Extrathoracic Subclavian Venipuncture Under Ultrasound Guidance

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Background Cardiac pacemaker and defibrillator leads are inserted through extrathoracic subclavian venipuncture using ultrasound (US) guidance, but there can be complications. The purpose of this study was to investigate a safer and improved implanting procedure.

Methods and Results Venipuncture guided by US with a 7.5 MHz convex transducer was performed to implant 32 leads in 18 patients. US enabled identification and location of the vein and needle tip during puncture and clarified the reasons for unsuccessful venipuncture. Venipuncture was successful on the second attempt or within 2 min in 90.6% (29/32) and 84.4% (27/32) of lead placements, respectively, although the vein was small (mean, 7.8 mm), deep (mean, 22.7 mm), and required a large angle of entry (mean, 52.4°). The subclavian artery or lung was adjacent to the vein in 50.0% and 27.8% of cases, respectively. The flexible wall of the vein interfered with the penetration of the needle in 33.3% of cases. It was often difficult to locate the needle tip because of poor visualization.

Conclusions Ultrasound guidance of subclavian venipuncture enables a safe and time-saving procedure by visualizing not only the needle but also the vein and surrounding structures, although further modifications of the needle are needed for better visualization. (Circ J 2005; 69: 1111–1115)

Key Words: Pacemaker; Ultrasound; Venipuncture

Subclavian venipuncture is commonly used for placing leads for permanent pacemakers or implantable cardioverter-defibrillators (ICDs). Because a median venipuncture may lead to insulation defects or conductor coil fractures at the costoclavicular ligament and subsequent malfunction of the device, lateral venipuncture of the extrathoracic portion of the subclavian vein or a cephalic vein approach using a cut-down procedure is performed. However, the lateral venipuncture method can be complicated with pneumothorax caused by injury to the apex of the lung and often necessitates the use of contrast venography for locating the exact course of the vein. In the cephalic vein approach, the presence of an appropriate vein is essential. As an increasing number of patients with pacemakers or ICDs are followed up for a longer period of time and biventricular pacing is becoming more frequent, the need to insert an additional lead is increasing. Because median venipuncture has a risk of damaging the preexisting lead, lateral venipuncture is preferred. There may not be a branch vein available for a cut-down technique. Furthermore, patients are often treated with anticoagulants or antiplatelet agents for associated cardiovascular or cerebrovascular diseases, which may lead to the development of postoperative hematoma after venipuncture or surgical dissection for vein isolation.

Venipuncture under 2-dimensional (D) or Doppler mode ultrasound (US) guidance has been reported for the jugular or subclavian vein with a technical success rate of 80–100%. However, the occurrence of pneumothorax or arterial injury was not completely avoided, for reasons that are not entirely clear. Thus, the purpose of this study was to examine the feasibility, safety, and efficacy of US-guided extrathoracic subclavian venipuncture, as well as elucidating the mechanism of the complications and the problems that need to be solved to improve outcomes in the future.

Methods

A total of 32 lead placements in 18 consecutive patients who underwent implantation of a pacemaker or ICD with subclavian venipuncture were examined (15 males, 3 females; age range, 33–87 years). Pacemakers were implanted for sick sinus syndrome and/or paroxysmal atrial fibrillation, atrial fibrillation with a slow ventricular rate or atrioventricular block in 8, 2, and 2 cases, respectively. ICDs were implanted for ventricular tachycardia and ventricular fibrillation in 5 and 1 cases, respectively.

After skin incision and preparation of the subpectoral fascial pocket under local anesthesia in the conventional manner, the left subclavian artery and vein were visualized by 2-D US using a 7.5 MHz sterile convex transducer (UST-995–7.5, SSD2000, Aloka Co, Tokyo, Japan) placed medially in the incision to make room for the puncture (Fig 1). The subclavian vein was identified by the direction of blood flow on the Doppler color flow map (CFM). When blood flow was not clearly detectable by CFM, as is often the case in the presence of impaired cardiac performance, venous return was transiently augmented by compressing the ipsilateral arm. While the long-axis view of the subclavian vein was depicted, a needle was advanced from the outer edge of the transducer toward the subclavian vein...
below the transducer (Fig 1B). No attached device for
directing the needle was used because of limited space for
the US transducer in the operative field. The needle was de-
picted as an echogenic line that extended toward the vein.
When the needle entered the vein, and an echogenic dot
was seen in the venous lumen (Fig 2), blood was aspirated
through the needle. After a guidewire was introduced
through the needle without resistance, it was advanced into
the right atrium under fluoroscopic control. The guidewire
in the subclavian vein was visualized with US (Fig 3).
These procedures were performed by a single operator
(first author) in this series.

