Intensive Care Med (2015) 41:705–707
DOI 10.1007/s00134-014-3628-6

Gregory A. Schmidt
Julien Maizel
Michel Slama

Ultrasound-guided central venous access: what's new?

Received: 1 December 2014
Accepted: 18 December 2014
Published online: 8 January 2015

G. A. Schmidt
Division of Pulmonary Diseases, Critical Care, and Occupational Medicine, University of Iowa, Iowa City, IA, USA
e-mail: Gregory-a-schmidt@uiowa.edu

J. Maizel (✉) · M. Slama
Medical Intensive Care Unit, Amiens University Medical Center, Amiens, France
e-mail: julien.maizel@u-picardie.fr

M. Slama
e-mail: slama.michel@chu-amiens.fr

J. Maizel · M. Slama
INSERM U-1088, University of Picardie, Amiens, France

Ultrasound (US) guidance has fundamentally changed ICU practice related to central venous catheter (CVC) access. Real-time techniques have been adopted for all anatomic sites of insertion. The past decade has seen several fundamental questions answered; novel modifications introduced, and new questions raised. Here, we review (1) the proven advantages of ultrasound guidance, (2) changing techniques afforded by ultrasound, and (3) the implications for teachers and trainees.

Many studies of internal jugular vein (IJV) CVC insertion confirm that, when compared with the anatomical landmark approach, ultrasound-guided cannulation decreases access time, number of attempts, arterial punctures, failure rates, and the risk of catheter-related bloodstream infection [1–3]. Meta-analyses affirm these findings [4] leading professional societies in Europe and the United States, as well as the Agency for Healthcare Research and Quality, to promulgate ultrasound-guidance as the standard of care [5]. Thus, all ICUs should have a dedicated machine so that ultrasound is readily available for vascular access and to facilitate training and simulation. Basic equipment includes a high-frequency (15–5 MHz), linear array transducer with the ability to save and store images for documentation and teaching purposes. Small, curvilinear probes may be helpful for pediatric insertions or in anatomically constrained areas around the clavicle of adults.

Remarkably, some practitioners have resisted the push towards ultrasound guidance, perhaps overestimating the difficulty in learning a new method, as discussed below. There are several important caveats. First, some practitioners use a quick-look technique, mark an entry point on the skin, and attempt puncture "blindly". This method is less successful than real-time guidance (73 vs. 100 %), more likely to cause complications (36 vs. 0 %), and simply cannot be recommended [2]. Second, most studies report on IJV cannulation, while fewer address subclavian (SC) and femoral vein (FV) insertion. Nevertheless, recent studies show that landmark methods are also inferior at the SC and FV sites [6], prolonging access time and causing more complications. Finally, most studies have compared orienting the transducer perpendicular to the vein (short-axis view) while the needle is inserted in the long-axis. The results reported can perhaps also be extrapolated to other real-time methods, some of which are mentioned below, but with less confidence.

Ultrasound opens new windows on the central veins. Once a vein can be seen directly, not just inferred from anatomic relationships, needles can be inserted from novel entry points, in "unusual" orientations, and without routinely employing Trendelenburg positioning. As an example, experienced US operators have learned that it is easier to access the subclavian vein from a site substantially more lateral than when using anatomic landmarks. If fact, while often termed "subclavian" insertion, entry is more often into the axillary vein. At this site, there is less

