

Ultrasound-Guided Central Venous Cannulation in Bariatric Patients

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Abstract

Background Central venous catheterization may be difficult in morbidly obese patients because anatomic landmarks are often obscured.

Methods We evaluated the efficacy and safety of ultrasound-guided central venous cannulation in 55 patients undergoing bariatric surgery. The usefulness of ultrasonic examination combined with intraatrial electrocardiogram as a diagnostic tool for catheter misplacement was studied.

Results Preliminary ultrasound examination of the neck vessels demonstrated anatomical variations in the position of internal jugular vein in 19 cases and four unrecognized asymptomatic thromboses of the right internal jugular vein. Central venous catheterization was successful in all 55 patients, in 51 with single skin puncture, and in 42 with single vein puncture. In three cases in whom the catheter was misplaced, this was detected by bedside ultrasonic examination during the procedure and immediately corrected by real-time echographic visualization. No arterial puncture, no hematoma, and no pneumothorax occurred in any patient. Successful catheter placement was also

confirmed in all patients by post-operative chest X-ray. No evidence of infection or thrombosis subsequently was noted.

Conclusions The use of ultrasound guidance may increase the success rate and decrease the incidence of complications associated with central venous cannulation. The advantages of this approach is visualization of the anatomical structures at puncture site prior to skin puncture and the ability to track needle and guide-wire placement during the procedure. With its high accuracy in detecting catheter misplacement, bedside ultrasonic examination combined with intraatrial electrocardiogram may further decrease morbidity associated with misplaced central venous catheters.

Keywords Morbidly obese patients · Central venous catheterization · Ultrasound · Intraatrial electrocardiogram

Introduction

Central venous catheters are generally used during surgery to allow measurements of hemodynamic variables, for delivery of medications, and for nutritional support. Ultrasound guidance has been recommended [1] to increase the success of catheter positioning and decrease the incidence of complications [2, 3], but it is not always routinely used [4]. In bariatric surgery, a central venous catheter may be necessary if there is difficulty of finding a viable peripheral venous access. In morbidly obese patients, however, placement of a central venous catheter may be difficult due to poorly identified neck landmarks. The risk of short- (mechanical) and long-term (infections, thrombosis) complications are increased due to metabolic abnormalities and associated comorbidities. Indeed, a high body mass index (BMI) has been reported as one of the most

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important risk factors for complications of placement during and post-procedure [5, 6]. Catheters are often positioned after induction of anesthesia, but obtaining a chest X-ray to check for correct positioning and absence of pneumothorax is usually delayed until after the operation.

We hypothesized that a method combining ultrasound and intraatrial electrocardiogram allows correct positioning of central venous catheters in morbidly obese patients undergoing bariatric surgery [7]. We used ultrasound to evaluate vein viability and to guide the insertion of the catheter and we then checked for correct placement of the catheter tip in the atrio-caval junction by intraatrial electrocardiogram [8, 9]. The results of the ultrasound plus intraatrial electrocardiogram were compared with chest X-ray, assumed as standard reference.

Methods

This study was submitted and approved by the institutional ethics committee. The entire procedure was explained to the patient as part of the anesthesiologic treatment plan, and a written informed consent was obtained. The internal jugular vein (IJV) was cannulated with an ultrasound-guided technique in 55 consecutive morbidly obese patients (Table 1) undergoing bariatric surgery (laparoscopic or open bilio-pancreatic diversion). No patients had untreated coagulopathy or platelets less than $10 \times 10^3/\text{mm}^3$ or an $\text{INR} > 2$. These were also exclusion criteria for surgery.

For each patient, the following data were recorded: gender, age, BMI, presence of risk factors for difficult central venous catheterization, clotting tests, comorbidities, length, and circumference of neck. For each attempt of cannulation, we recorded how many times the needle was introduced through the skin and how many times it entered the vein. This was done because there is evidence of increased risks of thrombosis and infection with multiple of vein and skin punctures, respectively [10, 11]. Thus, these independent events were analyzed separately.

The ultrasound-guided cannulation was performed by two operators with extensive experience in IJV catheterization by landmark technique and ultrasonography.

