Review Article

The role of ultrasonography in anesthesia for bariatric surgery

ABSTRACT

Bariatric surgeries are effective long-term management for morbid obesity with its adverse sequelae. Anesthesia of bariatric surgeries poses unique challenges for the anesthesiologist in every step starting with vascular access till tracheal extubation. The usage of ultrasound in anesthesia is becoming more prevalent with a variety of benefits, especially in the obese population. Ultrasound is successfully used for obtaining vascular access, with more than 15 million catheters placed in the United States alone. Ultrasound can also be used to predict difficult intubation, as it can confirm the tracheal intubation and assess the gastric content to prevent pulmonary aspiration. Ultrasound is also used in the management of mechanically ventilated patients to monitor lung aeration and to identify respiratory complications during positive pressure ventilation. Moreover, intraoperative echocardiography helps to discover the pulmonary embolism and guides the fluid therapy. Finally, ultrasound can be used to perform neuraxial and fascial plane block with a less overall time of the procedures and minimal complications. The wide use of ultrasound in bariatric anesthesia reflects the learning curve of the anesthesiologists and their mounting efforts to provide safe anesthesia utilizing the updated technology. In this review, we highlight the role of ultrasonography in anesthesia of bariatric surgery and discuss the recent guidelines.

Key words: Anesthesia, bariatric surgery, ultrasonography

Introduction

Bariatric surgeries are the effective long-term management for obesity with its secondary comorbidities such as hypertension, diabetes mellitus, and obstructive sleep apnea (OSA).[1] Morbid obesity is defined as a body mass index (BMI) greater than 35 kg/m^2. Morbid obesity has become a pandemic disease across the world with approximately 252000 in the United States in 2018.[2] The national institute of health guidelines in 1991 recommended undergoing bariatric surgeries for patients with a BMI of above 35 with comorbidity or with BMI above 40 kg/m^2.[3]

Anesthesia of bariatric surgeries poses unique challenges for anesthesiologists in every step from vascular access to tracheal extubation. Ultrasound (US) guidance in anesthesia is becoming more prevalent and helped to overcome such difficulties. US guidance has a variety of benefits, particularly with the employment of regional anesthetic procedures. US guidance is used to conduct peripheral nerve blocks, peripheral vascular accesses, and central vascular accesses. This review article will discuss the different applications of US and its role to provide safe anesthesia in bariatric surgery.

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The Role of Ultrasound Guidance for Vascular Access

Obtaining vascular access in obese patients is challenging and time-consuming, as it is difficult to determine the depth of the vessel due to the thickness of the subcutaneous tissue.[4] In addition, the anatomical landmarks are ill-defined. For instance, the neck region is usually concealed with fat that obstructs the insertion of central venous catheters (CVC).[4] US is frequently used for obtaining vascular access, with more than 15 million catheters alone in the United States.[5] It helps to overcome vascular access-related mechanical complications such as inadvertent arterial puncture and pneumothorax.[6-9] Pneumothorax is accounting for up to 30% of all mechanical adverse events after CVC insertion.[10] In the early 2000s, the use of real-time US guidance was recommended by many medical institutes including but not limited to the Center for Disease Control and Prevention and the National Institute for Health and Care Excellence.[11-13] Randomized control trials and observational studies reported improvement in the success rate of procedures when US guidance was used in inserting arterial catheters, peripheral intravenous lines (PIVs), peripherally inserted central venous catheters (PICCs), and CVC.[14-17] Unfortunately, the US guidance was not wildly accepted, and it is estimated that up to 55% of the CVC insertion through the internal jugular vein were performed without an US guidance.[18,19]

Recently, the bedside US was confined to single plane imaging for the installation of arterial, central, and peripheral lines,[20] and this limited the practitioners to only look at a vessel in one of two directions at a time. On the other hand, biplane US imaging allows the practitioner to see an artery in both the short and long axis, potentially increasing procedural success, efficiency, and safety.[21] Biplane imaging is not regularly used for vascular access, but it has been recommended to improve the visualization and decrease adverse events.[22]