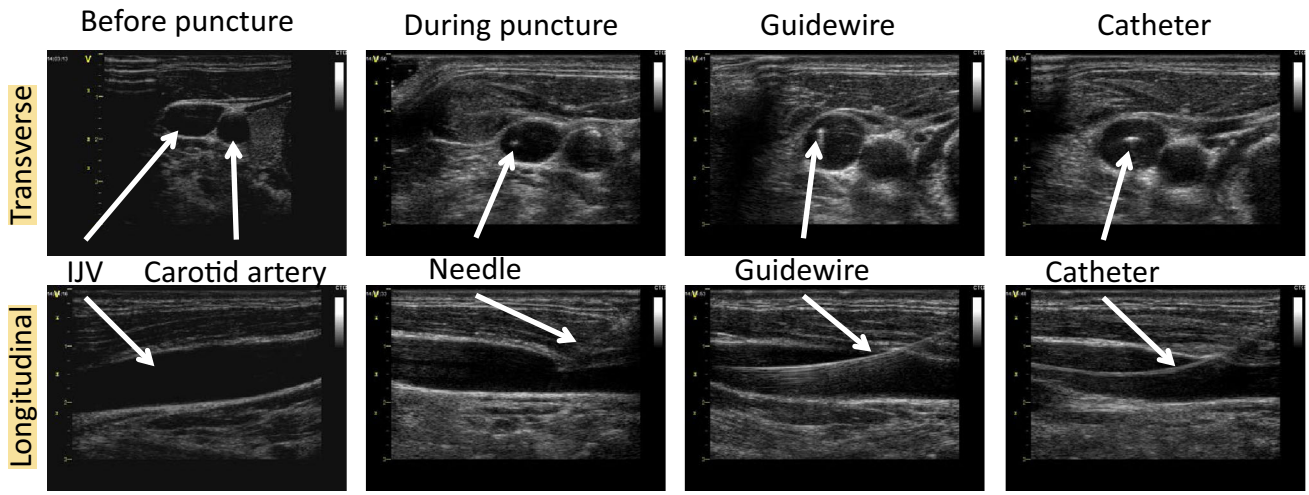

Fig. 1 Transverse and longitudinal ultrasonographic views during internal jugular vein (*IJV*) catheter placement. Note that in the longitudinal view the carotid artery is not visualized simultaneously with the jugular vein

overlap of the artery and vein and a greater (possibly safer) distance between vein and pleura. Many investigators have shown this approach to be safe and highly effective, although perhaps technically more demanding than a short-axis IJV puncture [7–9]. Ultrasound has also led to resurgence of the supraclavicular approach to the SC in which the transducer is placed in the supraclavicular fossa and oriented towards the junction of IJV and SC [10]. This method has also been successful in children.

Once an entry point is chosen, the US transducer can be oriented transverse to the vein, showing a short-axis image, or parallel to the vein, revealing it in long-axis (Fig. 1). The needle, too, can be in line with the transducer or perpendicular to it [11]. Each of these has advantages and disadvantages, often depending on the anatomic site or the particular anatomy of the patient. Smaller transducers offer some advantages in the confined space around the clavicle, where a micro-convex probe has been shown to be effective [7]. In one study, experienced emergency medicine physicians cannulated the axillary vein using both the longitudinal and transverse approaches. The longitudinal method was associated with fewer attempts, skin punctures, and arterial injuries, as well as requiring less time [8]. The large study of Fragou and colleagues used a longitudinal orientation, whereas O'Leary and co-investigators found the short-axis approach to be highly successful [6, 9]. Similar uncertainty surrounds the IJV. While most studies have described a short-axis view [2, 3], one showed a longitudinal, in-plane technique to increase needle visibility and permit following the needle tip all the way into the vein in a simulation model. On the other hand, a free-hand, short-axis technique was quicker than both longitudinal free-hand or needle-guided approaches. Needle guides may improve visualization of the needle, but are not more effective than free-hand methods in facilitating vessel puncture [12]. In a human torso mannequin, longitudinal puncture of the jugular vein was less likely than short-axis puncture to penetrate the posterior wall, suggesting a safety advantage. In a prospective study, anaesthetists with experience in ultrasound-guided cannulation have higher first pass success and fewer carotid artery punctures when using a short-axis, rather than a long-axis, approach [13]. A large prospective, randomized trial is needed to determine whether one approach is clearly superior. In the future, biplane or 3-D ultrasound may obviate this dilemma.

Ultrasound has spawned several innovations. For example, instead of relying on blood return to show venous entry, one method trusts visualization of the needle tip and dispenses with the syringe altogether. The wire is pre-loaded into the needle and, once US demonstrates venous puncture, the wire is advanced under direct vision. Another modification relates to Trendelenburg positioning, often recommended in the hope of maximally distending the vein. While the IJV cross-sectional area (CSA) is often much larger when supine than when the head is elevated (50 % increase in CSA), Trendelenburg offers little in addition (mean increase in CSA only 17 %) and, in some patients, even makes the vein smaller [4, 14, 15]. With US, the size of the vein can be directly ascertained and, when it is sufficiently large in the supine position, there is probably no reason to tilt the patient head-down.

A major challenge relates to learning and teaching ultrasound-guided cannulation, especially since many experienced clinicians are already comfortable using anatomic landmarks. Those who resist adopting US cite insufficient training, lack of equipment, or beliefs that US is too time-consuming. Some express concern that the availability of US will prevent newer physicians from attaining sufficient skill to insert catheters using anatomic

landmarks alone; a fear that is probably accurate and could be a problem in an emergency if US is unavailable [16]. Guidelines for standardized US training were recently published [17]. Instruction should include didactic training with video-based learning, but also hands-on simulation. With appropriate training, adequate skill can be acquired rapidly (only 8 procedures), even by novice operators [11].

In conclusion, US makes CVC insertion significantly safer and more successful. It is truly time for all intensivists to gain the skills necessary, and perhaps to explore different styles and approaches to find those that serve their patients best. When taught properly, new users quickly attain sufficient proficiency to make the investment worthwhile.

