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U.S. DISTRICT COURT
N.D. OF ALABAMA

IN THE UNITED STATES DISTRICT COURT
FOR THE NORTHERN DISTRICT OF ALABAMA
SOUTHERN DIVISION

DOYLE LEE HAMM,	]	
	]	
Plaintiff,	]	
	]	
v.	]	
	]	
JEFFERSON S DUNN, COMMISSIONER, ALABAMA DEPARTMENT OF CORRECTIONS; CYNTHIA STEWART, WARDEN, HOLMAN CORRECTIONAL FACILITY; LEON BOLLING, III, WARDEN, DONALDSON CORRECTIONAL FACILITY; OTHER UNKNOWN EMPLOYEES AND AGENTS, ALABAMA DEPARTMENT OF CORRECTIONS	]	**2:17-cv-02083-KOB**
	]	
Defendants.	]	

MEMORANDUM OPINION AND ORDER

As Chief Justice Roberts and Justice Alito have written, "because it is settled that capital punishment is constitutional, '[i]t necessarily follows that there must be a [constitutional] means of carrying it out.'" *Glossip v. Gross*, 135 S. Ct. 2726, 2732–33 (2015) (Alito, J.) (quoting *Baze v. Rees*, 553 U.S. 35, 47 (2008) (Roberts, C.J.) (plurality opinion)). Guided by that principle, the court has taken steps to ensure, as far as possible, that the execution of Doyle Lee Hamm meets constitutional standards.

Now, the court must rule on Plaintiff Doyle Hamm's request for a preliminary injunction enjoining Defendants from executing him using intravenous lethal injection. Mr. Hamm bears the burden of showing a substantial likelihood of success on the merits of his claim that Alabama's method of execution, *as applied to him*, "presents a risk that is sure or very likely to cause serious illness and needless suffering, and give rise to sufficiently imminent dangers."

Glossip, 135 S. Ct. at 2737 (quotation marks omitted). If Mr. Hamm can make that showing, *then* he must identify "an alternative that is feasible, readily implemented, and in fact significantly reduces a substantial risk of severe pain." *Id.* (quotation marks and alterations omitted).

Mr. Hamm contends that his current medical condition, caused by years of intravenous drug use, hepatitis C, and untreated lymphoma, renders his veins severely compromised, and that any attempt to insert an intravenous catheter into his peripheral veins could result in numerous painful sticks and/or infiltration of the lethal drugs into the surrounding tissue, causing a painful and gruesome death. And he asserts that he suffers from untreated lymphadenopathy, which would hinder Alabama's alternative method of placing a central line into one of the major veins located in his groin, chest, or neck. He seeks, instead, to have the State execute him by "oral injection" using the drugs and a variation on the procedure set out in Oregon's Death with Dignity Act. *See* Or. Rev. Stat. §§ 127.800–127.897.

On February 6, 2018, this court denied Defendants' motion for summary judgment on Mr. Hamm's amended complaint and stayed his execution "for the purpose of obtaining an independent medical examination and opinion concerning the current state of Mr. Hamm's lymphoma, the number and quality of peripheral venous access, and whether any lymphadenopathy would affect efforts at obtaining central line access." (Doc. 31 at 2). Defendants appealed this court's order and on February 13, 2018, the Eleventh Circuit vacated the stay, holding that this court had not made "sufficient factual findings to establish a significant possibility of success on the merits." (Doc. 38 at 8). The Court directed this court "to immediately appoint an independent medical examiner and schedule an independent medical examination, and to thereafter make any concomitant factual findings—pursuant to a hearing or

otherwise—by no later than Tuesday, February 20, 2018, at 5:00 p.m. Central Standard Time." (*Id.* at 11–12).

