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Ultrasound Identification of the Guidewire in the Brachiocephalic Vein for the Prevention of Inadvertent Arterial Catheterization During Internal Jugular Central Venous Catheter Placement

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BACKGROUND: Imaging the guidewire with ultrasonography in the internal jugular vein during central venous catheterization often is used to verify proper guidewire placement and to aid in prevention of inadvertent arterial catheterization. It is known, however, that inadvertent arterial catheterization can occur despite imaging the guidewire in the internal jugular vein because the guidewire may continue through the far wall of the internal jugular vein and into an adjacent artery. We propose confirmation of the guidewire in the brachiocephalic vein with ultrasonography as a more reliable method of confirming proper guidewire placement.

METHODS: A prospective feasibility study of 200 adult cardiothoracic surgery patients undergoing internal jugular vein catheterization was performed to determine whether the guidewire could be imaged with ultrasonography in the brachiocephalic vein. The guidewire was imaged in the internal jugular vein in a short-axis view, and the transducer was then angled caudally under the clavicle, following the guidewire into the brachiocephalic vein.

RESULTS: The right internal jugular vein was catheterized in 193 patients and the left internal jugular in 7 patients. The brachiocephalic vein was successfully imaged in all but 2 patients. In 3 patients, the guidewire could not be clearly identified in the brachiocephalic vein because of interference from the leads of a heart rhythm device (pacemaker or defibrillator) or preexisting catheter. In 2 patients, the guidewire was not seen initially in the brachiocephalic vein because of coiling in the internal jugular vein, and in 1 patient because of the guidewire passing into the right subclavian vein, but all 3 were subsequently imaged in the brachiocephalic vein after repositioning.

CONCLUSIONS: During internal jugular vein catheterization, the brachiocephalic vein was imaged with ultrasonography in 99% of patients (the lower 1-sided 99% confidence limit is 96%). The guidewire was imaged in the brachiocephalic vein in all cases except when leads from a heart rhythm device caused interference, although in some patients with leads, the guidewire could be imaged without difficulty. The absence of the guidewire from the brachiocephalic vein was indicative of a malpositioned guidewire. (Anesth Analg 2016;123:896–900)

Inadvertent catheterization of an adjacent artery during attempted placement of a central venous catheter is a serious, potentially life-threatening complication. The reported incidence of inadvertent arterial catheterization ranges from 0.1% to 1.0% when the traditional method of observing the color and pulsatility of blood is used to distinguish the vein from the artery.[1–5] Approaches previously used to prevent inadvertent arterial catheterization include fluoroscopy, pressure measurement, and ultrasound.

The reliability of fluoroscopy for preventing inadvertent arterial catheterization is uncertain.[6] Anecdotal reports demonstrate that fluoroscopy may fail,[7] and fluoroscopy is not always available for central venous catheterization.

Pressure measurement from the needle used to puncture the blood vessel was shown to be a highly reliable and convenient method for distinguishing artery from vein[8–11]; however, pressure measurement may fail to prevent arterial catheterization if the needle is moved from the vein into the adjacent artery after the pressure is measured. Very low arterial or very high venous pressure also may confound the use of pressure measurement.

Ultrasound has been recommended for guidance in puncturing the vein with a needle and for identification of the guidewire in the vein during internal jugular vein catheterization.[12–17] There are numerous reports, however, of inadvertent arterial catheterization despite the use of ultrasound guidance.[18–23a]

In addition to the use of ultrasound for directing the needle, identification of the guidewire in the vein has been suggested

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[a]Transesophageal echocardiography (TEE) is sometimes used to verify the presence of the guidewire in the superior vena cava and/or right atrium. This should be a highly reliable method of confirming venous placement of the guidewire (assuming that the guidewire is not confused with other wires or catheters). The use of TEE is applicable mainly for those patients where a TEE examination is required for reasons other than placement of a central venous catheter, because placement of a central venous catheter alone is not usually considered an indication for TEE. Even when TEE use is indicated for a particular patient, a second operator may be required to manipulate the probe and obtain images.

as a reliable method for avoiding arterial catheterization. Experience has shown, however, that the needle may pass through both sides of the internal jugular vein and into the adjacent artery.[7,24] The guidewire inserted through that needle also passes through both sides of the internal jugular vein and into the artery. The more proximal part of the guidewire may be identified within the internal jugular vein with ultrasonography, but the presence of the more distal part of the guidewire in the adjacent artery can be easily missed, conveying false assurance that arterial catheterization will not occur.

