# The use of ultrasound in obstetric anesthesia

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**Purpose of review**
The current review considers an array of recent applications for point-of-care ultrasound in clinical practice including diagnostic and therapeutic procedures that may be relevant for the obstetric anesthesiologist. The rapid advancement of technology and clinical applications for bedside ultrasound in obstetric anesthesiology requires an appraisal of the limitations and uses.

**Recent findings**
The review presents the most recent literature describing ultrasound-guided airway assessments, airway management, cricothyroidotomy, transthoracic echocardiography, gastric volume assessments, point-of-care lung ultrasound diagnoses, intracranial pressure assessments, vascular access, neuraxial blocks, and transversus abdominis plane blocks. Each ultrasound technique is presented along with the most recent advances in knowledge and some limitations to integration of these ultrasound skills in clinical practice.

**Summary**
Anesthesiologists have clearly embraced this facile versatile tool for bedside diagnostics and procedures. One limitation to widespread adoption is availability of suitable ultrasound skills and technology. Many of these ultrasound techniques have not yet established clear patient benefit, yet the sheer breadth of ultrasound techniques reported in the past few years demonstrate that our colleagues are becoming more proficient. It is important to follow the development of this emerging field to be aware of limitations to learning these skills and their potential clinical benefit. Proficiency in some of these point-of-care ultrasound techniques may become prerequisite for obstetric anesthesiologists to provide the best care.

**Keywords**
blocks, diagnosis, echocardiography, lung, ultrasound, vascular

## INTRODUCTION

Ultrasound provides the clinician with bedside eyes inside the body, potentially replacing digital palpation and anatomical assessment. Anesthesiologists have reported measures of intracranial pressure and optic nerve diameter [1], diagnoses of hypoxia and endobronchial intubation [2], lung and cardiac disorder [3▪▪,4], transthoracic echocardiography (TTE) [5▪▪], gastric volume assessments [6], as well as regional anesthesia techniques. This review will consider recent advances in the use of point-of-care ultrasound (POCUS) for diagnostic and therapeutic procedures that may be relevant for the obstetric anesthesiologist.

### Airway assessment

Failed intubation in pregnancy has a reported incidence from one in 443 [7] to 533 [8], and the maternal mortality rate from failed intubation is reportedly 2.3 per 100 000 general anesthetics [7]. The Obstetric Anaesthesia Airway guidelines [9▪▪] recommend a robust antenatal plan for women with anticipated difficult airway. Early labor epidural analgesia is one strategy that may obviate the need for general anesthesia for urgent cesarean delivery. However, early labor epidural analgesia does not guarantee successful surgical anesthesia [10▪▪], particularly in obese women who are more likely to suffer failed epidurals and are at greater risk of failed intubation. Ultrasound antenatal airway assessments can identify women who may benefit most from avoiding general anesthesia for cesarean delivery.

Hui *et al.* [11] used ultrasound to image the sublingual space in a nonpregnant population. Patients placed the curved array probe, covered with a sterile sheath, under their tongue in a longitudinal

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## KEY POINTS

- Ultrasound is an accessible bedside tool to enable many diagnoses and procedures for obstetric anesthesiologists, including assessments of intracranial pressure, hypoxia, hemodynamic collapse, airway, and gastric volume.
- Ultrasound is increasingly familiar to anesthesiologists for intravascular access and nerve blocks, and some guidelines recommend its routine use for these clinical procedures.
- Emerging applications include lung ultrasound to diagnose hypoxia and endotracheal intubation, although these currently have limited diagnostic sensitivity.
- Ultrasound is a potential tool for emergency obstetric anesthesia management, to assess difficult airways, to identify the cricothyroid membrane, to avoid rapid sequence induction if an empty stomach can be confirmed, and to identify the insertion point for a rapid spinal for emergency cesarean delivery.
- Limitations to practical application of ultrasound in routine clinical practice include the learning curve and uncertain patient benefit.

plane. The endpoint that predicted difficult intubation was inability to visualize the hyoid bone. The sublingual ultrasound was well tolerated, and this technique may be relevant in pregnant women.

