strong correlation between antral CSA and gastric volume.

Bataille et al. determined the cut-off value corresponding to increased gastric content by ultrasound measurement of antral CSA in non-laboring women in their third trimester. Ultrasound was performed before and after the intake of a non-clear fluid, followed by two
Table 2. Summary of gastric ultrasound studies

| Study | Study design          | Study population                                           | N   | Objectives                                      | Patient position | Scanning Plane | Empty | Fluid | Solid | P value |
|-------|-----------------------|------------------------------------------------------------|-----|------------------------------------------------|------------------|----------------|-------|-------|-------|---------|
| Wong  | Cross over study      | Non-obese term pregnant women                             | 15  | Gastric emptying                                | Semi-sitting     | Sagittal       | No    | Yes   | No    | < 0.05  |
| Carp  | Pilot                 | Females (OB, non-OB)                                       | 73  | Assessing delayed gastric emptying and risk of aspiration | RL               | Transverse     | Yes   | Yes   | No    | NA      |
| Wong  | Cross over study      | Obese term pregnant women                                 | 10  | Gastric emptying                                | Semi-sitting     | Sagittal       | No    | Yes   | No    | P = 0.23 |
| Barboni| Prospective case-control | Pregnant women in 3rd trimester for elective CD       | 10  | The reliability of bedside ultrasound for gastric contents | Supine/Right side with HOB 45° | Sagittal or Parasagittal | No   | Yes   | Yes   | < 0.05  |
| Arzola| Observational cohort  | Pregnant women                                             | 32  | Bedside ultrasonography for gastric content volume | Supine/RLD       | Sagittal or Right parasagittal | Yes   | Yes   | Yes   | < 0.0001 |
| Arzola| Observational cohort  | Pregnant women in non-labor                                | 103 | Rate of gastric emptying                        | Supine/RLD       | Sagittal       | Yes   | No    | No    | < 0.0001 |
| Bataille| Prospective cohort   | Pregnant women in spontaneous labor                        | 60  | Gastric content volume in parturients           | Supine           | Sagittal median | Yes   | Yes   | No    | During labor $P = 2 \times 10^{-7}$, Beginning of labor vs at full cervical dilatation $P = 0.006$ |
| Jay   | Prospective cohort    | Pregnant women in established labor                       | 73  | The cut off value of the gastric antral area    | Supine/RLD       | Sagittal       | Yes   | Yes   | Yes   | $P = 0.002$ |
| Zieleskiewicz | Prospective observational cohort | Term pregnant women in established labor | 40  | Fasted gastric antrum assessment at term pregnant women | Supine/RLD       | Sagittal       | Yes   | Yes   | No    | $< 0.001$ |
| Arzola| Randomised controlled & assessor-blinded | Pregnant women in non-laboring 3rd trimester | 60  | Fasted gastric fluid volumes                   | Semirecumbent/ Semirecumbent RL | Sagittal       | Yes   | Yes   | No    | $< 0.0001$ |
| Roukhomovsky | Prospective cohort study | Pregnant women in 3rd trimester | 34  | Mathematical model for gastric content volume  | Semirecumbent supine | Sagittal       | Yes   | Yes   | Yes   | $< 0.0001$ |

RL, right lateral; RLD, right lateral decubitus; HOB, head of the bed.
Empty — Yes: empty stomach, NO: not empty stomach
Fluid — Yes: stomach contains fluid, NO: no fluid in stomach
Solid — Yes: stomach contains solid food, NO: no solid food in stomach
antral CSA measurements on parturients who were in spontaneous labor during catheter placement for epidural analgesia and at full cervical dilatation. They suggested the use of 3.2 cm² as the cut-off value for an at-risk stomach in pregnant women based on the finding that, at the beginning of labor, CSA was > 3.2 cm² in 50% of pregnant women compared to only 13% at full cervical dilatation. Given the decreased amount of gastric contents during labor, they suggested that gastric motility and stomach emptying are both preserved during labor.

In 2015, Arzola et al. examined non-laboring term pregnant women one hour before elective cesarean section, after a minimum of six hours fasting for solids and two hours for clear fluids. Using a three-point grading system, most parturients at term had an empty stomach (Grade 0 or 1) after following conventional fasting guidelines. Only one patient had a gastric volume suggestive of higher than normal fasting secretions (Grade 2). These results were inconsistent with another study which suggested an antral CSA threshold of 3.2 cm² in the supine position to differentiate between an ‘empty stomach’ and a ‘full stomach.’ Over half of the subjects had a supine antral CSA > 3.2 cm², suggesting that the threshold proposed by Bataille et al. likely overestimated the number of patients at increased risk of aspiration. The results of the study by Arzola et al. suggested an antral CSA value of 10.3 cm² in the right lateral decubitus (RLD) position as a more accurate barometer of the upper limit of normal findings in pregnant patients at term. Ninety-five percent of their subjects had a gastric volume of < 1.5 ml kg⁻¹, and their antral CSAs in the RLD position were similar to those reported for non-pregnant adults by Perlas et al.

