

REVIEW ARTICLE

CURRENT CONCEPTS

Preventing Complications of Central Venous Catheterization

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IN THE UNITED STATES, PHYSICIANS INSERT MORE THAN 5 MILLION CENTRAL venous catheters every year.¹ Central venous catheters allow measurement of hemodynamic variables that cannot be measured accurately by noninvasive means and allow delivery of medications and nutritional support that cannot be given safely through peripheral venous catheters. Unfortunately, the use of central venous catheters is associated with adverse events that are both hazardous to patients and expensive to treat.²⁻⁴ More than 15 percent of patients who receive these catheters have complications.⁵⁻⁷ Mechanical complications are reported to occur in 5 to 19 percent of patients,^{5,6,8} infectious complications in 5 to 26 percent,^{5,7,9} and thrombotic complications in 2 to 26 percent.⁵ In this review, we explain methods for reducing the frequency of complications in adult patients.

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TYPES OF CATHETERS

ANTIMICROBIAL-IMPREGNATED CATHETERS

Catheters impregnated with chlorhexidine and silver sulfadiazine and catheters impregnated with minocycline and rifampin are the most frequently used types of antimicrobial-impregnated catheters. In randomized clinical trials, the use of these catheters has been shown to lower the rate of catheter-related bloodstream infections^{9,10} (Table 1). The use of catheters impregnated with chlorhexidine and silver sulfadiazine lowered the rate of catheter-related bloodstream infections from 7.6 infections per 1000 catheter-days (4.6 percent of catheters) to 1.6 infections per 1000 catheter-days (1.0 percent) (relative risk, 0.21; 95 percent confidence interval, 0.03 to 0.95; $P=0.03$).¹⁰ A cost-effectiveness analysis concluded that using these catheters would decrease direct medical costs by \$196 per catheter inserted.¹¹

The use of antimicrobial-impregnated catheters should be considered in all circumstances, especially when the institutional rate of catheter-related bloodstream infections is higher than 2 percent, which is the threshold at which chlorhexidine-and-silver-sulfadiazine-impregnated catheters may reduce overall costs.¹⁰ Current evidence suggests that minocycline-and-rifampin-impregnated catheters are even more effective for minimizing the risk of infection than those that are impregnated with chlorhexidine and silver sulfadiazine.²⁹ However, this evidence comes from a single randomized trial, and the cost effectiveness of these catheters relative to those that are impregnated with chlorhexidine and silver sulfadiazine has not been formally evaluated. Thus, either chlorhexidine-and-silver-sulfadiazine-impregnated catheters or minocycline-and-rifampin-impregnated catheters may be used.

The emergence of resistant organisms resulting from the use of antimicrobial-impregnated catheters remains a potentially important concern. Continued surveillance will be needed as the use of antimicrobial-impregnated catheters increases.

Table 1. Interventions to Prevent Complications.	
Type of Complication and Intervention	Rationale
Infectious	
Use antimicrobial-impregnated catheters	The use of antimicrobial-impregnated catheters reduces the risk of catheter-related bloodstream infections and reduces costs when the rate of catheter-related bloodstream infection >2% ⁹⁻¹¹
Insert catheters at the subclavian venous site	The risk of catheter-related infection is lower with subclavian catheterization than with internal jugular or femoral catheterization ^{5,9,12,13}
Use maximal sterile-barrier precautions during catheter insertion	Use of a mask, cap, sterile gown, sterile gloves, and large sterile drape reduces the rate of infections and reduces costs ¹⁴
Avoid the use of antibiotic ointments	The application of antibiotic ointments increases the rate of colonization by fungi, ¹⁵ promotes the development of antibiotic-resistant bacteria, ¹⁶ and has not been shown to affect the risk of catheter-related bloodstream infections ¹⁷
Disinfect catheter hubs	Catheter hubs are common sites of catheter contamination ¹⁸
Do not schedule routine catheter changes	Scheduled, routine replacement of central venous catheters at a new site does not reduce the risk of catheter-related bloodstream infection ^{19,20} ; scheduled, routine exchange of catheters over a guide wire is associated with a trend toward increased catheter-related infections ¹⁹
Remove catheters when they are no longer needed	The probability of colonization and catheter-related bloodstream infection increases over time ^{9,10,21}
Mechanical	
Recognize risk factors for difficult catheterization	A history of failed catheterization attempts or the need for catheterization at sites of prior surgery, skeletal deformity, or scarring suggests that catheterization may be difficult ⁸
Seek assistance from an experienced clinician	Insertion by a physician who has performed ≥ 50 catheterizations is half as likely to result in a mechanical complication as insertion of a catheter by a physician who has performed <50 catheterizations ⁶
Avoid femoral venous catheterization	The frequency of mechanical complications with femoral catheterization is higher than with subclavian or internal jugular catheterization ^{5,6,8,22-24} ; the rates of serious complications are similar with the femoral and subclavian approaches ⁵
Use ultrasound guidance during internal jugular catheterization	The use of ultrasound guidance during internal jugular catheterization reduces the time required for insertion and reduces the rates of unsuccessful catheterization, carotid-artery puncture, and hematoma formation ^{25,26}
Do not schedule routine catheter changes	Scheduled, routine replacement of catheters at new sites increases the risk of mechanical complications ^{19,27}
Thrombotic	
Insert the catheter at the subclavian site	Subclavian catheterization carries a lower risk of catheter-related thrombosis than femoral or internal jugular catheterization ^{5,28}