Conflicts of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

References

1. Milling TJ, Rose J, Briggs WM, Birkhahn R, Gaeta TJ, Bove JJ, Melniker LA (2005) Randomized, controlled clinical trial of point-of-care limited ultrasonography assistance of central venous cannulation: the Third Sonography Outcomes Assessment Program (SOAP-3) Trial. Crit Care Med 33:1764–1769
2. Airapetian N, Maizel J, Langelle F, Modeliar SS, Karakitsos D, Dupont H, Slama M (2013) Ultrasound-guided central venous cannulation is superior to quick-look ultrasound and landmark methods among inexperienced operators: a prospective randomized study. Intensive Care Med 39:1938–1944
3. Karakitsos D, Labropoulos N, De Groot E, Patrianakos AP, Kouraklis G, Poularas J, Samonis G, Tsoutsos DA, Konstadoulakis MM, Karabinis A (2006) Real-time ultrasound-guided catheterisation of the internal jugular vein: a prospective comparison with the landmark technique in critical care patients. Crit Care 10:R162
4. Wu SY, Ling Q, Cao LH, Wang J, Xu MX, Zeng WA (2013) Real-time two-dimensional ultrasound guidance for central venous cannulation: a meta-analysis. Anesthesiology 118:361–375
5. Lamperti M, Bodenham AR, Pittiruti M, Blaivas M, Augoustides JG, Elbarbary M, Pirotte T, Karakitsos D, Ledonne J, Doniger S, Scoppettuolo G, Feller-Kopman D, Schummer W, Biffi R, Desruennes E, Melniker LA, Verghese ST (2012) International evidence-based recommendations on ultrasound-guided vascular access. Intensive Care Med 38:1105–1117
6. Fragou M, Gravvanis A, Dimitriou V, Papalois A, Kouraklis G, Karabinis A, Saranteas T, Poularas J, Papanikolaou J, Davlouros P, Labropoulos N, Karakitsos D (2011) Real-time ultrasound-guided subclavian vein cannulation versus the landmark method in critical care patients: a prospective randomized study. Crit Care Med 39:1607–1612
7. Lanspa MJ, Fair J, Hirshberg EL, Grissom CK, Brown SM (2014) Ultrasound-guided subclavian vein cannulation using a micro-convex ultrasound probe. Ann Am Thorac Soc 11:583–586
8. Sommerkamp SK, Romaniuk VM, Witting MD, Ford DR, Allison MG, Euerle BD (2013) A comparison of longitudinal and transverse approaches to ultrasound-guided axillary vein cannulation. Am J Emerg Med 31:478–481
9. O'Leary R, Ahmed SM, McLure H, Oram J, Mallick A, Bhambra B, Bodenham AR (2012) Ultrasound-guided infraclavicular axillary vein cannulation: a useful alternative to the internal jugular vein. Br J Anaesth 109:762–768
10. Jordan JR, Moore EE, Haenel J, Burlew CC (2014) Ultrasound-guided supraclavicular access to the innominate vein for central venous cannulation. J Trauma Acute Care Surg 76:1328–1331
11. Nguyen BV, Prat G, Vincent JL, Nowak E, Bizien N, Tonnelier JM, Renault A, Ould-Ahmed M, Boles JM, L'Her E (2014) Determination of the learning curve for ultrasound-guided jugular central venous catheter placement. Intensive Care Med 40:66–73
12. Ball RD, Scouras NE, Orebaugh S, Wilde J, Sakai T (2012) Randomized, prospective, observational simulation study comparing residents' needle-guided vs free-hand ultrasound techniques for central venous catheter access. Br J Anaesth 108:72–79
13. Chittoodan S, Breen D, O'Donnell BD, Iohom G (2011) Long versus short axis ultrasound guided approach for internal jugular vein cannulation: a prospective randomised controlled trial. Med Ultrason 13:21–25
14. Nassar B, Deol GR, Ashby A, Collett N, Schmidt GA (2013) Trendelenburg position does not increase cross-sectional area of the internal jugular vein predictably. Chest 144:177–182
15. Samy Modeliar S, Sevestre MA, de Cagny B, Slama M (2008) Ultrasound evaluation of central veinsin the intensive care unit:effects of dynamic manoeuvres. Intensive Care Med 34:333–338
16. Maizel J, Guyomarc'h L, Henon P, Modeliar SS, de Cagny B, Choukroun G, Slama M (2014) Residents learning ultrasound-guided catheterization are not sufficiently skilled to use landmarks. Crit Care 18:R36
17. Moureau N, Lamperti M, Kelly LJ, Dawson R, Elbarbary M, van Boxtel AJ, Pittiruti M (2013) Evidence-based consensus on the insertion of central venous access devices: definition of minimal requirements for training. Br J Anaesth 110:347–356