The US images during the venipuncture were recorded
on S-VHS videotapes for later analysis. The following
parameters were measured off-line: (1) the number of veni-
puncture attempts and time needed for successful veni-
puncture (s); (2) the internal diameter of the subclavian
vein at the puncture site (mm); (3) the depth of venipunc-
ture, measured as the distance from the edge of transducer
(the surface of the pectoralis muscle) to the vein (mm); and
(4) the angle of entry of the needle, measured as the angle
between the course of the vein and the direction of needle
during puncture (degrees). For these measurements, still
images captured from the videotape were transferred to a
personal computer and then analyzed using CANVAS
version 5 software (Deneba Systems, Co, Victoria, USA).
The scale in the echo image was used for calibration. In
addition to these measurements, difficulties and problems
encountered during the venipuncture procedure were also
recorded.

Results
The subclavian vein was clearly visualized and identified
in every case. Occlusion of the vein with a thrombus was
not detected in any of the cases in this series. There were no
complications related to the venipuncture, such as arterial injury, hematoma formation, or pneumothorax. When the needle was advanced, resistance from penetrating the costoclavicular ligament was not felt. Every lead entered the subclavian vein posterior to the skin incision (extrathoracic portion). Fluoroscopy also showed that none of leads became trapped at the ligament.

Of the 32 lead placements, venipuncture was successful on the first, second, and third attempt in 21 (65.6%), 8 (25.0%), and 2 cases (6.3%), respectively. Five attempts were needed in 1 case because of difficult visualization of the needle in the US image. An additional puncture kit was not necessary for any of the leads implanted. The time needed for successful entry varied from 13 to 684 s (mean, 82.1 s): 13–84 s (mean, 30.1 s) for single venipuncture and 33–188 s (mean, 80.0 s) for 2 venipunctures. The most common reason for unsuccessful puncture was loss of the needle image, probably because of deviation of the needle out of the scanning plane. The echo images became unclear after the injection of local anesthetics. When a strong echo image of the needle tip was not visible, passive movement of tissue with the needle was helpful for identifying its location.

The internal diameter of the subclavian vein at the puncture site ranged from 3.5 to 12.4 mm (mean, 7.8 mm) and was smaller than 10 mm in 26 punctures (81.3%). The depth of the vein was 10.0–32.4 mm (mean, 22.7 mm) from the puncture site. The entry angle ranged from 32.2° to 72.6° (52.4° on average); it was larger than 45° in 24 punctures (75.0%).

As shown in Fig 1, the subclavian artery was situated
adjacent to the subclavian vein in 9 patients (50.0%), which required particular care not to penetrate it. When the posterior wall of the vein was passively moved with the needle, it was not advanced further. Because it was difficult to differentiate the resistance in penetrating the venous wall from that when penetrating the arterial wall, the US image was the only guide to avoiding arterial injury. A strong echo image of the surface of the rib or lung was situated adjacent to the vein in 5 cases (27.8%) (Fig 4) and in these cases, the needle was carefully advanced, guided by US, to prevent penetration of the posterior wall of the vein.

During the venipuncture for the second lead, the guidewire already in place caused an acoustic shadow that interfered with visualization of the vein (Fig 3). It was necessary to move the position to obtain better visualization of the vein. In 1 case, however, this method did not work and venipuncture was performed proximal to the puncture site of the first lead.