SINGLE-LUMEN AND MULTILUMEN CATHETERS

The number of lumina does not directly affect the rate of catheter-related complications.³⁰⁻³² Therefore, the choice of either a single-lumen or a multi-lumen catheter should be made according to the type required to deliver the needed medications or nutritional support.

INSERTION SITES**CHARACTERISTICS OF PATIENTS**

There are multiple approaches for internal jugular, subclavian, and femoral venous catheterization.³³ Successful catheterization by either the internal jugular or the subclavian route relies on a thorough un-

derstanding of the anatomy of the neck (Fig. 1). The internal jugular vein is located at the apex of the triangle formed by the heads of the sternocleidomastoid muscle and the clavicle. The subclavian vein crosses under the clavicle just medial to the midclavicular point. When it is difficult to identify the landmarks for one type of catheterization, another route should be considered. All patients should be assessed for factors that might increase the difficulty of catheter insertion, such as a history of failed catheterization attempts or the need for catheterization at a site of previous surgery, skeletal deformity, or scarring.⁸ When a difficult catheterization is anticipated, the importance of patient safety dictates that the procedure be performed or supervised by an experienced physician.

Internal jugular catheterization can be difficult in morbidly obese patients, in whom the landmarks of the neck are often obscured. Subclavian venous catheterization should be avoided in patients with severe hypoxemia, because the complication of pneumothorax is more likely to occur at this site and is less likely to be tolerated by such patients. Femoral catheterization should be avoided in patients who have grossly contaminated inguinal regions because femoral insertion places these patients at high risk for the development of catheter-related infections. If central venous access is needed for resuscitation from shock, femoral venous access should be considered because of the speed with which it can be performed, especially if it is believed that internal jugular or subclavian venous catheterization will be difficult. After resuscitation, the catheter can be replaced at the most appropriate site for the patient.

MECHANICAL COMPLICATIONS

Arterial puncture, hematoma, and pneumothorax are the most common mechanical complications during the insertion of central venous catheters (Table 2). Overall, internal jugular catheterization and subclavian venous catheterization carry similar risks of mechanical complications. Subclavian catheterization is more likely than internal jugular catheterization to be complicated by pneumothorax and hemothorax, whereas internal jugular catheterization is more likely to be associated with arterial puncture. Hematoma and arterial puncture are common during femoral venous catheterization. Because mechanical complications are most likely during catheterization at the femoral site, the internal jugular or subclavian venous route should be chosen

unless contraindicated. However, the rate of serious mechanical complications (e.g., pneumothorax requiring insertion of a chest tube or hemorrhage requiring blood transfusion or surgery) associated with subclavian insertion is similar to that associated with femoral insertion.⁵

INFECTIOUS COMPLICATIONS

Catheter-related infections are thought to arise by several different mechanisms: infection of the exit site, followed by migration of the pathogen along the external catheter surface; contamination of the catheter hub, leading to intraluminal catheter colonization; and hematogenous seeding of the catheter. A randomized trial found that subclavian venous catheterization was associated with a significantly lower rate of total infectious complications than femoral venous catheterization and a trend toward a lower rate of suspected or confirmed catheter-related bloodstream infections (1.2 infections per 1000 catheter-days, vs. 4.5 infections per 1000 with femoral catheterization; $P=0.07$).⁵ Available evidence suggests that subclavian catheterization is less likely to result in catheter-related infection than internal jugular catheterization, although the two approaches have not been compared in randomized trials.^{9,12,13} Thus, selection of the subclavian site appears to minimize the risk of infectious complications.