We reasoned that if the path of the guidewire could be "traced" with ultrasonography from the internal jugular into the brachiocephalic vein rather than simply identifying the guidewire within the internal jugular vein, then arterial placement of the guidewire could be ruled out with greater certainty. The guidewire could not be present in the brachiocephalic vein if it was located in the carotid or subclavian artery. Therefore, we performed this feasibility study to determine whether the guidewire could be routinely identified within the brachiocephalic vein during internal jugular central venous catheterization.

METHODS

Approval of the institutional review board was obtained with waiver of consent. Two hundred consecutive cardiothoracic surgical patients older than 18 years requiring internal jugular central venous catheterization were studied during a predefined study period of approximately 1 year. An undetermined number of the patients had undergone previous jugular catheterization during previous cardiac surgical procedures. All patients received an Arrow MAC introducer sheath (Teleflex, Morrisville, NC) placed over an 0.032-inch guidewire. Live ultrasound guidance with either SonoSite M-Turbo (SonoSite Ltd., Bothell, WA) or Philips iE33 (Philips, Bothell, WA) ultrasound machines was used for the placement of an 18-gauge thin wall needle into either the right or the left internal jugular vein using a short-axis view. Venous pressure was confirmed as previously described via a Compass device (Centurion Medical Products, Williamston, MI), which is a compact, single-use pressure transducer.[11] A 0.032-inch guidewire was then placed through the guidewire port of the Compass transducer. Venous pressure was confirmed again after guidewire placement and before removal of the needle. After removal of the needle, the guidewire was identified with ultrasound in the internal jugular vein in a short-axis view. The path of the guidewire was then "traced" into the brachiocephalic vein by sliding the transducer down the internal jugular vein to the clavicle and tilting the transducer under the clavicle, directing the beam into the mediastinum (Figure 1; Supplemental Digital Contents 1–4, Videos 1–4, http://links.lww.com/AA/B455, http://links.lww.com/AA/B456, http://links.lww.com/AA/B457, http://links.lww.com/AA/B458). Patient sex, age, body mass index (BMI; kilogram per square meter), site of venous cannulation (jugular/subclavian/femoral, right/left), number of attempts, and identification of guidewire in the brachiocephalic vein were recorded.

VIDEO+

RESULTS

Central venous catheters were placed in 200 patients, with an average age of 63 years (standard deviation = 16) and an average BMI of 28 (standard deviation = 6) kg/m^2.