Use of Ultrasound in Airway Management

Assessment of gastric content

Pulmonary aspiration of gastric contents is one of the dangerous anesthesia-related complications. Pulmonary aspiration of gastric contents occurs once every 2000–3000 elective general anesthesia, and it leads to about 20% incidence of in-hospital mortality.[23] Pulmonary aspiration causes significant morbidity including acute respiratory distress syndrome, multiple organ dysfunction, and brain damage among the survivors.[24] A patient undergoing anesthesia with a full stomach is a major risk factor for aspiration. Therefore, the feasibility of an objective tool to assess gastric content before anesthesia is critical to prevent pulmonary aspiration. Obesity can increase the risk of aspiration pneumonia, pulmonary thromboembolism, and respiration.[25] Mahajan *et al*.[26] showed that patients suffering from morbid obesity undergoing elective surgery were at a higher risk for regurgitation and pulmonary aspiration when compared with lean patients. Preoperative aspiration prophylaxis decreases the gastric volume and gastric pH in patients suffering from morbid obesity[26]; however, gastric content in obese patients must be assessed before any general anesthesia. Gastric US assessment is an emerging point-of-care tool that provides bedside information on gastric content and volume.[27] Furthermore, bedside US can determine the nature of gastric content (nil, clear fluid, thick, fluid/solid), and this qualitative information may be useful to assess the risk of aspiration, particularly in situations where prandial status is uncertain.[28] The study done by Kruisselbrink *et al*.[29] indicates that a positive gastric US result significantly increases the probability of a full stomach, and the negative ratio is 0, which suggests the high sensitivity of the gastric US.

Prediction of difficult intubation in obese patients

The intubation procedure has many coincident complications both in the intensive care unit (ICU) and in the operating room (OR). Intubation of difficult airways such in obese population increases the risk of life-threatening complications.[30] Prediction, assessment, and preparation of difficult airways are an integral part of successful intubation. Although the conventional measures are used for this purpose, the incidence of difficult intubation is about 1.5% with an increased rate in some populations, such as obese and pregnant patients.[31] Obesity is a significant risk factor for morbidity and mortality related to intubation and ventilation.[32] In obese population, a decrease in functional residual capacity (FRC) may lead to atelectasis formation and airway closure which decrease the safe apneic period.[33,34] Because intubating the trachea of the obese patients may lead to an increased likelihood of life-threatening complications, US is frequently used for airway management. Ji *et al*.[35] analyzed the diagnostic accuracy of radiologic methods in adult patients with difficult airways using meta-analysis, which provided that computed tomography (CT), X-ray, and US could be regarded as effective methods. These objective assessment tools significantly improved the specificity and sensitivity in predicting difficult airways.

Confirmation of endotracheal intubation

Tracheal tube insertion is the conventional method of airway protection during general anesthesia.[36] Because of the significant morbidity and mortality associated with the erroneous placement of the tracheal tube, reliable confirmation of the endotracheal tube insertion is essential especially in the emergency setting.[37] Visualization of the endotracheal tube placement can be limited and should not depend solely on the operator. US is likely to be available in many hospitals and can provide an accurate and rapid bedside procedure to confirm endotracheal intubation.[38,39] In a study conducted by Gottlieb *et al*.,[40] US technique was accurate and rapid to confirm endotracheal intubation, although the technique was less accurate in obese patients compared to thin patients. Also, results from Weaver *et al*.[41] showed that US imaging of the sliding lung sign in a cadaver model is an accurate method for confirmation of endotracheal tube placement.

The surgical airway in difficult airway management

Prediction and evaluation of a difficult airway are crucial steps in airway management and avoiding its complications. Life-threatening complications such as brain damage or death have incidence 38 times higher in the emergency departments (EDs) and 58 times higher in the intensive care unit compared to cases in the OR.[30] Misidentification of the cricothyroid membrane (CTM) is one of the leading causes of airway device misplacement, which may lead to fatal outcomes.[42] The Landmark palpation technique alone is often inaccurate, especially in time-sensitive emergency settings.[43] Also, patients frequently present with difficult-airway anatomical characteristics such as obesity. US provides an image of the structures which the physicians would palpate when performing cricothyrotomy. US improved physicians' ability to locate the CTM in overweight participants compared to using landmarks alone.[44] However, a study by Yildiz *et al*.[45] did not show an improvement with US. Furthermore, multiple studies show that the US technique takes longer than landmark palpation alone.[43,45,46] In an emergency setting, US would take longer and could add pressure to already a stressful situation because physicians would have to wait for the US machine to turn on, apply the gel, and place the transducer upon the patient's neck.