Fulkerson *et al.* [12▪▪] reviewed 10 studies that reported preoperative airway assessment of adults: pregnant women were included in one study and specifically excluded in three. The study outcome was a Cormack–Lehane grade 3 or 4 at laryngoscopy, predicted using an assortment of ultrasound measures. For the pregnant women [13], 12 obese women had a predicted difficult airway based on a hyomental distance of 53 mm compared with 66 mm in the easy intubation group. Specific predictors for ultrasound assessments of airway have not yet been established [12▪▪], and there is a need for standardized ultrasound scan measures for preoperative airway assessments.

### Airway management

For failed intubation during general anesthesia for cesarean delivery, the United Kingdom guidelines refer to the Difficult Airway Society guidelines technique [9▪▪]. One in 60 women who have failed intubation may require surgical airway access, and knowledge of these techniques may be life-saving if performed accurately [7]. You-Ten *et al.* [14▪▪] compared digital palpation of cricothyroid anatomy versus ultrasound among 56 women (half with BMI $> 30\,kg/m^2$). Ultrasound improved identification of the cricothyroid membrane, and this was of particular use among obese women for whom digital palpation was not accurate.

Learning cricothyroid puncture is challenging, and training may be more suited to a skills lab [15]. Residents and anesthesiology staff were trained on ultrasound using video, gel phantom, or general knowledge of airway anatomy. The 56 learners were assessed 3 weeks after the training session and demonstrated that despite some decline in knowledge, around 50% could successfully identify the cricothyroid membrane compared with less than a third at baseline. Although no technique will promise success, the concept of real-time performance with ultrasound as the needle pierces the cricothyroid membrane is logical [14▪▪].

### Gastric volume assessment

Rapid sequence intubation in pregnancy is recommended to protect against acid aspiration [7,8]. The rationale for gastric ultrasound in pregnant women is that if the stomach is known to be empty, rapid sequence induction and associated inherent risks at intubation may be avoided. In nonpregnant adults, the gastric antral area (GAA) correlates with gastric volume [16]. The GAA for a full stomach at risk for aspiration was measured as $340\,mm^2$ (sensitivity 91%, specificity of 71%) in nonpregnant patients. The stomach at risk for aspiration reportedly has a fluid or solid particle content of more than 0.8 ml/kg [4,16].

Perlas *et al.* [6] defined a 3-grade measurement for gastric volumes, obtained from 86 nonpregnant patients, scanned prior to anesthesia induction. Gastric ultrasound measurements were performed in supine and right lateral decubitus position Grade 0 = empty antrum; Grade 1 = ingested volumes $0.2 \pm 0.5$ ml/kg, expected in fasted patients; and Grade 2 = large ingested volumes $2.8 \pm 1.4$ ml/kg, and this is potentially associated with a risk for aspiration.

Arzola *et al.* [17] measured gastric volumes in 103 pregnant women prior to elective cesarean delivery under neuraxial block. There was agreement between the supine and the lateral decubitus position measures of GAA for 95% of the patients. Predicted gastric volumes in this pregnant cohort corresponded to actual ingestion of Grade 0 = 0.4 ml/kg, Grade 1 = 1.0 ml/kg, and Grade 2 = 2.7 ml/kg, and these are similar to volumes reported in the nonpregnant population.

Zieleskiewicz *et al.* [16] studied gastric ultrasound measures in fasted nonobese (BMI $< 35\,kg/m^2$) pregnant women who had effective labor



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analgesia. The women were at least 36 weeks pregnant, fasted for at least 6 h for solid food, and at least 2 h for clear fluids. One operator performed the initial ultrasound; 28 women were excluded as visualization of the gastric antrum was not possible. The same operator performed the second measurement 15 min after ingestion of a specified fluid volume in the remaining cohort of 40 women. The GAA was calculated using measures of the maximal anterior posterior diameter ($D1$) of the antrum and the longitudinal diameter ($D2$) of the antrum [16]: $\text{GAA} = [(\pi \times D1 \times D2)/4]$.