On February 15, 2018, the court appointed a physician as its independent medical examiner and ordered him to conduct a medical examination of Mr. Hamm, specifically the condition of his peripheral and central veins.[1] (Doc. 48). The court ordered the physician to report to the court the results of that examination and to advise the court on the standard of care used to place a central line. (*Id.*). The physician conducted the examination on the same day, and attorneys from both sides observed the examination. The physician's examination included viewing Mr. Hamm's veins, palpating them, and using an ultrasound to view the internal veins, organs, and lymph nodes. *See* Appendix A (Medical Report). As the court had requested, the physician made an oral report to the court in the evening of February 15, shortly after finishing the examination.

The medical expert reported that Mr. Hamm has numerous accessible and usable veins in both his upper and lower extremities. But he stated that the peripheral veins in Mr. Hamm's upper extremities, while accessible, are smaller and more difficult to access. The veins in Mr. Hamm's lower extremities—particularly from his knees down—are palpable, visible, and easily accessible, and further, the accessible veins in Mr. Hamm's lower extremities are of sufficient size to accept a catheter and substantial flow of liquid. Although he observed nodes in Mr. Hamm's groin area, he found that they would not impede access to the femoral vein. He commented that Mr. Hamm has "zero lymphadenopathy." He concluded that all of Mr. Hamm's central and deep veins are clear. In short, the physician found no likely problems obtaining

[1] For the reasons that the court explained on the record at the February 16, 2018 conference with the parties, the court sealed all information regarding the identity of the physician appointed as the court's independent medical expert. Because his identity must remain confidential, the court will not refer to him by name.

venous access on Mr. Hamm, particularly using the veins in his lower extremities. Because of the results of the examination, the court did not inquire as to the standard of care for starting a central line IV.

The next day, February 16, the court held a conference with the parties and counsel, which had originally been scheduled to have testimony concerning the Alabama Department of Corrections' lethal injection procedures. The court began the conference by relaying the oral report from the court's medical expert. The court advised the parties that the medical expert's report resolved the concerns regarding the status of Mr. Hamm's veins and lymphadenopathy. The court asked if Defendants would stipulate they would not attempt peripheral venous access in Mr. Hamm's upper extremities; they agreed to so stipulate.

The court then found that the medical evidence negated any need to delve further into Alabama's lethal injection protocol. Nothing about Mr. Hamm's condition, especially because of Defendants' stipulation, "presents a risk that [Alabama's current lethal injection protocol as applied to him] is sure or very likely to cause serious illness and needless suffering, and give rise to sufficiently imminent dangers." *Glossip*, 135 S. Ct. at 2737 (quotation marks omitted).

And given the medical expert's report that Mr. Hamm is not experiencing lymphadenopathy, the court determined that further inquiry into the procedure for obtaining central venous access would convert his as-applied challenge into a facial challenge to the lethal injection protocol. As the court found in its memorandum opinion on Defendants' motion for summary judgment, a facial challenge to Alabama's lethal injection protocol would be time-barred because such a claim accrued in 2002 and the statute of limitations on it expired in 2004. (*See* Doc. 30 at 13).

Mr. Hamm's counsel stated numerous objections on the record, which the court overruled.

The court promised counsel that it would forward the medical expert's report to them as soon as it received it. On February 19, 2018, the physician sent his written report to the court, and the court forwarded it to the parties.[2] The written report elaborates on the physician's oral report to the court with more technical analysis of Mr. Hamm's veins. The written report determines that Mr. Hamm has accessible and usable veins in his upper and lower extremities. But it further determines that the veins in Mr. Hamm's upper extremities would be accessible only by an advanced practitioner, such as a CRNA, PA, or MD, using an ultrasound. *See* Appendix A at 14.

The written report concludes:

> Mr. Hamm has accessible peripheral veins in the following regions.
>
> 1. Right great saphenous vein below the level of the knee. The vein is palpable from the medial aspect of the right knee to the anterior portion of the medial malleolus.
>
> 2. Left great saphenous vein below the level of the knee. The vein is palpable from the medial aspect of the left knee to the anterior portion of the medial malleolus.
>
> 3. Right and left internal jugular veins as well as the right and left subclavian veins and the right and left femoral veins. Access of these veins would require ultrasound guidance to perform and an advanced level practitioner would be required. (CRNA, PA or M.D.)
>
> 4. There are no veins in either the left or right upper extremities which would be readily accessible for venous access without difficulty.
>
> 5. Given the accessibility of the peripheral veins listed above, it is my medical opinion that cannulation of the central veins will not be necessary to obtain venous access.