Use of Ultrasound in Ventilation

US has shown its utility for plain organs, but the concept of whole-body US was established and extended to the lungs for managing critical situations such as ventilation.[47] Pulmonary US has become a standard bedside tool in many respiratory care settings.[48] Lung US can immediately provide a diagnosis of acute respiratory failure in up to 90.5% of cases.[49]

Also, Elshazly *et al*.[50] found that using the US-guided positive end-expiratory pressure (PEEP) approach improved the intraoperative oxygenation, compliance, and P/F ratio in the obese patients undergoing laparoscopic bariatric surgeries. By improving postoperative oxygenation, US reduced the incidence of early postoperative pulmonary complications in the form of hypoxia and atelectasis without causing hemodynamic instability in laparoscopic bariatric surgeries.[50] Lung aeration assessment can also be done with US to assess PEEP-induced recruitment[51] and even recovery from ventilator-associated pneumonia.[52]

Intraoperative Transthoracic Echocardiography Uses in Bariatric Surgery

Obesity as a risk factor of cardiac disease

Obesity is a key risk factor for many cardiovascular diseases, it predisposes to atrial fibrillation, heart failure up to sudden cardiac death.[53] Cardiac US is being used at the bedside by acute care physicians from a variety of disciplines, including emergency medicine, critical care, anesthesiologists, and trauma surgery, to assess hemodynamic instability.[54-57] Intraoperative cardiac US can guide particular therapies such as inotropic or vasopressor infusion and fluid bolus. This modality is known as rescue transthoracic echocardiography (TTE), hemodynamic TTE, focal cardiac ultrasonography (FOCUS), and point-of-care ultrasound (POCUS).[58-61]

Intraoperative TTE may detect cardiovascular problems that clinical evaluation or vital signs alone cannot detect. Diagnosis of these disorders with TTE may guide the appropriate therapy or particular hemodynamic monitoring. Intraoperative TTE is very effective for assessing cardiovascular status where transesophageal echo (TEE) is contraindicated when the esophageal access is restricted due to the nature of the bariatric operation.[58-61]

Risk of pulmonary embolism in obese patients

Obesity increases the risk of perioperative venous thromboembolism.[62,63] Due to restricted therapeutic options, perioperative pulmonary embolism (PE) poses a diagnostic difficulty and a significant risk of death. Despite breakthroughs in imaging technologies and clinical care, total mortality remains about 15%.[64-66] Mortality approaches 50% in individuals with major pulmonary embolism and cardiac arrest.[65-67] Furthermore, the inflammatory reaction to surgery causes a prothrombotic condition, which raises the risk further when combined with postoperative hospitalization, central venous catheterization, and immobilization. These variables are responsible for the fivefold rise in perioperative PE.[62] PE can be diagnosed via TTE by the presence of two of the following criteria: right ventricular (RV) end-diastolic diameter greater than 27 mm, RV hypokinesis, or tricuspid regurgitation velocity greater than 2.7 m/sec.[68] The sensitivity of TTE in diagnosis PE is up to 52%, while the specificity is up to 96%.[69] The thoracic cage is accessible in bariatric surgery which allows putting the probe in different echocardiography views except for the subcostal one. Both apical and parasternal views should be sufficient to diagnose PE in cases of sudden intraoperative collapse.

Regional Analgesia

The pain management of bariatric surgery includes neuraxial analgesia, fascial plane block, and conventional intravenous analgesics such as, but not limited to opioid therapy. The perioperative complications of opioid therapy especially in obese patients with obstructive sleep apnea (OSA) may include serious respiratory depression and delayed bowel functions.[70] These complications raised the concept of opioid-free anesthesia in bariatric surgery as part of the enhanced recovery after surgery program (ERAS).[71]

Implementing the ERAS in bariatric surgery improved the composite outcome, specifically shorter hospital length of stay and mortality.[72,73] Sapin *et al*.[73] investigated the impact of minimizing intraoperative opioids in favor of neuraxial anesthesia, and the postoperative US-guided transverse abdominis plane (TAB) block for sleeve gastrostomies.[73] The study showed shorter hospital stay by 18%, a decrease in the average use of morphine by 61%, and a decrease in average direct costs per case. However, there was no significant difference in the 30-day readmission rate between the pre-a nd post-implementation period.