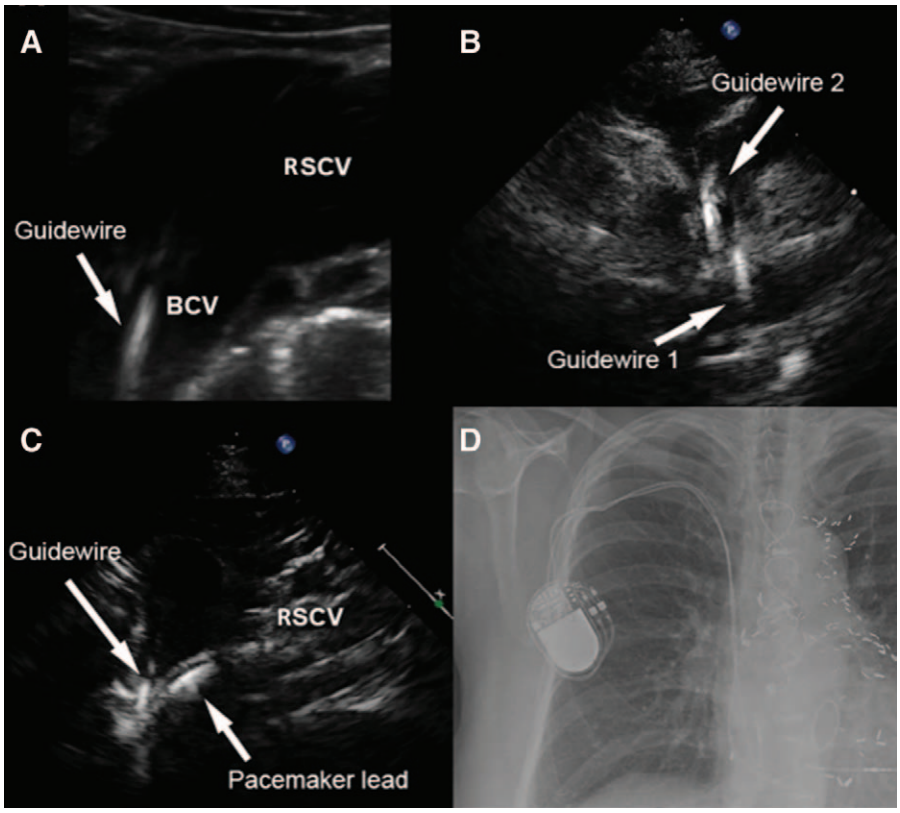

Figure 1. A, A guidewire is seen within the right brachiocephalic vein (BCV). B, Two guidewires are seen within the right brachiocephalic vein in a patient who underwent double catheterization of the right internal jugular vein before Medtronic CoreValve transcatheter aortic valve implantation. C, A guidewire is seen in the right brachiocephalic vein adjacent to the lead of a permanent pacemaker, which enters the brachiocephalic vein from the right subclavian vein (RSCV). D, The pacemaker and leads are shown on a chest x-ray. In a few cases, shadowing from pacemaker leads prevented identification of the guidewire.

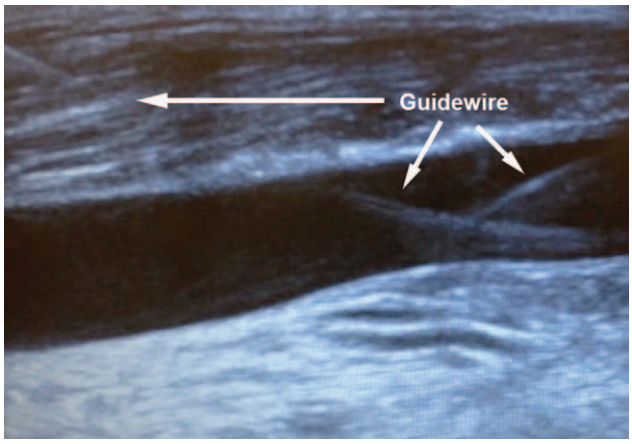

Figure 2. A guidewire is shown curled in the internal jugular vein. In 2 cases, absence of the guidewire in the brachiocephalic vein prompted a search for the guidewire that revealed a curled guidewire. A curled guidewire may be well shown in a long-axis view of the internal jugular vein but may be easily missed in a short-axis view.

