

# Video Analysis of Accidental Arterial Cannulation With Dynamic Ultrasound Guidance for Central Venous Access

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**Objective.** Accidental arterial cannulation during ultrasound-guided central venous cannulation is rarely reported and should be much less likely with dynamic guidance. Although accidental arterial penetration with the needle may occur periodically without notice and with little harm, actual arterial dilation and line placement may result in serious complications. **Methods.** This series reports 6 such cases of accidental arterial cannulation and central line insertion under dynamic ultrasound guidance. **Results.** Two of the arterial cannulations resulted in airway loss, with 1 of these ending in death. The remaining 4 arterial lines led to serious local complications. Ultrasound video analysis of each line placement or postplacement analysis was reviewed, and common pitfalls were extracted. In 3 cases, a central line went directly through the internal jugular vein (IJ) and into the carotid artery. In 1 case, a cordis introducer sheath traveled through the posterior wall of the common femoral vein and into the deep femoral artery branch below. Each patient was hypotensive and hypoxic, making traditional safety checkpoints such as aspiration of bright red blood and pulsatile flow from the syringe hub less reliable in identifying accidental arterial cannulation. All ultrasound-guided cannulations were performed by a standard short-axis approach with high-resolution linear array ultrasound transducers on modern equipment. **Conclusions.** The short-axis approach, as seen in this series, can provide a false sense of security to the practitioner and allows for potentially dangerous accidental arterial cannulation. In the setting of critically ill patients, it may be prudent to not only visualize the entire path of the needle with the long-axis approach but also confirm correct cannulation by tracing the guide wire in the long axis before line placement. **Key words:** carotid cannulation; central line complications; central venous access; ultrasound-guided vascular access; vascular access; vascular access complications.

## Abbreviations

HTN, hypertension; IJ, internal jugular vein

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Ultrasound guidance for central venous access has become the standard of care, and the Agency for Healthcare Research and Quality and multiple medical societies strongly support its use.<sup>1</sup> At least 2 meta-analyses also indicate that first-pass success is greater and complications fewer when ultrasound guidance is used in comparison to a traditional blind landmark technique.<sup>2,3</sup> Few reports of accidental arterial cannulation are present in the literature, and the casual reviewer may assume that serious complications no longer arise when ultrasound is used.<sup>4</sup> Theoretically, it should be extremely unlikely or impossible to accidentally cannulate the incorrect vessel (an artery) during ultrasound-guided central line placement, as long as proper technique is followed. In addition, if needle penetration into an artery is missed on ultrasound imaging, standard safety checks should reveal arterial

cannulation, and actual central line placement should be aborted. Typically, as was the custom for blind central line placement, the physician removes the syringe from the hub of the needle after blood is withdrawn from the central vein. The physician then feeds a guide wire through the needle hub into the central vein. If the blood coming from the needle hub is bright or pulsatile, then accidental arterial cannulation may have occurred, and that cannulation attempt is aborted.

This series describes 6 accidental arterial cannulations in critically ill patients that occurred with dynamic ultrasound guidance. An ultrasound quality assurance video of the actual placement or postplacement analysis by the physician was available for review in each case. The resulting analysis extracts potential pitfalls of ultrasound-guided cannulation that could be used by other sonologists to avoid similar mistakes.

### Case Descriptions

#### Case 1

A 67-year-old male patient with a history of hypertension (HTN), atrial fibrillation, and coronary artery disease presented to the emergency department with generalized weakness, shortness of breath, and vomiting. The patient was hypotensive, hypoxic (oxygen saturation, 85% with a face mask), and mildly hypothermic. Bilobar pneumonia and sepsis were diagnosed, and the patient was resuscitated with 2 L of fluid, but continued to be hypotensive. A central line was placed under ultrasound guidance into the right IJ by the attending physician and resident using a short-axis approach. Norepinephrine was administered, but in approximately 30 minutes, nurses noted substantial oozing from the central line site and increasing soft tissue swelling. The patient's dyspnea suddenly worsened, and he required emergent intubation. The intubation was unsuccessful despite multiple attempts because of substantial tracheal deviation. Cricothyrotomy was difficult and prolonged, and the patient died shortly afterward.