THROMBOTIC COMPLICATIONS

Patients who require central venous catheterization are at high risk for catheter-related thrombosis. Used routinely, ultrasonography with color Doppler imaging detects venous thrombosis in 33 percent of patients in medical intensive care units³⁴ and in approximately 15 percent of these patients the thrombosis is catheter-related. The risk of catheter-related thrombosis varies according to the site of insertion. In one trial, catheter-related thrombosis occurred in 21.5 percent of the patients with femoral venous catheters and in 1.9 percent of those with subclavian venous catheters ($P<0.001$).⁵ In an observational study, the risk of thrombosis associated with internal jugular insertion was approximately four times the risk associated with subclavian insertion.²⁸ Subclavian venous catheterization carries the lowest risk of catheter-related thrombosis. The clinical importance of catheter-related thrombosis remains undefined, although all thromboses have the potential to embolize.

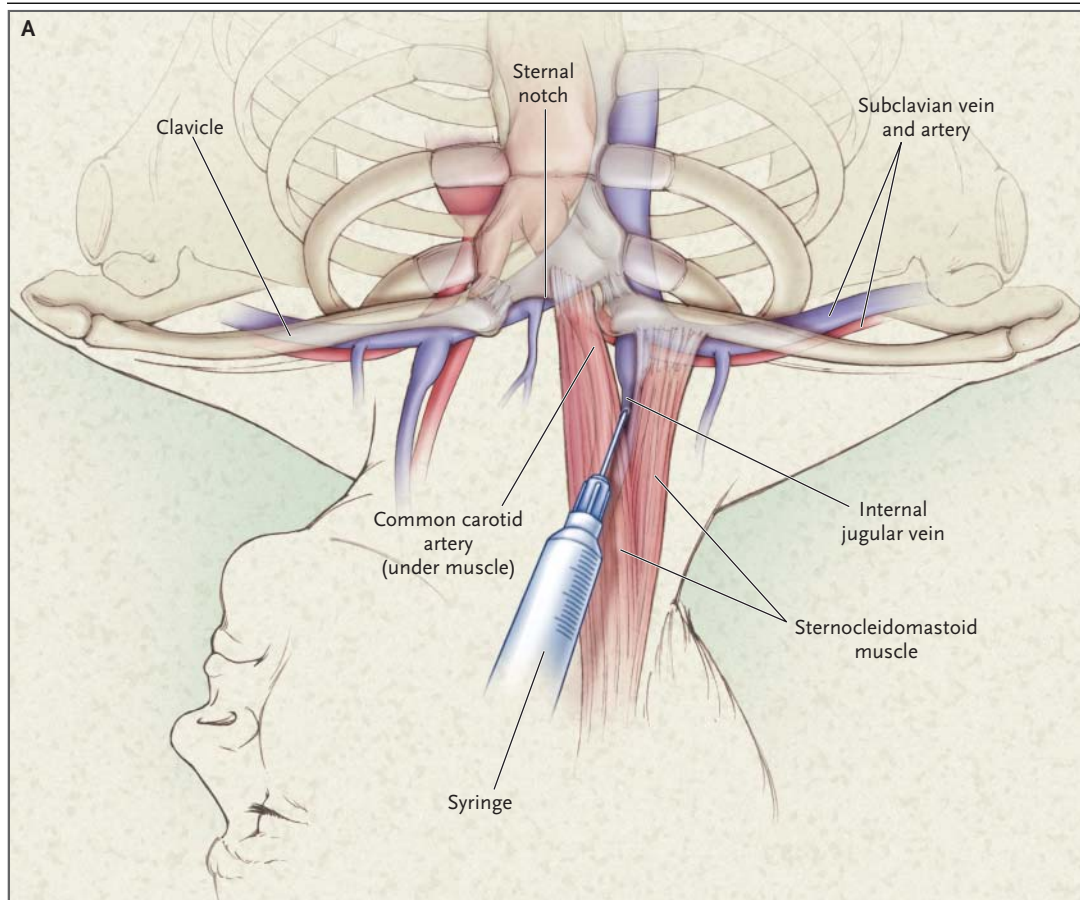
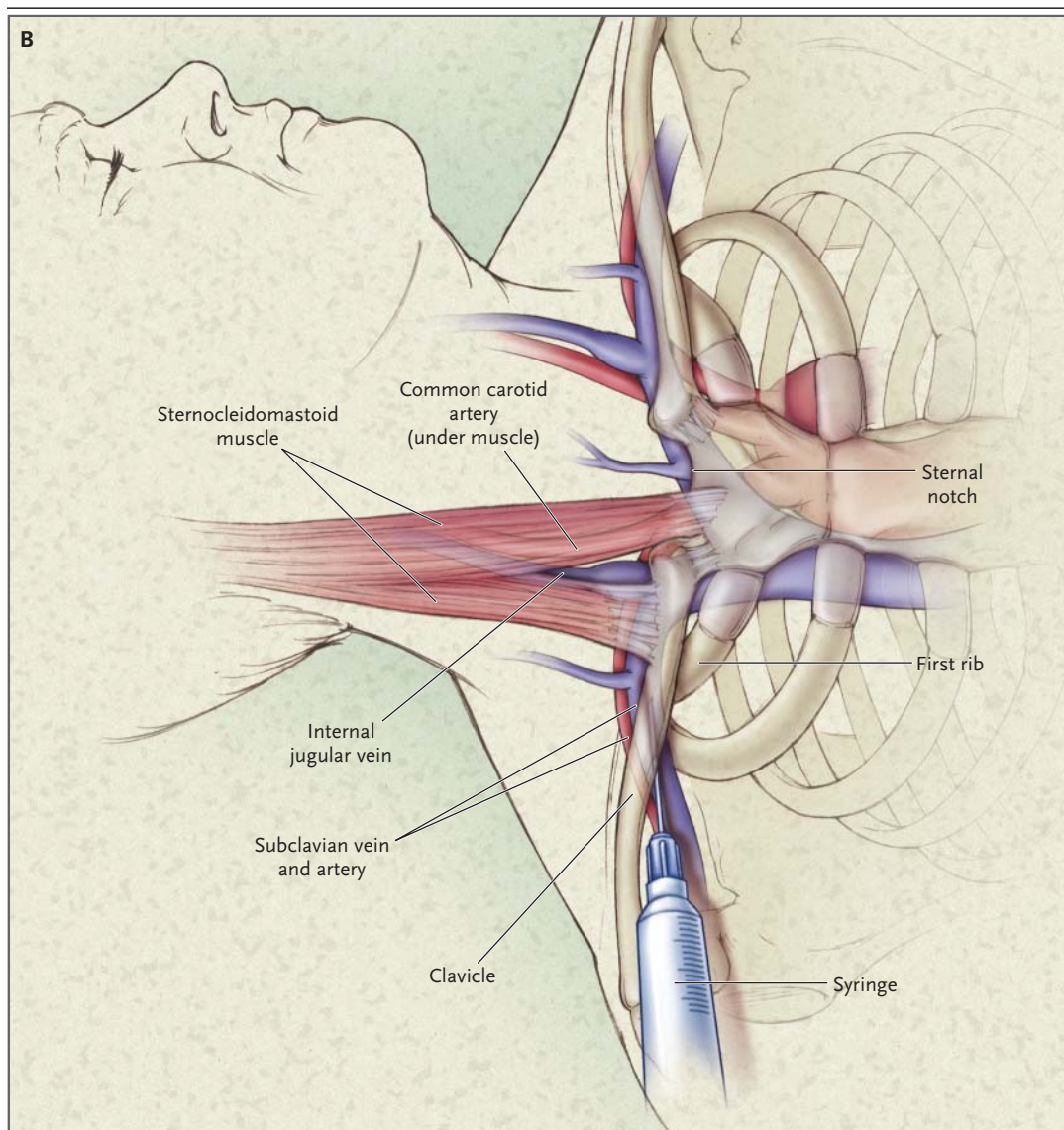


Figure 1. Technique for Catheterization at the Internal Jugular and Subclavian Sites.