One hundred thirty (65%) patients were men. The right internal jugular vein was cannulated in 193 patients (96%) and the left internal jugular vein in 7 (4%) patients. The vein was entered in a single attempt in 177 (89%), 2 attempts in 18 (9%), and 3 attempts in 5 (2%) patients. The brachiocephalic vein was visualized successfully in 198 (99%) patients, and the guidewire was visualized in the brachiocephalic vein in 195 (98%) patients. There were 2 patients in whom the brachiocephalic vein could not be visualized (1 patient was morbidly obese [BMI = 60 kg/m^2] with a very large neck, whereas in the other patient, the left brachiocephalic vein could not be visualized). Among the 9 subjects with morbid obesity (BMI > 40 kg/m^2), the brachiocephalic vein was identifiable in all but this one. In 3 patients, the guidewire could not be seen apparently because of interference from the leads of a heart rhythm device (pacemaker or defibrillator) or preexisting central venous catheter. Although leads from a heart rhythm device may obscure the view of the guidewire, this is not invariable because the guidewire was found in the brachiocephalic vein of several patients with heart rhythm device leads (Figure 1). In 2 patients, the guidewire was not seen initially in the brachiocephalic vein because of coiling in the internal jugular vein but was visualized subsequently in the brachiocephalic vein after repositioning (Figure 2). In 1 patient, the guidewire was not seen initially in the brachiocephalic vein because of the guidewire passing from the internal jugular vein into the right subclavian vein, but it was seen in the brachiocephalic vein after repositioning with fluoroscopy (Figure 3).

DISCUSSION

We found that the brachiocephalic vein could be imaged by ultrasonography in 99% of 200 consecutive adult cardiothoracic surgical patients. The guidewire could almost always be identified in the brachiocephalic vein except for a few cases in which bright echos from heart rhythm device leads or a preexisting central venous

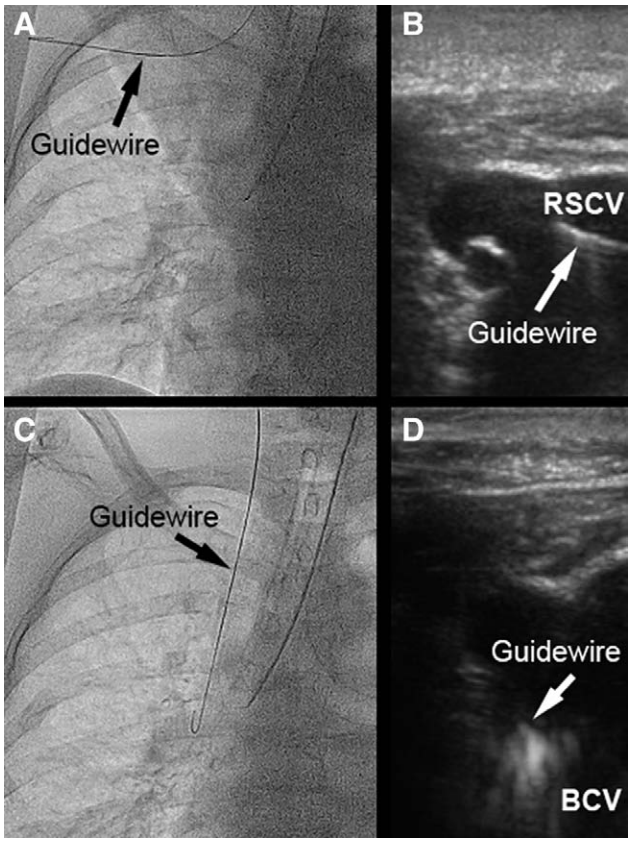

Figure 3. In this case, the guidewire was not found in the brachiocephalic vein. Further ultrasound imaging demonstrated the guidewire in the right subclavian vein (B). Because fluoroscopy was available in this hybrid operating room, a fluoroscopic image was obtained that verified that the guidewire was situated in the right subclavian vein (A). The guidewire was partially withdrawn and then readvanced into the superior vena cava with fluoroscopic guidance (C). After guidewire repositioning, ultrasound imaging also demonstrated the guidewire within the brachiocephalic vein (D).

catheter prevented the guidewire from being seen.[b] The absence of the guidewire in the brachiocephalic vein was an indication that the guidewire was not properly placed, having coiled within the internal jugular vein or having entered the right subclavian vein instead of the brachiocephalic vein (Figures 2 and 3). On the basis of these results, we conclude that using ultrasonography to identify the guidewire in the brachiocephalic vein is a practical method for confirming venous placement of the guidewire before inserting a central venous catheter into the internal jugular vein.