Table 1 Patients' characteristic

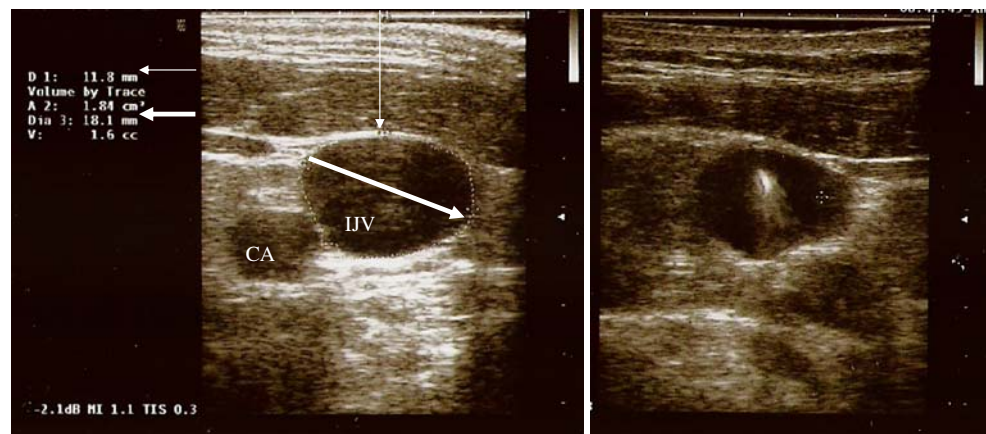
Anthropometric characteristics	Values
Gender (M/F)	32/23
Age (years)	44±11
Body mass index (kg/m^2)	49±7.4
Neck circumference (cm)	52±6
Neck height (cm)	5.5±1.9

Data are absolute numbers or mean ± SD

The IJV was catheterized after induction of anesthesia and before starting the start of surgery. The neck area was prepared and draped sterile with the patient supine and under mechanical ventilation. A 10-MHz linear-array ultrasound probe was covered with ultrasonic gel and wrapped in a sterile plastic sheath. Standard ultrasound two-dimensional imaging was used to measure depth, caliber, and position of the IJV (Fig. 1). The vein was compressible by gentle pressure of the probe on the skin and pulsation of the carotid artery was observed. Color Doppler imaging was used for evaluating any irregular blood flow. Catheterization was performed under continuous dynamic observation of real-time two-dimensional images obtained by placing the transducer parallel and superior to the clavicle and an out-of-plane needle alignment. A 19-gage, 10-cm standard needle was advanced through the skin under ultrasound guidance into the IJV with the direct free-hand puncture technique. Either single- or two-operator technique was used to access the vein [12]. A Seldinger guide wire was placed through the needle into the vein and the needle was removed. Before advancing the catheter through the guide wire into the IJV, the operator visualized the guide wire into the superior vena cava and/or the right atrium by a quick ultrasound scan on a subclavicular acoustic window. If the operator could not visualize the guide wire through the subclavicular acoustic window, an aberrant position was suspected, and an ultrasound examination of the two subclavicular veins and the contralateral IJV was immediately performed. A 20-cm bi-lumen catheter (Certofix[®], B. Braun Medical, Bethlehem, PA, USA) was advanced over the guide wire until the 20-cm mark was at skin level, and the guide wire was then removed. An ECG adapter (Certodyn[®] Universal Adapter, B. Braun Medical, Bethlehem, PA, USA) was placed between ECG monitor and right-arm electrode. This electrode was connected to a cable leading to the ECG adapter, which, in turn, was connected to a metal needle just above the catheter hub. The ECG conduction was switched from a regular three-lead surface ECG to a right intraatrial ECG. The catheter was slowly withdrawn until the highest P wave was seen, indicating that CVC was in the right atrium, and then until P wave returned to normal configuration, indicating that CVC was positioned in the atrio-caval junction. The CVC was then secured at the skin with suture.

A bedside B-Mode and M-Mode ultrasonography over the parasternal line at the second and third intercostal spaces was used for detecting occult pneumothorax before surgery and repeated in case of clinical signs of pneumothorax throughout surgery (Fig. 2). In the ultrasound examination, lung sliding and comet-tail artifacts were sought, with the presence of lung sliding ruling out pneumothorax and, conversely, absence of both

Fig. 1 *Left* Evaluation of neck vessels before procedure. CA carotid artery, IJV internal jugular vein, *thin arrow* distance from skin, *thick arrow* major vein diameter. *Right* Visualization of the needle tip in the IJV during procedure



lung sliding and comet-tail artifact confirming it. In the M-Mode, lung sliding generates a homogeneous granular pattern (the seashore sign), which rules out pneumothorax [13]. A chest X-ray obtained after surgery, usually about 6–8 h after catheter placement, was used as standard reference for successful catheter positioning and absence of pneumothorax.