In the central approach for internal jugular venous catheterization (Panel A), the apex of the triangle formed by the two heads of the sternocleidomastoid muscle and the clavicle serves as a landmark. The internal jugular vein runs deep to the sternocleidomastoid muscle and then through this triangle before it joins the subclavian vein to become the brachiocephalic vein. After the landmarks have been identified, sterile barriers have been prepared, and local anesthesia has been administered, the patient is placed in Trendelenburg's position with the head rotated 45 degrees away from the site of cannulation. The physician places the index and middle finger of his or her nondominant hand on the carotid artery and inserts a 22-gauge "finder" needle through the skin, immediately lateral to the carotid pulse and slightly superior to the apex of the triangle. The needle is advanced past the apex of the triangle, in the direction of the ipsilateral nipple, at an angle of 20 degrees above the plane of the skin. The vein is usually located near the surface of the skin and is often encountered after less than 0.5 in. (1.3 cm) of the needle has been inserted. If the first pass is unsuccessful, the needle should be directed slightly more medially on the next insertion attempt. With the finder needle in place, an 18-gauge introducer needle is then inserted alongside it and into the vein.

In the infraclavicular approach for subclavian venous catheterization (Panel B, facing page), the subclavian vein arises from the axillary vein at the point where it crosses the lateral border of the first rib. It is usually 1 to 2 cm in diameter and is fixed in position directly beneath the clavicle. It is separated from the subclavian artery by the anterior scalene muscle. For catheterization, the patient is placed in Trendelenburg's position, and a small rolled towel is placed between the shoulder blades. After identification of the landmarks, sterile preparation, and administration of local anesthesia, the skin is punctured 2 to 3 cm caudal to the midpoint of the clavicle with an 18-gauge, 2.5-in. (6.3-cm) introducer needle. The needle is advanced in the direction of the sternal notch until the tip of the needle abuts the clavicle at the junction of its medial and middle thirds. The needle is then passed beneath the clavicle, with the needle hugging the inferior surface of the clavicle. If no blood returns with passage of the needle, the needle is withdrawn past the clavicle while gentle suction is applied. Blood return may be achieved during withdrawal of the needle. If the first pass is unsuccessful, the needle should be angled in a slightly more cephalad direction on the next insertion attempt.



INSERTION TECHNIQUE

PREPARATION

When inserting a catheter, one should use maximal sterile-barrier precautions, including a mask, a cap, a sterile gown, sterile gloves, and a large sterile drape. This approach has been shown to reduce the rate of catheter-related bloodstream infections and to save an estimated \$167 per catheter inserted.¹⁴ The use of chlorhexidine-based solutions for skin preparation may be preferable to the use of povidone-iodine solutions, because chlorhexidine reduces the risk of catheter colonization.^{35,36} A video that shows the insertion of catheters at the internal jugular and sub-

Table 2. Frequency of Mechanical Complications, According to the Route of Catheterization.*

Complication	Frequency		
	Internal Jugular	Subclavian percent	Femoral
Arterial puncture	6.3–9.4	3.1–4.9	9.0–15.0
Hematoma	<0.1–2.2	1.2–2.1	3.8–4.4
Hemothorax	NA	0.4–0.6	NA
Pneumothorax	<0.1–0.2	1.5–3.1	NA
Total	6.3–11.8	6.2–10.7	12.8–19.4

* Data are from Merrer et al.,⁵ Sznajder et al.,⁶ Mansfield et al.,⁸ Martin et al.,²² Durbec et al.,²³ and Timsit et al.²⁴ NA denotes not applicable.

Table 3. Types of Catheter-Associated Infections.*

Type	Description
Catheter colonization	Growth of organisms from a catheter segment by either semiquantitative or quantitative culture†
Catheter-related bloodstream infection	Isolation of the same organism from a blood culture and from a semiquantitative or quantitative culture of a catheter segment, accompanied by clinical symptoms of bloodstream infection without any other apparent source of infection‡
Exit-site infection	Erythema, tenderness, induration, or purulence within 2 cm of the exit site of the catheter

* Information is adapted from Pearson.⁴⁴

† In the semiquantitative culture technique,⁵⁷ the catheter segment is rolled on a culture plate, which is observed for colony formation; the growth of ≥ 15 colony-forming units defines colonization. In the quantitative technique,⁵⁸⁻⁶⁰ the catheter segment is processed in broth and sonicated, and the broth is surface-plated onto a culture plate; the growth of 1000 or more colony-forming units defines colonization.

‡ For the prediction of catheter-related bloodstream infections in patients without burns, the semiquantitative culture technique has a sensitivity of 86 percent, a specificity of 88 percent, a positive predictive value of 33 percent, and a negative predictive value of 99 percent.⁶⁰ The quantitative culture technique has a sensitivity of 89 percent, a specificity of 94 percent, a positive predictive value of 73 percent, and a negative predictive value of 98 percent.⁶⁰

clavian sites is available as Supplementary Appendix 1 with the full text of the article at <http://www.nejm.org>.