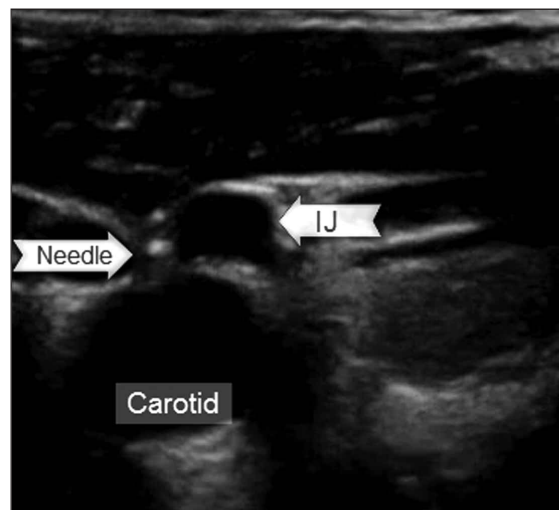
Review of the original video showed that the hypotensive patient had a collapsing IJ, and the needle in the short axis can be seen plunging down toward the carotid artery just below the IJ

(Figure 1). A real-time video recording shows the needle progress (Video 1). The attending physician, supervising the procedure, saw slowly dripping dark blood and had the resident insert the guide wire, satisfied that he was in the IJ. No further imaging was required because the wire fed easily and line placement went without incident. However, the needle had gone through the IJ and hit the carotid artery.

#### Case 2

A 75-year-old female patient with a history of diabetes, HTN, and a cerebrovascular accident presented with altered mental status and a fever. She was discovered to have a urinary tract infection, leukocytosis, and an elevated lactate level. The patient received 2 L of saline for hypotension but became increasingly unstable and hypoxic. A resident and attending physician placed a cordis introducer sheath into the patient's right femoral vein using dynamic ultrasound guidance with a standard short-axis approach. Dark blood was returned with no pulsatile flow noted. The patient was given vasopressors and then underwent intubation. As her blood pressure improved, nursing staff noted increasing swelling at the catheter site, and blood was backing up into the tubing. An ultrasound examination revealed that the cordis tracked through the common femoral vein and entered

**Figure 1.** The carotid artery sits just underneath the IJ, which is compressed by the needle, about to penetrate its posterior wall and enter the carotid artery below.



the proximal deep femoral artery, then running into the common femoral artery (Video 2). A femoral vein line was placed on the opposite side, and drips were switched over. The cordis was removed, and pressure was applied to the right groin. The patient was transferred to the intensive care unit, but bleeding and swelling at the area worsened. She eventually required vascular surgery to correct an arteriovenous fistula and control bleeding.

### Case 3

A 48-year-old female patient with a history of diabetes presented with nausea and vomiting for 2 days. She was hypotensive and hypoxic on evaluation and found to have substantial pulmonary edema. The patient underwent intubation, and a central line was placed into the right IJ by a standard short-axis ultrasound guidance technique. The IJ was large and easily cannulated. The blood from the syringe was dark and flowed slowly. She started receiving vasopressors, resulting in an improved blood pressure. As the patient's condition improved, the nurses noted increased swelling at the site as well as oozing of blood around the dressings. A blood gas study was run from an arterial line and compared with one drawn from the central line. The values were identical and confirmed carotid placement. The carotid line was removed, and pressure was applied. The patient continued to bleed heavily after admission to the intensive care unit, and vascular surgery specialists were eventually consulted. They identified a tear in the carotid artery with a focal dissection, which required surgical repair. After a prolonged course in the hospital, the patient was discharged home. Review of the ultrasound recording made during dynamic needle guidance revealed that the physician placing the line collapsed the medial portion of the IJ and entered the carotid artery, which sat partially underneath the IJ (Video 3).

### Case 4

A 67-year-old male patient with a history of HTN and diabetes mellitus who was receiving chemotherapy for esophageal cancer that had metastasized to his liver and lungs presented with increasing lower extremity and abdominal wall edema and generalized malaise. The patient

was hypoxic, and chest radiography revealed mild pulmonary edema with no evidence of pneumonia. The patient's blood pressure steadily dropped, and his mentation worsened. A right IJ line was placed under ultrasound guidance by a standard short-axis technique. Dark blood slowly dripped from the needle hub, and the wire was fed without difficulty. The patient received norepinephrine, and his pressure quickly normalized.

Nurses later noted increased swelling and oozing of blood on the right side of the neck. Despite local pressure to control swelling and oozing, the patient soon began to have increasing respiratory difficulty, and his neck was noted to be grossly asymmetric with a shift of the trachea to the left. He underwent emergent intubation. The physician caring for the patient performed an ultrasound evaluation of the central line and noted that it was traveling through the IJ and into the carotid artery. The line was removed, and the patient's bleeding was controlled after fresh frozen plasma administration and continued pressure. He recovered and was able to leave the hospital 6 days later. The actual cannulation procedure was not recorded properly, but just after guide wire insertion, an ultrasound video revealed that the guide wire was traveling through the IJ and its posterior wall and then into the carotid artery (Figure 2 and Video 4).