Continuous variables were expressed as mean \pm standard deviation (SD) and compared by Student's *t* test. Discrete variables were compared using chi-square test. Correlation between continuous variables was assessed by Pearson's correlation coefficient. For ordinal data, the Spearman rank correlation was used. A *p* value <0.05 was considered significant. SPSS software, version 15.0, was used.

Results

Preliminary ultrasound examination of the vessels showed anatomical variations in the position of internal jugular vein in 19 patients and unrecognized asymptomatic thromboses of the right internal jugular vein in four patients (Table 2). In these cases, the catheterization was performed successfully using left instead of right internal jugular vein.

Catheterization was successful in all patients, in 51 with single skin puncture, and 42 with single vein puncture. In four cases, a double skin puncture was needed because of the difficulty in the insertion of the guide wire; in 13 cases, a double-vein puncture was identified because the needle went through the vein and needed to be pulled back into the lumen. In three cases, the catheter was misplaced into the ipsilateral subclavian vein, and this was detected by bedside ultrasonic examination during the procedure and immediately corrected by real-time echographic visualization. In only one case, a catheter misplacement was suspected by ultrasonic examination and absence of intraatrial electrocardiogram modification, but it was not possible to visualize the tip of the catheter and the misplacement was confirmed by chest X-ray. In 49 patients, the catheter tip was in the atrio-caval junction or superior vena cava, and in six cases, it was judged to be too proximal. In no case was the catheter tip located in a too distal position, such as right atrium or inferior vena cava. No arterial puncture, no hematoma, and no pneumothorax occurred in any patient. There was no evidence of infection or thrombosis occurring postoperatively. There was a close concordance between ultrasonic findings with intraatrial electrocardiogram and chest radiography.

Fig. 2 B-Mode (*left*) and M-mode (*right*) pleural ultrasonography. The M-mode shows lung sliding (*the seashore sign*), rules out pneumothorax. P pleura

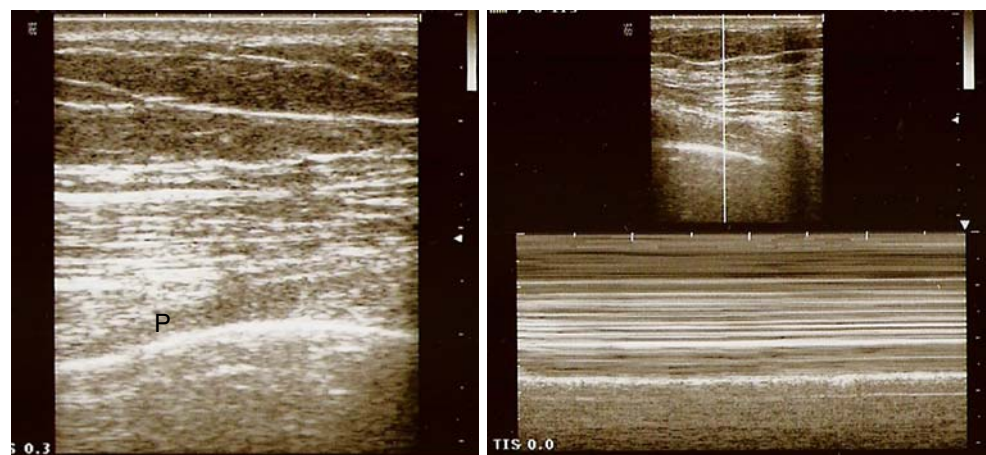


Table 2 Jugular vein characteristics by ultrasound evaluation

Findings	Values
Depth (mm)	15±4.3
Area (cm ²)	1.8±1.1
Diameter (mm)	16±6.4
Atypical location (<i>n</i>)	19
Thrombosis (<i>n</i>)	4

Data are absolute numbers or mean ± SD

The success of catheter positioning on the first attempt was related to IJV vein major diameter, but not to other anatomical characteristics (Fig. 3). In the four cases requiring multiple skin punctures, the IJV diameter was ≤6 mm, and successful cannulation was obtained by a second skin puncture at the proximal end of the neck nearby the confluence of the IJV with subclavian vein, where the IJV diameter was ≥10 mm.

Discussion

The main findings of the present study are that (1) the anatomic variability of IJV was frequent in morbidly obese patients and (2) a diameter of IJV <10 mm was predictive of difficult positioning, whereas a diameter of IJV <6 mm was predictive of unsuccessful positioning, thus requiring an alternative access.