- Details of the grading scale are described in “scanning points” described later in this article.

Zieleskiewicz et al. studied non-obese pregnant women who were permitted to drink water during labor under epidural analgesia in an observational prospective cohort study, in which gastric ultrasound measurements were taken after fasting for a minimum of six hours for solid food and at least two hours for clear fluids. Using “gastric antral area (GAA)” (corresponding to CSA in other studies), cut-off values for GAA to detect ingested volumes > 0.4, > 0.8 and > 1.5 ml kg⁻¹ in laboring women were determined. GAA was calculated using the maximal anterior posterior diameter (D1) of the antrum and the longitudinal diameter (D2) of the antrum. A proportional increase was observed in GAA with the volume of clear fluid ingested. In the supine position, the cut-off value for GAA to detect a gastric fluid volume > 0.4 ml kg⁻¹ was 3.87 cm², and the cut-off for a gastric volume > 1.5 ml kg⁻¹ was 6.08 cm². The first cut-off value corresponded to an empty stomach and thus a low risk for pulmonary aspiration. The second cut-off value corresponded to a full stomach and thus an increased risk of pulmonary aspiration. These findings are consistent with those of Arzola et al. and Wong et al., which showed that the mean GAA in fasting parturients was larger in comparison to values reported in fasting non-pregnant patients.

Roukhomovsky et al. conducted a prospective observational cohort study to develop a mathematical model for predicting the volume of gastric contents in women in late pregnancy, and to assess the performance of an ultrasound qualitative grading scale for diagnosing clear fluid volumes > 0.8 ml kg⁻¹ and > 1.5 ml kg⁻¹. Gastric volume was measured after obtaining MRI images (as the gold standard), which allowed qualitative assessments of gastric content based on a 0 to 2 grading scale described in a previous study. Gastric contents were not visible in 21% of women, whereas 79% had solid and/or liquid gastric contents. The authors concluded that ultrasound measurements of antral CSA correlated well with MRI-measured GCV, and that ultrasound measurements of the gastric antrum combined with measurements of antral CSA assisted in the diagnosis of gastric fluid volumes > 1.5 ml kg⁻¹ in such patients. That study also reported that 75% of women who had grade 2 antrum had a gastric fluid volume > 1.5 ml kg⁻¹. However, a large number of women with grade 0 antrum had a GCV ≤ 0.8 ml kg⁻¹ and all of these patients had a GCV < 1.5 ml kg⁻¹, suggesting that a grade 0 antrum may correlate with an “empty” or low volume stomach, as previously reported by Perlas et al.

In a randomized controlled study conducted by Arzola et al., pregnant women in the third trimester of pregnancy underwent baseline gastric ultrasound assessments of gastric contents (empty, fluid, or solid) after an overnight fast of at least eight hours. Gastric volume was assessed by measuring the cross-sectional area (CSA) of gastric volume. Women were assigned to six groups who drank either 50 ml, 100 ml, 200 ml, 300 ml, or 400 ml apple juice, and a control group. The study found that an antral CSA of 9.6 cm² in the semi-recumbent right lateral position could discriminate low from high gastric volume. This cut-off value is consistent with their previous report of 9.6 cm² as the 95th percentile for fasting women before cesarean delivery. This result, however, was inconsistent with that reported by Zieleskiewicz et al., which was carried out on laboring women who underwent epidural analgesia. One reason for the inconsistency between findings of the two studies may be the lack of randomization and controlled fluid volumes in both studies.

One potential criticism of ultrasound scanning is its subjectivity in drawing conclusions. However, this...
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has been assessed in both pregnant and non-pregnant populations, with reassuring results. In 2014, Arzola et al. conducted a cohort study aiming to assess the consistency of raters in diagnosing the correct status of gastric contents, along with the overall proportion of correct and incorrect diagnoses of non-laboring pregnant women, all of whom had fasted overnight for at least eight hours. These women were randomized into three groups (empty, clear fluid, and solid content groups). A correct diagnosis was noted in 87.5% of cases, thereby confirming the consistency of bedside ultrasound assessment of gastric contents of parturients in the third trimester by anesthesiologists, and the significant agreement in interrater reliability for qualitative ultrasound. The study also found high reliability between each rater and the other two raters combined.