Id. The court accepts the medical expert's written report.

[2] To maintain the privacy of the physician, a redacted report is filed as Attachment A with this memorandum opinion and order. The court will file the original report under seal.

With the record now more fully developed concerning Mr. Hamm's medical condition, the court again considers whether he established the prerequisites for a preliminary injunction. "The same four-part test applies when a party seeks a preliminary injunction [as when a party seeks a stay of execution]." *Grayson v. Warden*, 869 F.3d 1204, 1239 n.90 (11th Cir. 2017). The movant must show that "(1) he has a substantial likelihood of success on the merits; (2) he will suffer irreparable injury unless the injunction issues; (3) the stay would not substantially harm the other litigant; and (4) if issued, the injunction would not be adverse to the public interest."[3] *Valle v. Singer*, 655 F.3d 1223, 1225 (11th Cir. 2011).

As more fully stated on the record at the February 16 conference, the court finds that Mr. Hamm has failed to show a substantial likelihood of success on the merits or that he will suffer irreparable injury unless the injunction issues. Mr. Hamm based his as-applied complaint on the allegations that he lacks adequate peripheral veins to allow peripheral venous access, and that his lymphadenopathy would hinder central venous access. But, as the court stated on the record at the February 16 conference, based on the independent medical examiner's report about Mr. Hamm's venous access and lack of lymphadenopathy, and based on Defendants' stipulation that they will not attempt peripheral venous access in Mr. Hamm's upper extremities, the court finds that Mr. Hamm has adequate peripheral *and* central venous access for intravenous lethal injection of a large amount of fluid. He cannot show any medical factors that would make the Alabama lethal injection protocol, as applied to him, more likely to violate the Eighth Amendment than it would for any other inmate who would be executed following that protocol.

[3] The Supreme Court has added that a court deciding whether to enjoin an execution must apply "a strong equitable presumption against the grant of a stay where a claim could have been brought at such a time as to allow consideration of the merits without requiring entry of a stay." *Hill v. McDonough*, 547 U.S. 573, 584 (2006) (quotation marks omitted). This court already found that Mr. Hamm brought his request for an injunction in a timely manner, and the Eleventh Circuit agreed. (*See* Doc. 30 at 13–18, 24; Doc. 38 at 4–7). The court will not address that factor again.

As a result, Mr. Hamm cannot show a substantial likelihood of success on the merits of his as-applied claim. For the same reasons, he cannot show that he will suffer irreparable injury without a preliminary injunction. Therefore the court DENIES Mr. Hamm's request for a preliminary injunction.

DONE and **ORDERED** this 20th day of February, 2018.

Karon O. Bowdre

KARON OWEN BOWDRE
CHIEF UNITED STATES DISTRICT JUDGE

APPENDIX A

Examination Date February 16, 2018

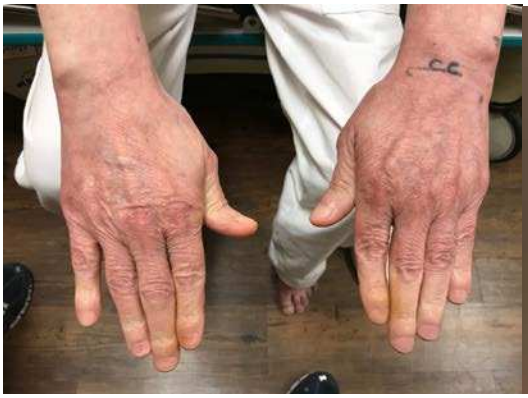
Patient Mr. Doyle Hamm

I examined Mr. Doyle Hamm strictly with regards to his venous system, both deep and superficial in both upper and lower extremities.. Mr Hamm was visually examined along with palpation of his veins. A ultrasound was performed to document the size and patency of his veins. Mr. Hamm's medical records, that were provided, were reviewed.. He has a significant history of hepatitis C and lymphoma of the left orbit. He was previously examined on 1/3/18 by a CRNP with regards to venous access. He was found at that time, to have large straight saphenous veins in both lower extremities and both of his feet. He was documented as having visible veins in the right wrist as well.. No cervical, supraclavicular or axillary lymphadenopathy was palpated.