Obesity has been described as a risk factor for unsuccessful central venous cannulation or complications; thus, a technique more reliable than one based on anatomic landmarks only is warranted [14]. Initially, we aimed at comparing an ultrasound-guided technique with simple landmark-based technique in patients undergoing bariatric surgery in a random fashion. However, this study was stopped because of a high incidence of failure (three out of

seven attempts) and the need of too many skin punctures. Moreover, a large hematoma developed after three inadvertent arterial punctures in a subject in whom a post-procedural ultrasound examination of neck vessels showed an atypical position of the IJV. This and recent case reports of more serious complications of vessel catheterization by landmark-based technique in morbidly obese patients [15, 16] prompted us to conduct this study using ultrasound-based technique alone. The high incidence of puncture failures using simple landmark-based technique in our planned control group was probably due to the very high BMI (>55 kg/m²) of the patients, and that no more than six attempts were made. No study has investigated the incidence of failure and complications of central venous cannulation in morbidly obese patients, though an elevated BMI is considered as a risk factor [5, 6].

Fugiki et al. compared the success of simulated IJV puncture between morbidly obese patients (BMI >40) and a non-obese control group (BMI <30) [17]. Right IJV puncture was simulated using an ultrasound probe. The results of the study showed no statistically significant difference in success rate of IJV puncture between morbidly obese and non-obese patients. However, in the morbidly obese group, there was a significant increase in overlap between IJV and carotid artery, and therefore, the authors recommend the use of ultrasound for IJV cannulation in obese patients [17]. Our results confirm that the ultrasound guidance is useful for catheter positioning and decreasing complications in morbidly obese patients. Indeed, using ultrasound imaging the problems connected with short neck, deep veins, anatomical variations, and lack of landmarks are overcome. A reduction in the number of punctures may reduce skin and vein trauma, thus possibly reducing the risk of catheter-related sepsis and thrombosis [10]. Reduced skin punctures reduce the chances of iatrogenic pneumothorax, which may be a life-threatening complication in mechanically ventilated patients [11]. The risk for the above complications is greater in patients undergoing bariatric surgery because of metabolic abnormalities and co morbidities (diabetes, hypercholesterolemia, hypertriglyceridemia, hypertension). None of these complications occurred in our sample probably because of the high number of successes at first attempt and the low number of second skin or vein puncture. The use of ultrasound imaging can also identify patients in whom central venous access may be more difficult and those in whom complications might be more serious. We were able to detect pre-existing thromboses, small diameter IJVs, and atypical IJV location. Anatomical variations in the position of the IJV have been shown in a high percentage of general population by ultrasound imaging [18, 19]. It is not unusual that the IJV is partly or fully superficial to the carotid artery, which makes accidental arterial puncture a possible risk. In

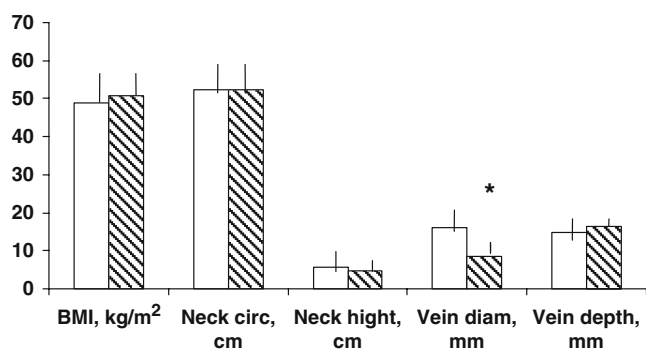
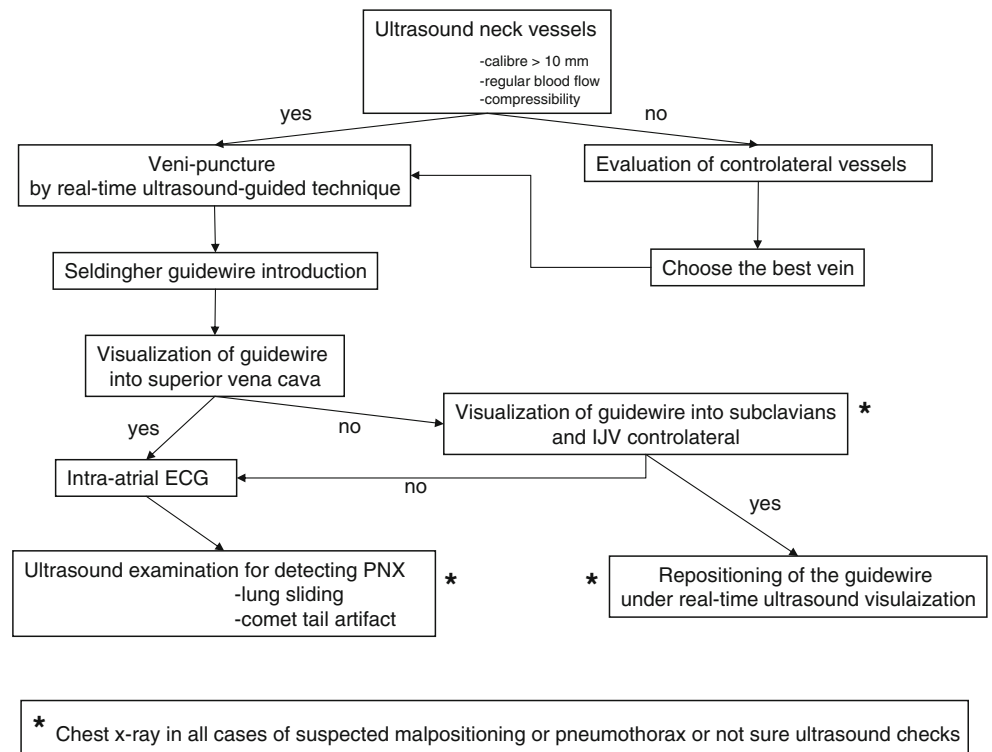