We are unable to determine whether identification of the guidewire in the brachiocephalic vein is more or less reliable than other techniques for preventing inadvertent arterial catheterization because this study was not powered

[b]Moving the guidewire while imaging may allow the guidewire to be detected despite shadowing from adjacent leads or catheters. Chart review showed that about 17% of patients in this study had heart rhythm device leads; however, all but a few of these were left-sided systems in which the leads would enter the superior vena cava from the left brachiocephalic vein; when the right internal jugular approach is used for central venous catheterization, leads from the left side would not be expected to interfere with imaging the guidewire in the right brachiocephalic vein.

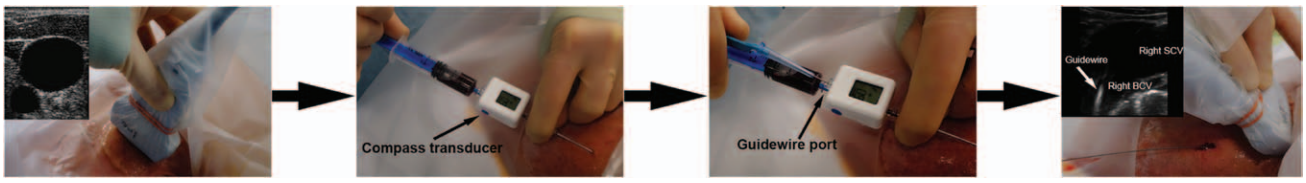

Figure 4. Our technique for verifying venous placement of the guidewire is shown. Live ultrasound guidance is utilized with a short-axis view of the internal jugular vein for guiding the needle. The pressure is measured at the needle tip using a Compass transducer. After insertion of the guidewire through the guidewire port of the Compass transducer, the pressure at the needle tip is measured again to confirm a venous pressure at the site of guidewire insertion. Finally, the guidewire is "traced" with ultrasound from a short-axis view of the internal jugular vein, sliding the transducer down the neck to the clavicle and then tilting the transducer under the clavicle to image the guidewire in the brachiocephalic vein.

for that purpose. Because of our routine use of ultrasound guidance and pressure measurement, the incidence of inadvertent arterial catheterization in our practice is extremely small; we do not know the number of patients who would be required to adequately power a study to detect an effect on inadvertent arterial catheterization, but undoubtedly the number would be very large. This study was only intended to determine the feasibility of using ultrasound to identify the guidewire in the brachiocephalic vein.

However, using ultrasonography to identify the guidewire in the brachiocephalic vein would be expected to be superior for confirming venous placement of the guidewire compared with identifying the guidewire in the internal jugular vein.[25] The reason for this is that the needle used to puncture the internal jugular vein can pass through the vein and enter the adjacent artery, either the carotid,[7,24] or if the approach is low enough in the neck, the subclavian artery.[26] If this event is not appreciated by color and pulsatility or pressure measurement, it may be well missed by ultrasound, because the wire can appear to be properly situated in the internal jugular vein, on short- or long-axis views. Identifying the guidewire in the brachiocephalic vein, which is anatomically closer to the heart than either the carotid artery or subclavian vein, would seem to make arterial catheterization extremely unlikely. A possible exception to this could occur if the needle passed transarterially (through the carotid or subclavian artery) and then entered the adjacent vein; although hypothetically possible, this must be quite rare as we have not seen any cases or case reports of this scenario. The possibility of missing transarterial placement can be minimized by tracing the entire course of the guidewire from the internal jugular vein into the brachiocephalic vein, as shown in the Supplemental Video.