Perlas *et al.* [6] reported that ultrasound can reliably identify an empty stomach in the nonpregnant population. There are conflicting reports regarding identification of an empty stomach in pregnant women. Arzola *et al.* [18] established in his cohort that the gastric volume could be reliably confirmed, in contrast with prior studies in pregnant women. They postulated that improvements in technology explained this difference.

There are other limitations to use of gastric ultrasound. First, the effect of neuraxial block on gastric volume is unclear [16], and the pregnant women studied had prolonged fasting duration [6]. In addition to technical difficulty to visualize the antrum, the measures of D1 and D2 may be erroneous in pregnancy, as the stomach is displaced cephalad [18]. Although measures of gastric volume may be more accurate in the lateral decubitus position [16], supine measurement may be necessary in an emergency. The failure rate to achieve a good scan is reportedly between 13 [17] and 36% [16]. Finally, training in gastric ultrasound assessment may not be available to residents in anesthesiology [19]. When exposed to training in gastric ultrasound, 33 scans were required for competency to achieve a success rate of 95% [18]. Furthermore, studies report measures by expert operators, which may not be replicable in a clinical situation [6,16,17]. It may be too early to predict the utility of ultrasound to detect gastric contents, to base clinical decisions on the gastric aspiration risk, and to plan airway management for general anesthesia [19]. Improved training and familiarity with clinical decision-making based on measured gastric volumes may come in the future, but currently lack reliability.

## Lung ultrasound

Several recent studies have used POCUS to diagnose hypoxia, endobronchial intubation, lung fluid, and more. In pregnancy, the most common reason for lung interstitial fluid overload is preeclampsia. A recent review by Mittal and Gupta [3▪▪] demonstrated the incredible number of disorders that an adept operator can diagnose, including pneumothorax and interstitial fluid, pleural effusion, endobronchial intubation, bronchospasm, and pulmonary embolism. The authors presented an algorithm to investigate causes of hypoxia and to review mnemonics that may 'COVER' potential causes of hypoxia, albeit currently with low sensitivity. One valuable technique may be identification of endobronchial intubation. Auscultation may be limited in obese pregnant patients, and ultrasound can confirm this diagnosis [3▪▪]. Ramsingh *et al.* [2] used ultrasound to identify tracheal or bronchial intubation to a sensitivity of 93 versus 66% for auscultation.

Another comprehensive review by Picano *et al.* [20▪▪] described ultrasound to diagnose pulmonary congestion, pleural effusion, and lymphatic drainage. The authors suggested that fluid in the lungs is a particularly suitable medium to detect through ultrasound even when other lung disorders may be elusive. According to their review, it is relatively easy to learn these techniques, in particular to identify B-lines: specific 'comet-like signals' that sway with respiration. Monastesse *et al.* [21] reported lung ultrasound to detect causes of hypoxia such as atelectasis, endobronchial intubation, and pulmonary edema. The authors suggested that in light of the high likelihood of hypoxemia during surgery, a rapid reliable tool should be available to aid the diagnosis of atelectasis. They reported lung ultrasound performed by two physicians with 6-month and 5-year experience, respectively, in echocardiography, for 30 patients undergoing mechanical ventilation during laparoscopic surgery. The evaluation was performed by dividing the thorax into 12 sections, and they applied the lung ultrasound score to measure aeration loss, and this score also considers presence of B-lines and lung consolidation. The diagnosis of pneumothorax can be made using four specific ultrasound signs [3▪▪]: 'Absence of lung sliding, B-lines, and lung pulse and the presence of lung point'. According to a 2009 article, identification of pneumothorax using ultrasound is a simple technique to learn [22].