The examination of his veins on 2/16/18 was performed in both a sitting as well as standing position. There were two parts to his examination. First, visual inspection along with palpation of both the left and right upper and lower extremities as well as the neck and feet. Second, a venous ultrasound examination of both the left and right upper and lower extremities, axillary, subclavian and jugular veins was performed.

Examination of the upper extremities:

Visual and Palpation. As can be seen from the Photos A and B, there are no prominent superficial veins on visual examination on the upper extremities including the left and right arm, forearm and hands. There are no prominent superficial veins visible that would support an IV of sufficient size to administer intravenous fluids. The examination included the palmar and volar aspects of the hand, wrist, forearm, the antecubital fossa and arms.



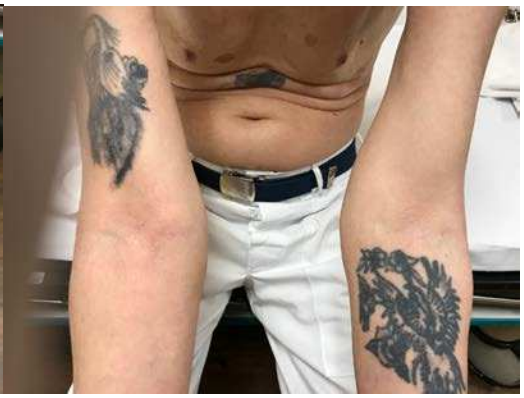
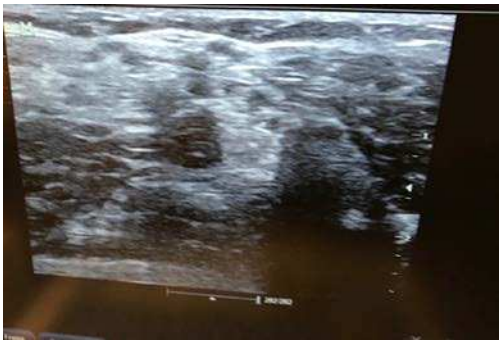


Photo A Photo B

Ultrasound examination of the upper extremities. Technique: Using a 6.0 -7.5 MHz probe, a real-time gray scale sonography was performed with and without transducer compression along the course of the basilic vein, the axillary vein, the subclavian vein and the internal jugular vein. Color doppler was also applied with and without distal compression maneuvers. Select spot images were saved. Ultrasound examination of the left and right antecubital fossa did reveal the basilic vein and it was readily visualized with ultrasound. These veins were of adequate size but would be very difficult to access without the use of ultrasound. See photos C and D.



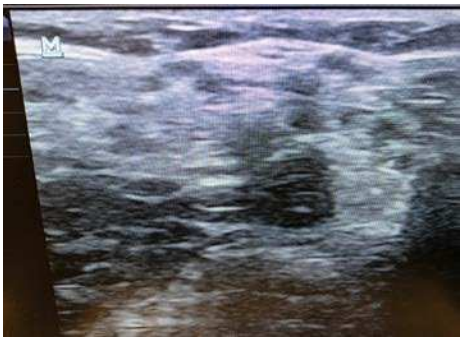


Photo C Left Basilic Vein Photo D Right Basilic Vein

The more proximal veins including the left and right axillary veins, the left and right subclavian veins and the left and right internal jugular veins were easily identified and compressible representing

excellent flow and no proximal obstruction. There was no lymphadenopathy present in either left or right axilla, supraclavicular or cervical regions present on ultrasound. See photos E,F,G,H,I and J.