Fig. 3 Anatomical characteristics and outcome of catheter positioning. The values of y-axis refer to each different anatomical characteristic with the appropriate dimension. *Open bars* Success at first attempt, *striped bars* difficult. **p*<0.05

Fig. 4 Proposed algorithm for safe positioning of central venous catheter



our morbidly obese patients, the number of anatomic variations in the IJV location was 19 out of 55, which is higher than that reported for general adult population [20].

Bedside ultrasonic examination was also highly accurate to reveal the exact positioning of the catheter and allowed to re-positioning, if needed, under real-time ultrasound guidance. The use of the intraatrial electrocardiogram helped positioning the catheter tip into the atrio-caval junction, in accordance with the recent guidelines, suggesting that this position is the only one suitable to avoid thrombosis [21, 22]. Finally, bedside ultrasonic examination performed immediately after the procedure confirmed the absence of pneumothorax. No pneumothoraces occurred in our study, probably because we used the internal jugular instead of subclavian approach and the ultrasound-guided technique which allow to follow the tip of the needle during the whole procedure. Usually, in lean patients, a CXR is always indicated in difficult cannulation if more than one attempt has been made at a point low in the triangle, just superior to the clavicle, and if the cannulation is performed high in the triangle and with ultrasound guidance, the incidence of pneumothorax is almost non-existent. In morbidly obese patients, this approach is impossible because of neck shortness and lack of anatomical landmarks, so the risk of complications such as pneumothorax does exist, especially if multiple attempts are made. Because of the good concordance between color Doppler ultrasonography with intraatrial electrocardiogram and chest radiography, we think that chest X-ray may be used

only when catheter misplacement or pneumothorax are suspected but not detected by ultrasonography.

Under a methodological point of view, we could not find any difference using either single- or double-operator technique. Moreover, the use of a 10-MHz linear-array ultrasound probe allowed to visualize needle and guide wire during the whole procedure even if these were standard components of the catheterization kits and not versions modified for the use with ultrasound [23]. The catheter was rarely visualized by ultrasound after guide wire withdrawal. We performed lung-sliding examination with B-mode and then confirmed it by M-mode, as originally described by Lichtenstein and coworkers, even if more recent studies suggest that identification of lung sliding in B-mode is sufficient to detect pneumothorax. We chose Lichtenstein's method because it is the only one validated in case of small and hidden PNX, as potentially expected in our patients and has a sensitivity comparable to high-resolution TC [24].

To the best of our knowledge, the present study is the first one investigating the ultrasound-guided central venous cannulation in combination with placement control using intraatrial electrocardiogram in bariatric surgery patients. The association of ultrasound and intraatrial electrocardiogram may be considered as a useful option for optimizing the use of hospital resources and minimize time consumption and radiation exposure [25, 26].

Based on the results of this study, we can make a recommendation of using ultrasound guidance for IJV cannulation for a quick assessment of anatomic variations,

choice of suitable vessel, and catheter tracking. Moreover, we can propose ultrasound plus intraatrial ECG (Fig. 4) as a promising method tested in 55 patients with success, as a routine alternative to CXR. A larger study allowing specificity and sensitivity analysis of the proposed combined ultrasound/ECG methodology in relation to CXR to detect PNx and other complication will be needed.

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