**Figure 2.** The IJ and carotid artery are overlapping. The guide wire was briefly traced in the short axis by the sonologist, who missed its downstream passage through the posterior wall of the IJ into the carotid artery as shown. Carotid line placement was confirmed clinically.



### Case 5

A 69-year-old female patient with a history of emphysema, chronic renal failure, and diabetes presented with severe respiratory distress and an altered mental status. She was hypotensive and hypoxic but afebrile. Despite 2 L of normal saline, her hypotension worsened. The patient received a left IJ line after an ultrasound examination revealed that her right IJ was severely scarred. The IJ was cannulated after multiple attempts because of complete collapse of the vessel with inspiration. During the procedure, the patient became increasingly hypoxic and confused, requiring emergent endotracheal intubation after the central line placement. Nurses noted increasing swelling at the IJ insertion with improving blood pressure, and it was increasingly more difficult to infuse fluids through the central line. A closer look revealed arterial pulsation in the line and massive swelling of the left side of the neck, resulting in tracheal displacement to the right. Pressure control was unsuccessful, and the patient required reversal of her anticoagulation. She later underwent emergent repair of the artery by vascular surgery. She died of her infection and its complications 7 days later. Ultrasound video review of the portion of the procedure that was available showed the needle penetrating the carotid artery, which was very close to the IJ.

### Case 6

A 14-year-old female patient with no medical history was brought to the emergency department with dysuria for almost 1 week and back pain for 3 days. The patient was hypotensive with a blood pressure of 74/38 mm Hg, a temperature of 101.9°F, and a heart rate of 130 beats per minute. She had episodes of confusion noted by nursing staff. Two large-bore intravenous lines were started, and the patient was quickly given 2 L of normal saline, but her hypotension worsened. Two more liters were given with little effect. The patient was in septic shock, was oliguric, and required a central line. The patient's IJ collapsed substantially with each breath, even in the Trendelenburg position. The line was placed successfully with dynamic ultrasound guidance by the standard short-axis approach. Blood was noted to trickle slowly from the needle hub and appeared relatively dark given that she was receiving high-flow supplemental oxygen at that time.

The patient had further decompensation requiring intubation, norepinephrine, and dobutamine. The nursing staff noted that there was increased leaking at the central line site and marked swelling. Inspection revealed pulsating arterial blood in the large-diameter central line, and the line was removed. Despite constant pressure, the patient continued to have leaking and swelling on the right side of the neck. After several hours, vascular surgery specialists were consulted emergently. Surgical exploration was avoided after an angiogram showed no further leaking and no dissection. Review of the ultrasound quality assurance video made during the procedure revealed the needle coming to the posterior wall with the carotid artery just deep to it and leading to obvious penetration.

## Discussion

Ultrasound guidance is widely thought to be the standard of care for central line placement. Government-sponsored organizations, medical societies, and a multitude of studies support ultrasound use for all central line placements. Research specifically indicates that in femoral vein and IJ central line insertion, dynamic ultrasound guidance of the needle during central vein cannulation decreases complication rates and improves success.<sup>2,3,5</sup> Recently, multiple researchers have also studied ultrasound guidance for arterial and peripheral venous line placement, showing increased first-pass success.<sup>6-9</sup> Few studies are available that cast doubt on the utility of ultrasound guidance for central line placement.<sup>10</sup> However, proper training, technique, and care are required with ultrasound-guided central line placement just as with traditional blind placement.

Several recent studies have indicated that novice sonologists may lose track of their needle tips during dynamic ultrasound guidance while using the short-axis method.<sup>11-14</sup> They may be unaware when a needle completely punctures through the targeted central vein, exiting on the other side and leading to inadvertent puncture of adjacent structures. A recent case report described the potential of accidental arterial cannulation even with use of ultrasound guidance in central line placement



by the short-axis method.<sup>4</sup> More than likely, this is only 1 example of occurrences that are simply rarely reported.