Few studies have specifically used lung ultrasound in pregnancy, but one study by Zieleskiewicz *et al.* [23] compared lung ultrasound findings in 20 women with preeclampsia with healthy pregnant controls. Among the women with severe preeclampsia, five had edema detected by the ultrasound along with increased left ventricular (LV) end-diastolic filling pressures. This preliminary study highlights the potential value of lung ultrasound described in the critical care and perioperative surgery literature, as these ultrasound tools may have a role for the critically ill pregnant patient.



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## Transthoracic echocardiography

TTE and its uses in pregnant women were recently reviewed by Dennis [5▪▪,24]. TTE can diagnose postpartum cardiomyopathy associated with genetic and hormonal conditions or an underlying condition such as severe preeclampsia [5▪▪,24]. Clinicians can use TTE to establish the hemodynamic status by assessing myocardial contractility, preload, and end-diastolic volumes of both ventricles [25,26▪▪]. TTE can contribute to an emergency diagnosis of maternal critical illness [27] and may assess myocardial contractility, preload, and end-diastolic volumes of the ventricles. For example, in a woman with sudden onset hemodynamic collapse, TTE can illustrate an empty LV (e.g. post-partum hemorrhage), an overloaded right ventricle (e.g. pulmonary or amniotic fluid embolism), or pericardial effusion [27]. These conditions are characterized by abrupt presentation during pregnancy or labor and delivery, with a high maternal and fetal morbidity and mortality. In such an emergency scenario, an Obstetric Anesthesiologist who is familiar with TTE can initiate focused aggressive therapies such as antibiotics, blood management, or hysterectomy, depending on the TTE findings [26▪▪].

## Intracranial pressure

Ultrasound can detect changes in the optic nerve sheath diameter that occur in preeclampsia [1]. Several recent studies used ultrasound to diagnose intracranial hypertension. The optic nerve sheath was thicker in women with preeclampsia ($n = 26$) compared with healthy pregnant controls ($n = 25$), and 20% of the women with preeclampsia demonstrated values associated with intracranial hypertension. The clinical significance of this needs to be further investigated. An accompanying editorial by Rollins and Flood [28] postulated that ultrasound measurements of the optic nerve sheath may enable assessment of cerebrospinal fluid leak and to supplement epidural blood patch.

## Vascular access

Two recent reviews of anesthesia for the obese pregnant woman mentioned their difficult intravenous access [29,30]. Given the increased prevalence of morbid obesity, alternative techniques are required to reliably achieve intravenous access in obese pregnant women [29]. Two predominant causes of intravenous access failure include lack of a detected vein and failure to advance the needle or the catheter into the vessel lumen [31]. Although there are no reports of ultrasound-guided peripheral intravenous access in obese pregnant women, two recent studies highlighted the usefulness of ultrasound for obese patients, and the recent vascular access guidelines from the United Kingdom support use of ultrasound to aid peripheral intravenous access [32▪▪].

Brandt *et al.* examined seven anatomic regions for vascular access in 55 patients who had BMI above 40 kg/m$^2$ prior to bariatric surgery. The authors reported that most patients had visible or palpable peripheral veins, that the 7/55 patients without visible veins were superobese with a mean BMI of 51.5 kg/m$^2$, and that ultrasound enabled identification of peripheral intravenous access in all their obese patients [33]. In the other study, anesthesia faculty, residents, or medical students used ultrasound to place large-bore peripheral intravenous access in 100 patients. The majority (96%) of the ultrasound-guided cannulations were successful on the first attempt, and the median time for each cannulation was 72 s [31].

Dietrich *et al.* [34] reviewed ultrasound for vascular access and in particular the advantages related to reduced complications such as inadvertent arterial cannulation and decreased number of punctures. Ultrasound can identify a misplaced guidewire and cannula, and demonstrate anatomical variants. These benefits are of additional importance for pregnant women with thrombocytopenia or coagulopathy.