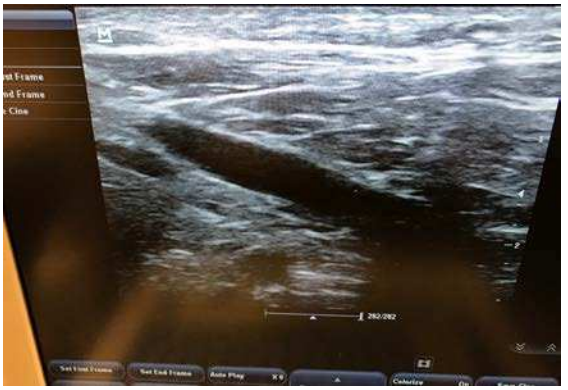


Photo E Left Axillary Vein

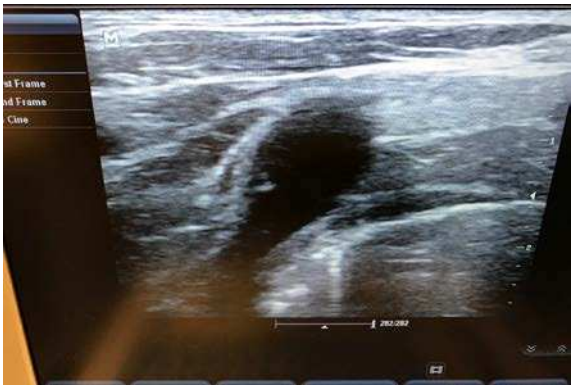


Photo F Left Subclavian Vein

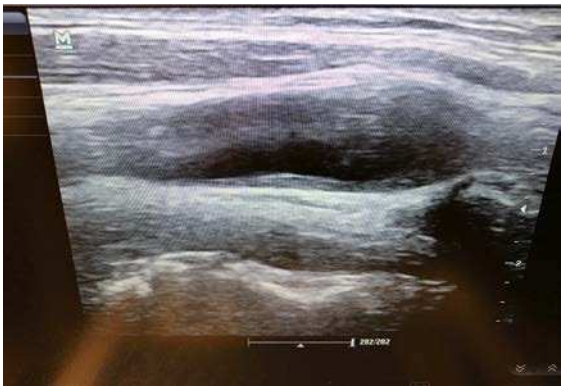


Photo G Left Internal Jugular Vein

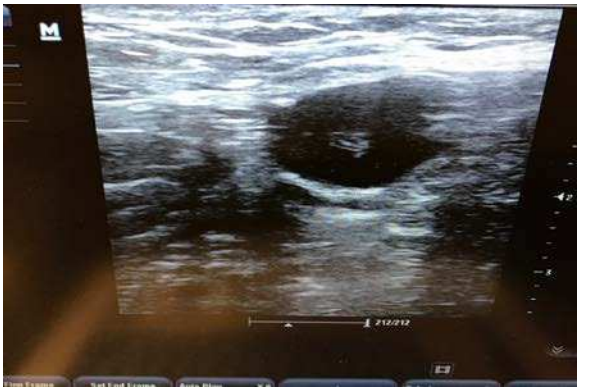


Photo H Right Axillary Vein

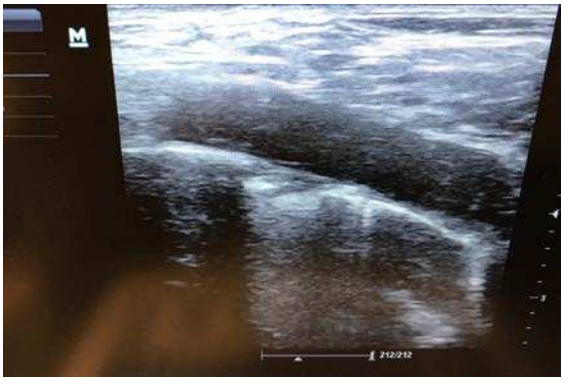


Photo I Right Subclavian Vein

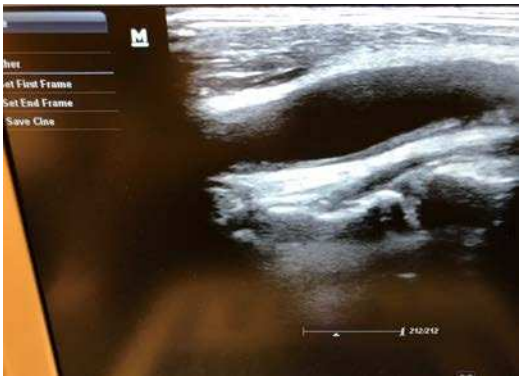


Photo J Right Internal Jugular Vein

Examination of the lower extremities.

Visual and Palpation. It should be noted that both Mr. Hamm's lower extremities, left and right side, were hyperpigmented consistent with venous stasis. No edema in the lower extremities was seen. No secondary varicose veins were identified. The right leg has both an easily seen and palpable great saphenous vein which extends from just below the medial aspect of the right knee to anterior to the medial malleolus. The left leg has a great saphenous vein which is seen (not as easily as the right leg) and is palpable from just below the medial aspect of the left knee to anterior to the medial malleolus. See photos K and L.

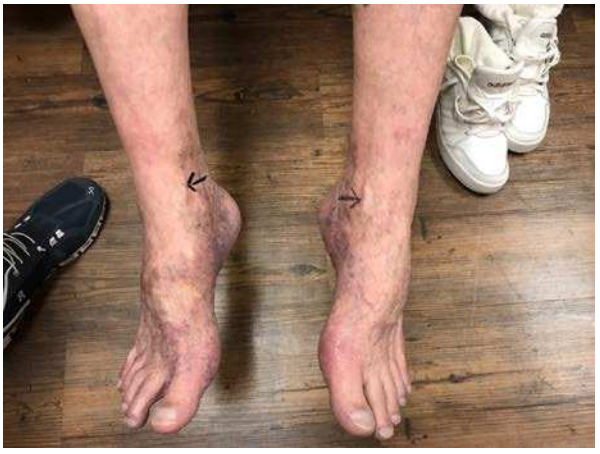


Photo K

Photo L

Ultrasound examination. Technique: Using a 6.0-7.5 MHz probe, a real-time gray scale sonography was performed with and without transducer compression along the course of the femoral vein, the popliteal vein, the great saphenous vein and small saphenous vein. The examination was performed with the patient in the standing position.. Doppler was also applied with and without distal compression maneuvers. Select spot images were saved.

Findings. Right side. The right great saphenous vein has venous valvular insufficiency.The right great saphenous vein measures 6.0 millimeters at the saphenofemoral junction, 5.8 millimeters at the mid thigh level, 4.7 millimeters at the knee level and 5.4 millimeters at the mid calf level.There were two lymph nodes identified at the level of the right groin but do not impede venous flow. The right small saphenous

vein is competent. The right small saphenous vein measures 2.0 millimeters at the saphenopopliteal junction and 2.2 millimeters at the mid calf region. There is no evidence of deep venous thrombosis, reflux or obstruction in the deep venous system. There is no edema present. See photos N, O, P, Q, R and S.