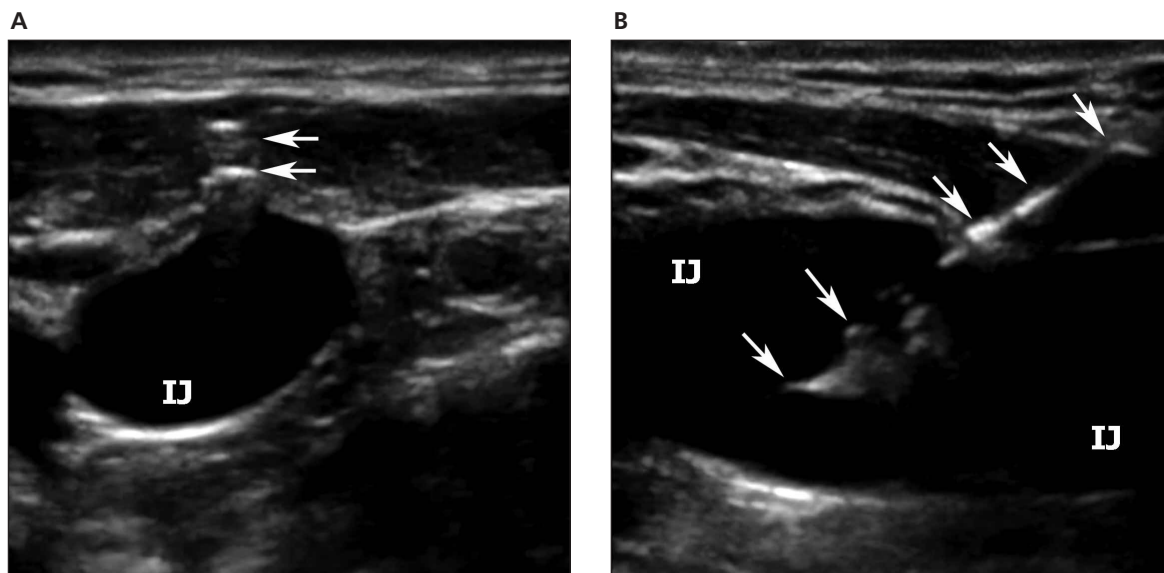
The physicians who either placed or supervised resident line placement in each of the cases described had hospital credentialing in emergency ultrasound based on American College of Emergency Physicians ultrasound criteria.<sup>15</sup> All residents received a 2-day introductory ultrasound course, which included 3 hours of didactic and hands-on education in ultrasound-guided vascular access. Residents were trained in 1-person dynamic ultrasound guidance techniques using both short- and long-axis approaches. Each line placement was directly supervised by an ultrasound-credentialed attending physician. The total number of ultrasound-guided central lines placed at the facilities during the time frame covering these 6 cases was more than 500. However, other similar errors occurred but were not reported or not recorded on video quality assurance instruments. Thus, the cases described here should in no way be used to determine a frequency of errors.

In normotensive patients, when the syringe is taken off the needle hub before wire insertion, arterial placement of the needle would result in pulsing bright red blood briskly squirting from the needle hub. However, all of the patients described were substantially hypotensive, and

blood trickled out of the needle hub as in a typical venous cannulation. In addition, hypoxic patients may have surprisingly dark arterial blood when oxygen saturations are low. Thus, standard fail-safe techniques of looking for bright red blood that is pulsing from the needle hub may not detect accidental arterial cannulation if ultrasound guidance fails to ensure proper needle placement.

In cases 1, 4, and 6 the IJ was noted to overlie the carotid artery. Contrary to conventional teaching, the IJ and carotid artery frequently do not sit side by side, and overlap is seen in many patients.<sup>16,17</sup> This makes it easier for a needle that punctures the posterior wall of the IJ to accidentally enter the carotid artery.<sup>11</sup> The practitioner is more likely to be unaware of what the her needle tip is actually doing when using the short-axis approach in comparison to the alternative long-axis approach, in which the entire length of the needle is visualized and the target vein is seen longitudinally (Figure 3).<sup>12–14</sup> In patients whose IJ and carotid artery lie side by side with no overlap, loss of the needle on ultrasound guidance is likely to result in nothing more than posterior wall penetration. However, in patients with IJ and carotid artery overlap, accidental penetration of the posterior wall by a needle whose location has been lost by the sonologist may lead to unintended penetration of the carotid artery.

**Figure 3.** Examples of short- and long-axis needle guidance approaches for an IJ. **A**, Needle approaching the vein in the short axis, with a portion of the needle shaft shown (arrows). **B**, Needle approach in the long axis, with the needle shaft shown (arrows).



The **femoral artery** typically **does not sit underneath the femoral vein, and the side-by-side and artery-over-vein positions** are the **most common** anatomic variants.<sup>18,19</sup> However, the patient in case 2 still had accidental arterial cannulation through a process similar to that in the patients with IJ-carotid artery overlap. The key in this patient was **unseen posterior wall penetration** of the **common femoral vein**. After puncturing the posterior wall of the common femoral vein, the needle traveled deep enough to hit the **deep femoral artery** after it had split from the common femoral artery. The blood that returned from the needle was dark and dripped out slowly.

In summary, the short-axis approach, as seen in this series, can provide a false sense of security to the practitioner and allows for potentially dangerous accidental arterial cannulation. In the setting of critically ill patients, it may be prudent to not only visualize the entire path of the needle with the long-axis approach but also confirm correct cannulation by tracing the guide wire in the long axis before line placement.

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