Siddiqui *et al.* [35] simulated the needle insertion point for internal jugular vein catheterization in pregnant ($n = 99$) and nonpregnant ($n = 66$) women. Needle puncture according to the anatomical landmarks would have punctured the carotid artery in 19% of the pregnant versus 10% of the nonpregnant women. Needle puncture according to carotid palpation would have doubled the frequency of carotid artery puncture compared with nonpregnant women. This study supports National recommendations both from the Agency for Healthcare Quality and Research, United States, and from the National Institute for Health and Care Excellence, United Kingdom, for ultrasound use for central vein catheterization [36,37], also in pregnant women [35].

## Neuraxial blocks

In pregnant women, it can be challenging to establish neuraxial block using the traditional method of landmarks assessment, due to anatomical and physiological changes such as obesity, edema, lordosis, scoliosis, and previous spinal surgery. The overall incidence of difficult neuraxial blockade seems to be around 4% [38▪▪]. According to Stendell *et al.* [38▪▪], the most frequent predictors for difficult neuraxial block among 73 579 patients were unrecognizable

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landmarks or difficult in palpation; operator experience is also important. Blocks that are more difficult to establish have a higher frequency of complications such as inadvertent dural puncture paresthesia and other neurological sequelae [38▪▪].

Positioning the patient properly to facilitate the block can be challenging due to the gravid uterus [19]. In 2016, a publication based on two meta-analyses reported that preprocedural ultrasound reduced the number of attempts needed to establish the block compared with traditional palpation using landmarks [39▪▪]. This is not a uniform finding across all patient populations, as illustrated by Tawfik *et al.* [40], who failed to demonstrate an advantage of establishing a neuraxial block with ultrasound versus landmark palpation in a nonobese population (BMI $< 35\ kg/m^2$) with full-term singleton pregnancy undergoing elective cesarean delivery. The use of preprocedure ultrasound reduced the number of punctures and was associated with improved efficacy of neuraxial block and higher patient satisfaction in the study by Ansari *et al.* [41]. Sahin *et al.* [42] reported that obese pregnant women, with nonpalpable anatomical land, required less attempts to succeed to neuraxial block when ultrasound was used. Arzola [39▪▪] showed no advantage to ultrasound-assisted neuraxial block in preventing postdural puncture headache when neuraxial block was performed by an experienced anesthesiologist.

The disadvantages of ultrasound include time to perform the procedure while the painful labor continues. In one study, using ultrasound lengthened the procedural time by 75 s in a population of 75 laboring women, versus 75 women in whom a neuraxial block was performed using traditional landmarks [41]. This may be precious time when a woman is waiting for immediate analgesia in labor; furthermore, in the study setting, it is likely that this time was optimally short as the staff were aware of the study and knew where to locate the ultrasound and bring it expeditiously to the labor room.

Ultrasound-guided assessment is usually preprocedural, however changes in patient posture may alter this neuraxial block insertion point. A recent publication reported real-time median oblique and sagittal scans of the mid-lumbar spine of 10 morbidly obese women. One operator held the probe, and the second one used a Touhy needle, advanced under vision until the tip of the needle was at the posterior part of the ligamentum flavum. At this point, a loss of resistance technique confirmed the epidural space location, under ultrasound vision. Women with challenging anatomy were included, and epidural catheter insertion was successful in all cases using between one and three attempts, without inadvertent spinal [43▪▪]. It is tempting to imagine being able to visualize the needle pass through the anatomical structures until it reaches the epidural space in real time. Other authors have reported using this technique in patients with normal anatomy [44,45]; Tran *et al.* [44] performed ultrasound in 19 pregnant women using a needle guide to enable a single operator to perform the technique. New technologies such as three-dimensional real-time ultrasound [46] for neuraxial block tantalize with potential advantages of real-time technology. A reliable single-operator system for real-time neuraxial block placement may be a useful tool but the technology is not reliable yet.