In the context of emergent situations such as acute fetal compromise or maternal hemodynamic alteration, it may not be possible to place the parturient in the right lateral position. To this end, Jay et al. described a qualitative ultrasound assessment measure for use in the supine position. In 2017, they conducted a prospective observational cohort study on women in established labor to calculate the cut-off value of the antral cross-sectional area measured in the supine position to diagnose an ‘empty’ stomach (Grade 0) in laboring women. For each parturient, ultrasound assessment of gastric contents was performed in the supine and right lateral decubitus positions, with scores ranging from 0 to 3 on a qualitative grading scale. The cut-off value for the antral area measured in the supine position was 3.81 cm², which was higher than the value previously reported in the non-obstetric population (3.4 cm²). Two-thirds of women who had their last solid meal < 8 hours before assessment had an antral area > 3.81 cm², whereas two-thirds of women with a prolonged fasting period of > 8 hours had an antral area < 3.81 cm². Compared to the success rate of 96% in laboring women when measuring the antral cross-sectional area in the supine position reported by Bataille et al., Jay et al. reported a success rate of 90% (81/90) using this technique. Thus, Jay et al. suggested that a single examination of the antrum in the supine position may allow qualitative analysis of gastric contents for an easy and fast diagnosis of a full stomach (Grades 2 and 3). However, their results were based on data from a single technique (ultrasound examination of the antral area).

Learning curves
The gastric ultrasound scanning technique is simple and relatively easy to learn. One study targeting anesthesiologists reported a 95% success rate in bedside qualitative ultrasound assessment after performing approximately 33 examinations with appropriate training and supervision.

Technique
The technique allows operators to determine the following information.
1. The type of gastric content (empty, clear fluid, thick fluid/solid)
2. Volume of gastric content when clear fluid is present.

Scanning points
A curvilinear ultrasound probe is used.
   i. Right lateral decubitus (RLD) position
   ii. Identification and scanning of the gastric antrum
   iii. Qualitative assessment: Grade 0 (empty), Grade 1 (≤ 1.5 ml kg⁻¹, negligible amount of volume), Grade 2 (> 1.5 ml kg⁻¹, excessive amount of volume)
   iv. Cross-sectional area of the antrum (CSA) correlates with gastric volume

Useful website for learning the gastric ultrasound scanning technique
http://gastricultrasound.org/

Conclusion
Perioperative ultrasound use has significantly increased over the past decade, and techniques for lumbar spine ultrasound and gastric ultrasound are now well-established. The incidence of conus medullaris injury from neuraxial blockade and pulmonary aspiration during general anesthesia is low in general. However, when they do occur, they have devastating consequences.

Neural injury and epidural hematoma from neuraxial blockade are serious complications. Lumbar spine ultrasound can identify the correct level of entry and reduce the number of needle attempts. This, in turn, can reduce the risk of accidental conus medullaris injury and epidural hematoma.

Perioperative pulmonary aspiration continues to be a significant challenge in anesthesia practice. Management of a pregnant patient who presents with a potentially full stomach needs the greatest attention in the perioperative period. Gastric ultrasound is a relatively newer technique of point-of-care ultrasound which is increasingly used in anesthesia practice. Several areas still need to be investigated with regard to defining training requirements for anesthesiologists to acquire accurate assessment abilities. Furthermore, more advanced modalities of ultrasound appear to play a role in the future of gastric assessment. Gastric ultrasound is a technically simple and acquirable bedside diagnostic tool for all anesthesiologists which could potentially help in the accurate assessment of risk and safe guidance of anesthesia management.

The morbidity and mortality resulting from neural
damage and pulmonary aspiration have substantially decreased due to new developments in anesthesia practice (e.g., inadvertent preoperative assessment, use of neuraxial blocks over general anesthesia, improved tracheal intubation techniques and equipment). Anatomical imaging derived from lumbar spine ultrasound and gastric ultrasound can provide important information during preoperative assessment and planning of anesthesia management. It will be important for us to continue to be vigilant in our day-to-day practice.

We believe that ultrasound will continue to grow as an important part of our clinical practice by providing us with additional useful clinical information. Competency in ultrasound scanning of the lumbar spine and gastric region may become essential for all anesthesiologists in the future.

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Conflict of interest

None.

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