Photo N GSV Right Mid Calf

Photo O GSV Right Knee

Photo P GSV Right Mid Thigh

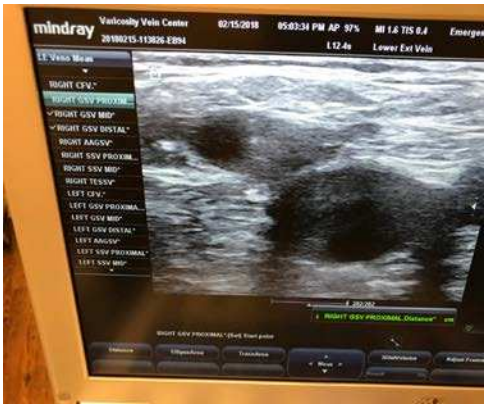


Photo Q GSV Proximal

Photo R Right Inguinal Lymph Nodes

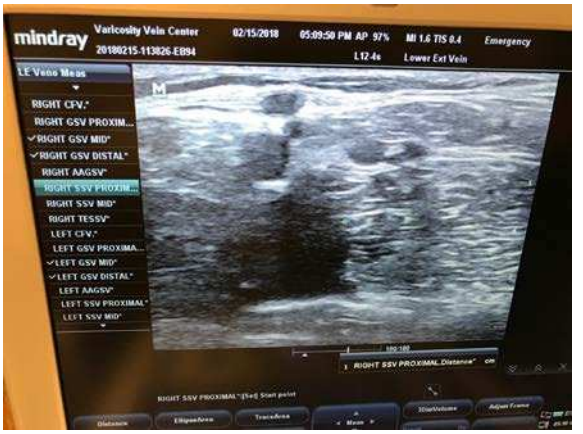


Photo S Right Small Saphenous Vein

Findings. Left side. The left great saphenous vein has venous valvular insufficiency. The left great saphenous vein measures 5.6 millimeter at the saphenofemoral junction, 3.4 millimeters at the mid thigh, 2.5 millimeters at the knee and 2.5 millimeters at the mid calf region. The left small saphenous vein is competent.. The left small saphenous vein measures 4.2 millimeters at the saphenopopliteal junction and 3.4 millimeters at the mid calf region. There are no lymph nodes present in the left inguinal region. There is no evidence of deep venous thrombosis, reflux or obstruction in t the deep venous system. See photos T, U, V, and X..

Photo T Left Distal GSV

Photo U Left GSV Mid Thigh

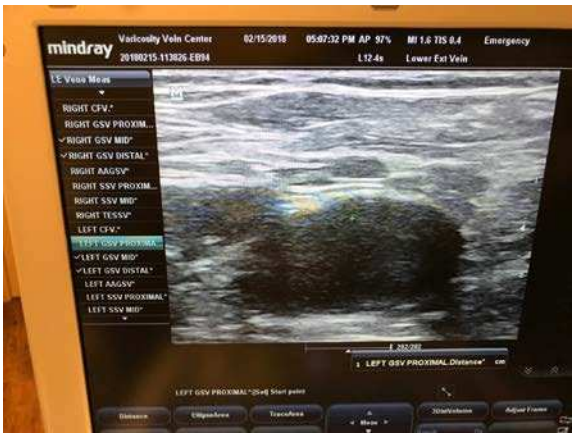


Photo V Left Proximal GSV

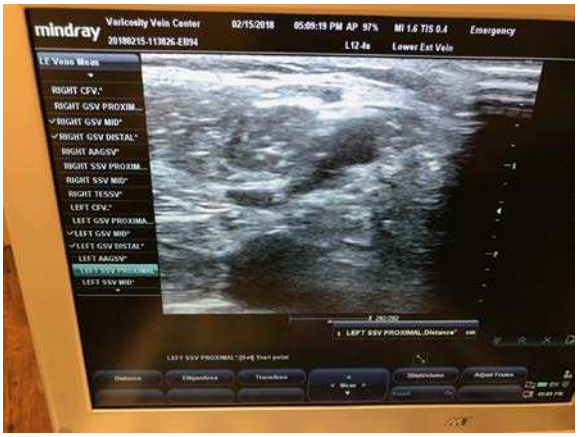


Photo W Left Small Saphenous Vein

In summary, Mr. Hamm has accessible peripheral veins in the following regions.

1. Right great saphenous vein below the level of the knee. The vein is palpable from the medial aspect of the right knee to the anterior portion of the medial malleolus.

2. Left great saphenous vein below the level of the knee. The vein is palpable from the medial aspect of the left knee to the anterior portion of the medial malleolus.