Neuraxial analgesia (Epidural analgesia)

Epidural analgesia has demonstrated its efficacy in reducing the postoperative morphine needs, diminishing the lung complications, postoperative ileus, and the endocrine-metabolic response to surgical aggression.[74] Ibrahim *et al*.[75] has found that US-guided thoracic epidural with opioid-free analgesia has shown a significant decrease in pain scores within 24 hrs after bariatric surgery, also a significantly shorter time for discharge from the postoperative care unit along with higher patient satisfaction.

The classical palpation method for neuraxial analgesia (spinal, epidural, or combined spinal-epidural (CSE)) may be questioned though it remains the first choice for clinical practice.[76] Especially, in bariatric patients where obesity obscures anatomical landmarks along with positioning challenges. Anesthesiologists can experience difficulty in appreciating the midline and vertebral interspaces.[76] Multiple attempts are often required, and excessive adipose tissue can increase the incidence of false-positive loss of resistance during epidural placement. Furthermore, obese patients are more likely to experience a longer procedure time, a higher incidence of accidental dural puncture, a higher incidence of epidural venous puncture, and higher overall failure and complication rates during neuraxial anesthesia placement.[76,77] Neuraxial US (pre-procedural or real-time) can be used to identify the intervertebral space(s), the midline for insertion, determine the depth from the skin to the epidural space, the best needle insertion point, and the best angle for needle insertion.[77] This leads to decrease of the number of attempts required for epidural placement, the risk for epidural hematoma, and post-surgical low back pain.[77] The use of pre-procedural US imaging has shown a higher first-attempt success rate for epidural catheter placement, less need for needle repositioning, which leads to shorter total procedure time. A randomized controlled study done by Vernon *et al*.[78] regarding US-assisted epidural labor analgesia in obese women stated that although US assessment took more time than palpation method, this assessment leads to less time to identify the space, fewer trials, know the depth of the epidural or subarachnoid space and avoid false sensation of loss of resistance. All that lead to less total time of procedure with no affection of patients' anxiety nor satisfaction. Moreover, Li *et al*.[79] showed that the usage of pre-puncture US examination to guide spinal anesthesia of cesarean delivery in the obese parturient leads to a higher first-attempt success rate, fewer skin punctures, significantly shorter total procedural time, and significantly higher patient satisfaction than landmark group. Not only the use of preprocedural US examination has helped the anesthesiologists but also the use of real-time US. Ni *et al*.[76] compared the US-based system with computer-aided image interpretation to traditional palpation technique for neuraxial anesthesia placement in obese parturients undergoing cesarean delivery. The study showed that the first insertion success rate was significantly higher, and the time taken to identify the needle puncture site was less in the US group. The mean difference between the epidural depth measured by the handheld US and needle depth was 0.29 cm.

Abdominal wall blocks

The usage of the fascial plane block had improved perioperative pain management in bariatric surgery. Using the US did not only improve the success rate of fascial plane blocks but also decreased the overall time needed to perform such procedures [Table 1].

Conclusion

The usage of ultrasonography has proven its beneficial effects in bariatric anesthesia in many domains such as obtaining vascular access, overcoming airway management