The anterior wall of the subclavian vein was pushed down onto the posterior wall without penetration of the needle (no blood aspirated) in 6 cases (33.3%, Fig 5). In such instances, the needle was tilted to reduce the entry angle and to increase the safety margin when advancing the needle and the needle was thrust into the vein. In another case, the anterior wall of the vein was unusually inflexible and the venous lumen collapsed without penetration of the needle.

Although the entry angle was rather large, the guidewire did not show an acute curve (Fig 3). Postoperative chest roentgenography showed no unusual bending of the lead in any case.

Discussion

The results of this study can be summarized as follows: (1) US-guided extrathoracic subclavian venipuncture was feasible in every patient in this series; (2) the technical success was 100% and the time and number of attempts needed for successful venipuncture was minimal in most cases despite a large entry angle and a small vein diameter; (3) the subclavian artery and/or lung was close to the subclavian vein and in the course of needle entry, but complications related to these structures were avoided by careful manipulation under visual guidance; (4) the flexibility of the venous wall was responsible for unsuccessful venipuncture.

US showed that the size, depth, course, and flexibility of the vein varied greatly among individual patients. There was clear visualization of the vein and surrounding structures, which is not provided by fluoroscopic guidance. The US images showed why venipuncture was unsuccessful on the first attempt and led to an improved outcome of subsequent attempts; successful venipuncture was obtained by the second attempt and within 2 min in 90.6% (29/32) and 84.4% (27/32) of lead placements, respectively. US also reduces the radiation exposure of the patient and operator.

Our results also revealed that ‘flexibility of the vein’ was the main reason for unsuccessful needle entry. It can lead to repeated attempts to puncture, consequently prolonging the operation and increasing the risk of complications. To the best of our knowledge, there is no previous published evidence of this phenomenon. A large angle of entry and loose connective tissue around the vein might also contribute to failed venipuncture. It was often necessary to thrust the needle in order to enter the vein and that can be performed efficiently and safely only when the vein and needle are visualized.

Fyke et al1 devised a specially designed Doppler transducer that could detect blood flow and correctly navigate the direction of the needle to increase the technical success; however, they still experienced arterial injury and pneumothorax, probably caused by injury to the subclavian artery or lung situated behind the vein but along the course of the needle, as was often found in our series (Figs 1,4). The Doppler method does not provide a visual image of these structures, but 2-D images enable precise control of the needle tip, eliminating such complications.

The needle is often difficult to visualize because its surface is smooth and reflects the US away from the transducer, and we found that passive movement of the tissue during advancement of the needle was helpful for locating the needle tip because such movement appears on the image even when the needle is slightly out of the scanning plane. It is necessary to devise some marking on the needle that can be recognized by US and indicates whether the needle is following the appropriate course.

Another advantage of US-guided lead insertion is that contrast venography is not needed for locating the vein and examining venipatency. The 2-D images provide morphological and positional information, while CFM indicates vein patency without the use of contrast media. Blood flow can be examined repeatedly or even continuously during the procedure. The subclavian vein can be compressed by a surrounding hematoma or the vein can be filled with thrombus following repeated venipuncture, events that can also be responsible for unsuccessful puncture, but are clearly recognized in the US images.

To obtain successful results with US-guided venipuncture, the operator needs to be capable of both visualizing the vein and surrounding structures and inserting the needle with this technique. US-guided puncture is commonly done in other fields (eg, percutaneous transhepatic biliary drainage or percutaneous nephrostomy). Based on our results in this series of patients, it should be possible for physicians to master this procedure with experience in several cases.

Study Limitations

First, this was not a comparative study. We decided not to include a control group because the usefulness of US guidance has already been reported by a number of investigators and we had experienced many cases of difficult venipuncture under fluoroscopic control. Instead, this study was designed to obtain insights for improving US-guided venipuncture. A small study population was another limitation; however, despite that the results elucidated the mechanism of unsuccessful venipuncture and did provide useful insights to means of improving the safety and efficiency of the procedure.

In conclusion, US guidance for subclavian venipuncture helps achieve a safe and timely procedure with minimal loss of materials by its ability to visualize not only the needle but also the vein and surrounding structures, although further modifications of the needle are needed for better imaging.

References