Arzola [39▪▪] highlighted that many practitioners in the United States may avoid using ultrasound due to the lack of technical expertise. Regular training with ultrasound to assist neuraxial block is required to simplify block placement with ultrasound in difficult cases (patients with scoliosis, obesity, etc.). Current evidence suggests that when a difficult neuraxial block for labor is predicted, the block will be performed with fewer punctures and with improved efficacy using ultrasound guidance to identify the insertion site. Lack of training limits the use of ultrasound as a rescue option when faced with a difficult neuraxial block placement. We advocate that all clinicians become familiar with the ultrasound-guided neuraxial block so that it is available for difficult cases and it may be a useful technique if the neuraxial block failed and requires replacement.

## Transversus abdominis plane block

Pain after cesarean delivery comprises a major burden [47,48], yet the ideal analgesic is a balancing act between good analgesia versus potential risks. For example, intrathecal morphine is considered very effective, yet causes pruritus and reported respiratory side effects [49]. One potential alternative option is to use a transversus abdominis plane (TAP) block using a local anesthesia infiltration. The local anesthesia drug mixtures used in TAP blocks vary widely. Wang *et al.* [50] used fentanyl in a randomized control study in which all patients received a TAP block regime, there was no advantage to the addition of fentanyl.

In 2015, two reviews considered TAP block for postcesarean analgesia. Fusco *et al.* [51▪▪] considered 11 studies and reported outcomes such as efficacy and safety. The therapeutic regimens of TAP block were heterogeneous and included ropivacaine, bupivacaine, or levobupivacaine, with or without additives such as narcotics, compared with intrathecal



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analgesia (fentanyl and/or morphine). Use of ultrasound to guide TAP block may improve accurate local anesthesia placement and reduce accidental injury [51▪▪]. This review did not demonstrate a benefit for TAP block performed with ultrasound guidance versus intrathecal opioids unless intrathecal morphine was omitted, for example, when TAP block was performed for cesarean delivery under general anesthesia.

Ripolles *et al*. [52] reviewed ultrasound-guided TAP block in 10 randomized controlled trials and again reported that intrathecal morphine is superior. Clearly, it is desirable to avoid general anesthesia, where possible, for cesarean delivery, but urgent cases may require general anesthesia despite the most prodigious planning with early-labor epidural analgesia [53], and these women could reap the analgesia benefit of a TAP block.

One advantage of TAP blocks is that they can be performed after surgery in a supine patient. However, there is no evidence to support TAP block as a routine procedure for postcesarean delivery analgesia, and intrathecal morphine should be encouraged.

## SUMMARY

Writing this review was a fascinating yet challenging task, not in the least due to frequent concurrent e-mail alerts from prominent journals regarding publication-ahead-of-print of relevant novel studies. Anesthesiologists have clearly embraced this facile versatile tool for bedside diagnostics and procedures, made easier as technology and mobility have improved. In our clinical obstetric anesthesia practice, we have adopted ultrasound-guided neuraxial block, as we consider that the benefit is clear when an obese patient requires rapid de novo neuraxial anesthesia for emergency cesarean delivery. Ultrasound-guided vascular access is a bread-and-butter technique for residents today. We considered that of all the ultrasound techniques reviewed, identification of the cricothyroid membrane might be an important one to learn, considering the disturbingly high chance of failure using palpation alone. In the presence of sudden hemodynamic collapse, TTE can direct therapeutic modalities, according to findings suggestive of sepsis or of embolus.

One challenge will be to define who should gain and retain proficiency in these ultrasound techniques. Ultrasound technical prowess for anesthesiologists may become a universally expected skill, similar to intubation, neuraxial block placement, and vessel cannulation, or rather remain the domain of select enthusiastic anesthesia practitioners who are willing and able to gain expertise. Medical school curriculum recognizes this [54], and students will likely become familiar with using ultrasound to make diagnoses; moreover, they may be more facile with the technology than their faculty. Standards for curriculum and recommendations regarding essential learning of ultrasound tools will streamline the expectations for individual practitioners. Meanwhile, the future is exciting but still ambiguous regarding which ultrasound techniques will become a valid necessity for routine and emergency anesthesia care of pregnant women.

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