Table 1: Fascial plane blocks in bariatric surgery and ultrasound role

Block	Author (year)	Groups studied and interventions	Results and findings	Conclusion
Transversus abdominus plane (TAP) block	Sapin *et al*. (2021)[73]	1988 patients who underwent laparoscopic sleeve gastrectomy were divided into two groups The pre-implementaion group received general anesthesia The post-implementation group received general anesthesia with TAP block in the recovery room as a part of the ERAS protocol.	Mean hospital stay was 18% lower in the postimplementation group. The average opioid morphine milligram equivalents administered in the postoperative period was 61% less than that of the pre-implementation period. No significant difference in 30 days readmission rate between the two groups.	Using US-guided TAP block as a part of the ERAS program improved pain control and decreased the need for opioids
TAP block	Emile *et al*. (2019)[80]	92 patients undergoing bariatric surgery were classified into two groups Group I received US-guided TAB block after surgery before recovery from GA Group II didn't receive TAB block	The mean pain score was significantly lower in group I at 1, 6 hours, with no significant difference at 12 and 24 hrs. PONV at 24 hrs was significantly lower in group I. With a significantly shorter time to full ambulation.	Using US-guided TAP block managed to achieve lower pain scores, lower opioid requirements, lower PONV scores, earlier ambulation, and comparable hospital stay.
Landmark based TAP block	McDermott *et al*. (2012)[81]	36 patients received standard landmark-based technique TAB block bilaterally. The position of the needle and the spread of local anesthesia was then evaluated using US.	The study was terminated early due to an unacceptably high level of peritoneal needle placements. The needle tip and local anesthetic spread were in the correct plane in only (23.6%) of the injections.	US usage improved correct placement of the needle during performance of the TAB block without needing a longer time to perform.
Transmuscular quadratus lumborum block (QLB) and TAP block	Shafeek *et al*. (2018)[82]	60 patients undergoing laparoscopic bariatric surgery were divided into three groups. The first group received QLB after induction of anesthesia, the second group received TAB and the third group didn't receive any form of regional analgesia.	Results showed that the time to first rescue analgesia postoperatively was longer significantly in the QLB group than the TAB group and significantly lower in the GA group. Also, Total Morphine (mg.) needed at 24 hrs was significantly less.	Abdominal wall blocks especially US-guided QLB provide better analgesia for patients undergoing laparoscopic bariatric surgery with an opioid-sparing effect.
QLB	Omran *et al*. (2021)[83]	30 patients undergoing laparoscopic bariatric surgery were divided into two groups. The first received bilateral US-guided QLB while the second group didn't.	QLB group showed significantly less HR and Mean arterial blood pressure intraoperatively. Also, showed improved pain scores till 12 hrs postoperatively than the control group, with no improvement till 24 hrs. QLB group also showed a longer time to the first rescue analgesia and early ambulation.	US-guided QLB improved intraoperative and postoperative analgesia in patients undergoing laparoscopic bariatric surgery.
Erector Spinae Plane Block (ESPB)	Zengin *et al*. (2021)[84]	63 patients with morbid obesity who underwent laparoscopic bariatric surgery were included. Patients were randomly assigned to the bilateral erector spinae plane block (ESPB) group or the control group.	Total intraoperative remifentanil dose was significantly lower in the ESPB group when compared to controls. In the ESPB group, none of the patients required additional analgesia during follow-up. In contrast, all control patients required analgesia. ESPB group had significantly lower VAS scores at all postoperative time points.	Bilateral US-guided ESPB appears to be a simple and effective technique to improve perioperative pain control and reduce the intraoperative opioid need in patients suffering from morbid obesity undergoing bariatric surgery.

challenges, and decreasing the complications of positive pressure ventilation. In laparoscopic bariatric surgery, the US-guided vascular access had a safe profile especially in the case of CVC placement. Applying the US in managing the airway decreased the associated compilations of the unanticipated difficult airway. The US-guided positive end-expiratory pressure (PEEP) technique enhances intraoperative oxygenation and compliance. In addition, the use of US-guided neuraxial analgesia improved composite outcomes and improved outcomes for the fascial plane block, especially the TAP block. Finally, implementing the FOCUS in intraoperative care showed a sensitivity of 52% and a specificity of 96% in identifying pulmonary embolism. The wide use of the US in bariatric anesthesia reflects the learning curve of the anesthesiologists and their mounting efforts to provide safe anesthesia utilizing the updated technology.

Abbreviation list

- Us: Ultrasound
- BMI: Body mass index
- CTM: cricothyroid membrane
- CSE: combined spinal-epidural
- CT: computed tomography
- CVC: central venous catheter
- ERAS: enhanced recovery after surgery program
- ESPB: Erector Spinae Plane Block
- FOCUS: Focal cardiac ultrasonography
- CU: intensive care unit

- OSA: obstructive sleep apnea
- OR: operating room
- PICC: peripherally inserted central venous catheters
- TAP: transverse abdominis plane
- TTE: transthoracic echocardiography
- TEE: transesophageal echocardiography
- PE: pulmonary embolism
- QLB: quadratus lumborum block

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