EXPERIENCE WITH CATHETERIZATION

As with most medical procedures, the level of experience of the physician reduces the risk of complications.^{6,37} Insertion of a catheter by a physician who has performed 50 or more catheterizations is half as likely to result in a mechanical complication as insertion by a physician who has performed fewer than 50 catheterizations.⁶ If a physician is unable to insert a catheter after three attempts, he or she should seek help rather than continue to attempt the procedure. The incidence of mechanical complications after three or more insertion attempts is six times the rate after one attempt.⁸

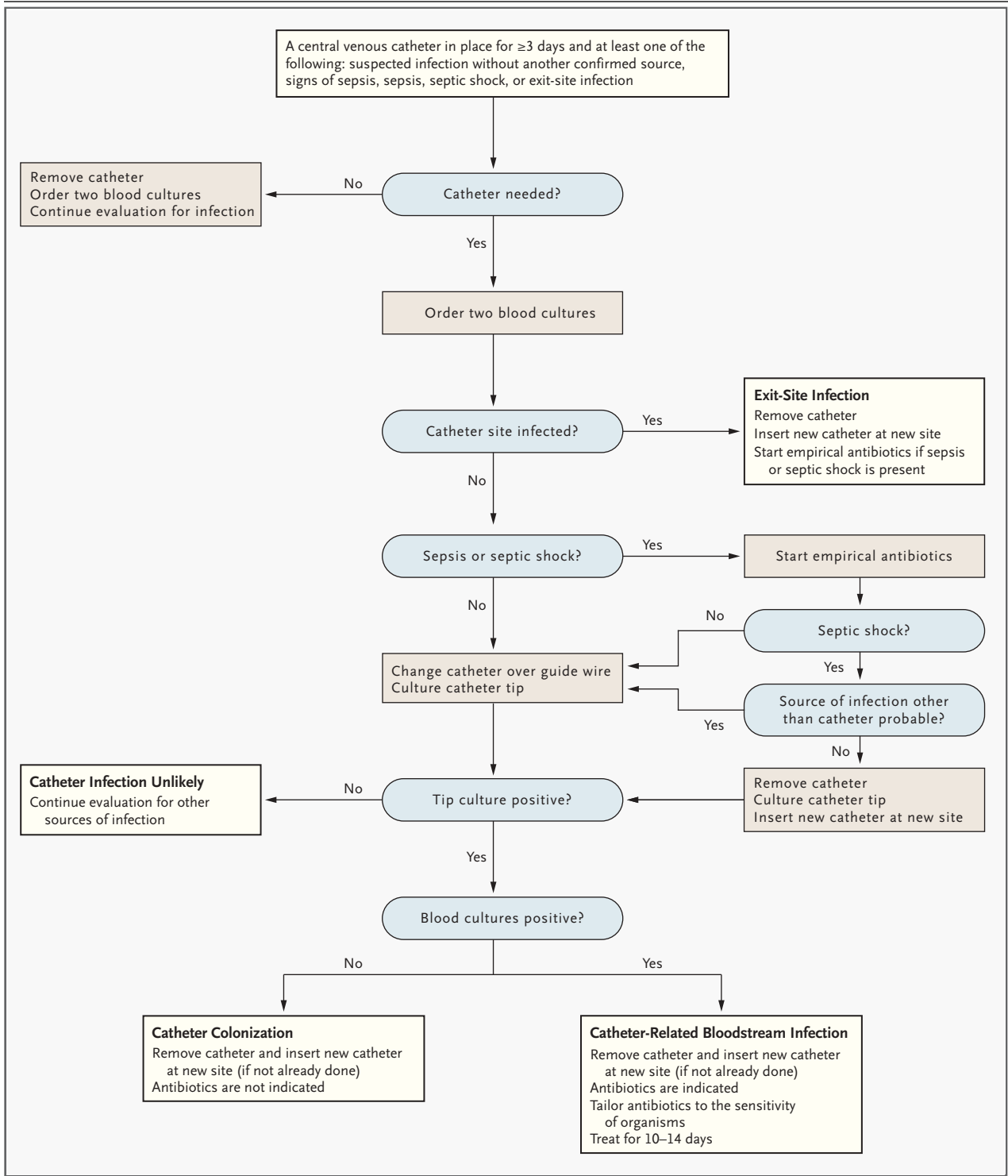
ULTRASOUND GUIDANCE

The use of ultrasound guidance has been promoted as a method for reducing the risk of complications during central venous catheterization. In this technique, an ultrasound probe is used to localize the vein and to measure its depth beneath the skin. Under ultrasound visualization, the introducer needle is then guided through the skin and into the vessel. During internal jugular venous catheterization, ultrasound guidance reduces the number of mechanical complications, the number of catheter-placement failures, and the time required for insertion.^{25,26} However, its use during subclavian venous catheterization has had mixed results in clinical trials,^{26,38,39} probably for anatomical reasons. The