In addition, identification of the guidewire in the brachiocephalic vein provides assurance that the guidewire is not malpositioned within the venous system. Attempting to pass a catheter over a guidewire that has curled in the internal jugular vein or one which has entered the subclavian vein may result in difficulty advancing the catheter or even injury to the vein.[27]

Our process for placing an internal jugular vein central venous catheter is shown in Figure 4. We use ultrasound guidance for inserting the needle into the vein, pressure measurement from the needle tip to confirm venous placement of the needle, repeated pressure measurement from the needle tip after insertion of the guidewire to confirm venous placement of the guidewire, and identification of the guidewire in the brachiocephalic vein using ultrasound as a final confirmation of venous placement before insertion of the central venous catheter.

Our process for ensuring that the central venous catheter is placed properly is deliberately redundant, using both pressure measurement and ultrasound imaging. An argument could be made that ultrasound is unnecessary if pressure measurement is used. Pressure measurement, however, is not infallible. For example, the needle that is inserted into the internal jugular vein can be moved inadvertently into the adjacent artery after the pressure measurement is completed. One possible solution for avoiding this problem is to place a plastic intravenous catheter over needle into the internal jugular vein and measure the pressure from the intravenous catheter. The likelihood that the plastic intravenous catheter would pass through the vein and into the adjacent artery after pressure measurement is extremely low.[28] Another possible method to ensure that inadvertent arterial puncture is detected is to measure the pressure after guidewire placement through the guidewire port of the Compass transducer. The pressure in the guidewire port should reflect the pressure in the blood vessel where the guidewire was placed.[11c] Another limitation of pressure measurement is that pressure measurement does not demonstrate that the guidewire actually entered the brachiocephalic vein as intended; the guidewire may curl in the internal jugular vein or enter a subclavian vein instead.

An argument also could be made that pressure measurement is unnecessary if the ultrasound is used to identify the guidewire in the brachiocephalic vein before inserting the central venous catheter. If pressure measurement is not performed, however, the guidewire occasionally will be placed into the artery despite the use of ultrasound guidance. Although the absence of the guidewire in the brachiocephalic vein under these circumstances may warn the operator and prevent inadvertent arterial catheterization, placing the guidewire into the artery may not be harmless. There is also the problem that the brachiocephalic vein may not be visualized in occasional patients, or the guidewire may not be seen because of shadowing from preexisting catheters or heart rhythm device leads, as shown in this study.

[c]Hypothetically, using the Compass transducer guidewire port may not prevent inadvertent arterial placement of the guidewire, if the needle is advanced from the vein into the artery during guidewire insertion, allowing the guidewire to enter the artery. If the needle is then withdrawn from the artery into the vein before the arterial pressure is noted (the pressure is measured from the needle tip), the observed pressure would be venous, but the guidewire would be inserted into the artery. We believe that this is a very rare event.

In summary, this study shows that the brachiocephalic vein can be identified with ultrasound in at least 96% (lower 1-sided confidence limit) of cardiothoracic surgery patients during central venous catheterization of the internal jugular vein, and the guidewire can be visualized in the brachiocephalic vein unless shadowed by cardiac rhythm device leads or preexisting catheters. We recommend this technique for final verification of proper venous placement of the guidewire.

DISCLOSURES

Name: Andrew Bowdle, MD, PhD, FASE.
Contribution: This author helped design the study, conduct the study, analyze the data, and write the manuscript.
Conflicts of Interest: Andrew Bowdle consulted for Centurion Medical Products as a scientific advisor.
Name: Srdjan Jelacic, MD.
Contribution: This author helped design the study, conduct the study, analyze the data, and write the manuscript.
Conflicts of Interest: Srdjan Jelacic declares no conflicts of interest.
Name: Kei Togashi, MD, MPH.
Contribution: This author helped design the study, conduct the study, analyze the data, and write the manuscript.
Conflicts of Interest: Kei Togashi declares no conflicts of interest.
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Contribution: This author helped design the study, conduct the study, analyze the data, and write the manuscript.
Conflicts of Interest: Renata Ferreira declares no conflicts of interest.
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