fixed anatomical relation between the subclavian vein and the clavicle makes ultrasound-guided catheter insertion more difficult and less reliable than landmark-based insertion. As with all new techniques, ultrasound-guided catheterization requires training. In hospitals where ultrasound equipment

Figure 2 (facing page). Management of Suspected Catheter-Related Bloodstream Infection.

Sepsis is defined as a systemic response to infection, manifested by two or more of the following conditions: temperature above 38.5°C or below 36.0°C; heart rate above 90 beats per minute; respiratory rate above 20 breaths per minute or partial pressure of arterial carbon dioxide below 32 mm Hg; and white-cell count greater than 12,000 per cubic millimeter or less than 4000 per cubic millimeter or with 10 percent immature (band) forms.⁶¹ Septic shock is defined as sepsis-induced hypotension or a requirement for vasopressors or inotropic agents to maintain blood pressure despite adequate fluid resuscitation, along with the presence of perfusion abnormalities that may include (but are not limited to) lactic acidosis, oliguria, or acute alteration in mental status.⁶¹ When blood cultures are obtained, samples from peripheral sites are preferred. Catheter-tip cultures should be performed by the semiquantitative or quantitative technique.^{27,62,63} Empirical antibiotic therapy for suspected catheter-related bloodstream infection should include vancomycin. Antibiotics that are effective against gram-negative organisms should be added, especially if the patient is immunocompromised or has neutropenia, is infected with gram-negative organisms, or has other risk factors for infection with gram-negative organisms. In patients with a catheter-related bloodstream infection, treatment for more than 14 days is indicated in patients with endocarditis (duration of treatment, 4 to 6 weeks) or *Staphylococcus aureus* bacteremia (2 to 3 weeks).⁶⁴



is available and physicians have adequate training, the use of ultrasound guidance should be routinely considered for cases in which internal jugular venous catheterization will be attempted.

RECOGNITION OF ARTERIAL PUNCTURE AND PREVENTION OF AIR EMBOLISM

In a patient with normal blood pressure and normal arterial oxygen tension, arterial puncture is usually easy to identify by the pulsatile flow into the syringe and the bright-red color of the blood. However, in patients with profound hypotension or marked arterial desaturation, these findings may not be present. If there is any doubt as to whether the introducer needle is in the artery or the vein, an 18-gauge, single-lumen catheter (included in most kits) should be inserted over the wire and into the vessel. This step does not require the use of a dilator. This catheter can then be connected to a pressure transducer to confirm the presence of venous waveforms and venous pressure. Simultaneous samples for measurement of blood gases can then be drawn, one from the catheter and another from an artery. There should be a substantial difference in the oxygen tension if the catheter is located in a vein.

A spontaneously breathing patient generates negative intrathoracic pressure during inspiration. If a catheter is open to room air, this negative intrathoracic pressure can draw air into the vein, resulting in air embolism. Even small amounts of air can be fatal, especially if transmitted to the systemic circulation through an atrial or ventricular septal defect. To prevent this complication, catheter hubs should be occluded at all times, and the patient should be placed in Trendelenburg's position during insertion. If air embolism occurs, the patient should be placed in Trendelenburg's position with a left lateral decubitus tilt to prevent the movement of air into the right ventricular outflow tract. One hundred percent oxygen should be administered to speed the resorption of the air. If a catheter is located in the heart, aspiration of the air should be attempted.

PROPHYLACTIC ANTIBIOTICS

Most studies of the use of prophylactic antibiotics have demonstrated that this strategy is associated with reductions in the rate of catheter-related bloodstream infections.⁴⁰⁻⁴² However, this use of antibiotics is discouraged because of concern that it will encourage the emergence of antibiotic-resistant organisms.⁴³

MAINTENANCE OF THE INSERTION SITE

OINTMENTS, SUBCUTANEOUS CUFFS, AND DRESSINGS

Application of antibiotic ointments (e.g., bacitracin, mupirocin, neomycin, and polymyxin) to catheter-insertion sites increases the rate of catheter colonization by fungi,¹⁵ promotes the emergence of antibiotic-resistant bacteria,¹⁶ and has not been shown to lower the rate of catheter-related bloodstream infections.¹⁷ These ointments should not be used.⁴⁴ Likewise, the use of silver-impregnated subcutaneous cuffs has not been shown to reduce the incidence of catheter-related bloodstream infections and therefore is not recommended.^{15,45,46} Because there are conflicting data on the optimal type of dressing (gauze vs. transparent material)^{47,48} and the optimal frequency of dressing changes,^{49,50} evidence-based recommendations cannot be made.

HUBS AND NEEDLELESS ACCESS DEVICES

Catheter hubs are a common source of contamination,¹⁸ especially during prolonged catheterization.⁵¹ The use of two types of antiseptic-containing hub has been shown to decrease the risk of catheter-related bloodstream infections.^{52,53} In some hospitals, the introduction of needleless access devices has been linked to an increase in the rate of these infections.^{54,55} In one instance, this increase was due to a high rate of noncompliance with the manufacturer's recommendations to change the end cap with each use and to change the device every three days.⁵⁴ In another, more frequent hub changes were required before the rate of catheter-related bloodstream infection returned to base line.⁵⁵

CATHETER MAINTENANCE

Every catheter should be removed as soon as it is no longer needed, since the probability of catheter-related infections increases over time. The risks of catheter colonization and catheter-related bloodstream infection are low until the fifth to seventh days of catheterization, at which time the risks increase.^{9,10,21} Multiple trials have tested strategies for reducing the risk of catheter-related infections, including scheduled, routine replacement of catheters by exchange over a guide wire and scheduled, routine replacement at a new site. However, none of these strategies have been shown to decrease

the rate of catheter-related bloodstream infections.^{19,20,56} In fact, scheduled, routine exchanges of catheters over a guide wire are associated with a trend toward an increased rate of catheter-related infections.¹⁹ Furthermore, the more frequently a catheter is replaced with a new catheter at a new site, the more likely it is that the patient will have a mechanical complication during insertion.^{19,27} A meta-analysis of 12 randomized trials of catheter-replacement strategies concluded that the data do not support either scheduled, routine exchange of catheters over a guide wire or scheduled, routine replacement at a new site.¹⁹ Accordingly, central venous catheters should not be replaced on a scheduled basis.⁴⁴

SUSPECTED CATHETER-RELATED BLOODSTREAM INFECTION

Even with optimal efforts to prevent infectious complications of central venous catheterization, catheter-associated infections will develop in some patients (Table 3). In any patient who has a central venous catheter, symptoms and signs of infection without another confirmed source should raise the concern that the catheter may be the source of the infection (Fig. 2). Once a catheter-associated infection is suspected, two samples of blood should be drawn for culture to evaluate the possibility of bacteremia. Two cultures of blood from peripheral sites should be evaluated because it is difficult to determine whether a positive culture of blood from a central venous catheter indicates contamination of the hub, catheter colonization, or a catheter-related

bloodstream infection.^{65,66} However, a negative culture from a catheter indicates that the presence of a catheter-related bloodstream infection is unlikely.⁶⁷

The catheter site should be examined carefully. If there is any purulence or erythema, an exit-site infection is likely, and the catheter needs to be removed. If the patient has signs of either sepsis or septic shock, empirical antibiotic therapy should be begun to treat *Staphylococcus epidermidis* or *S. aureus* infections. Antibiotic therapy for gram-negative organisms should be added, especially if the patient is immunocompromised or has neutropenia or has other risk factors for infection with gram-negative organisms. The catheter should be changed over a guide wire.^{56,62,63} This technique reduces the number of insertion-related complications and is safe, even in patients with sepsis, as long as antibiotic therapy has been initiated.^{56,63} In patients who have septic shock and no other source of infection, the catheter should be removed and replaced with a new one at a new site.

If a culture of the catheter tip is positive, the patient has either catheter colonization or a catheter-related bloodstream infection, and a catheter that was replaced over a guide wire should be removed. If the catheter-tip culture is negative, then catheter colonization and catheter-related bloodstream infection are unlikely, and efforts should be made to identify another source of infection.

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