3. Right and left internal jugular veins as well as the right and left subclavian veins and the right and left femoral veins. Access of these veins would require ultrasound guidance to perform and an advanced level practitioner would be required. (CRNA, PA or M.D.)

4. There are no veins in either the left or right upper extremities which would be readily accessible for venous access without difficulty.

5. Given the accessibility of the peripheral veins listed above, it is my medical opinion that cannulation of the central veins will not be necessary to obtain venous access.

[redacted], M.D.

Practice Guidelines for Central Venous Access

A Report by the American Society of Anesthesiologists Task Force on Central Venous Access

PRACTICE Guidelines are systematically developed recommendations that assist the practitioner and patient in making decisions about health care. These recommenda- tions may be adopted, modified, or rejected according to clinical needs and constraints, and are not intended to re- place local institutional policies. In addition, Practice Guide- lines developed by the American Society of Anesthesiologists (ASA) are not intended as standards or absolute require- ments, and their use cannot guarantee any specific outcome. Practice Guidelines are subject to revision as warranted by the evolution of medical knowledge, technology, and prac- tice. They provide basic recommendations that are sup- ported by a synthesis and analysis of the current literature, expert and practitioner opinion, open forum commentary, and clinical feasibility data.

- What other guideline statements are available on this topic?

X Several major organizations have produced practice guidelines on central venous access[128–132]

- Why was this Guideline developed?

X The ASA has created this new Practice Guideline to provide updated recommendations on some issues and new recommendations on issues that have not been previously addressed by other guidelines. This was based on a rigorous evaluation of recent scientific literature as well as findings from surveys of expert consultants and randomly selected ASA members

- How does this statement differ from existing guidelines?

X The ASA Guidelines differ in areas such as insertion site selection (*e.g.*, upper body site) guidance for catheter place- ment (*e.g.*, use of real-time ultrasound) and verification of venous location of the catheter

- Why does this statement differ from existing guidelines?

X The ASA Guidelines differ from existing guidelines because it addresses the use of bundled techniques, use of an as- sistant during catheter placement, and management of ar- terial injury

Methodology

A. Definition of Central Venous Access

For these Guidelines, central venous access is defined as placement of a catheter such that the catheter is inserted into a venous great vessel. The venous great vessels include the superior vena cava, inferior vena cava, brachiocephalic veins, internal jugular veins, subclavian veins, iliac veins, and common femoral veins.* Excluded are catheters that terminate in a systemic artery.

B. Purposes of the Guidelines

The purposes of these Guidelines are to (1) provide guidance regarding placement and management of central venous catheters, (2) reduce infectious, mechanical, thrombotic, and other adverse outcomes associated with central venous catheterization, and (3) improve management of arterial trauma or injury arising from central venous catheterization.

C. Focus

These Guidelines apply to patients undergoing elective cen- tral venous access procedures performed by anesthesiologists or health care professionals under the direction/supervision of anesthesiologists. The Guidelines do not address (1) clin- ical indications for placement of central venous catheters, (2) emergency placement of central venous catheters, (3) patients with peripherally inserted central catheters, (4) placement and residence of a pulmonary artery catheter, (5) insertion of tunneled central lines (*e.g.*, permacaths, portacaths,

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Developed by the American Society of Anesthesiologists Task Force on Central Venous Access: Stephen M. Rupp, M.D., Seattle, Washington (Chair); Jeffrey L. Apfelbaum, M.D., Chicago, Illinois; Casey Blitt, M.D., Tucson, Arizona; Robert A. Caplan, M.D., Seattle, Washington; Richard T. Connis, Ph.D., Woodinville, Washington; Karen B. Domino, M.D., M.P.H., Seattle, Washington; Lee A. Fleisher, M.D., Philadelphia, Pennsylvania; Stuart Grant, M.D., Durham, North Carolina; Jonathan B. Mark, M.D., Durham, North Carolina; Jeffrey P. Morray, M.D., Paradise Valley, Arizona; David G. Nickinovich, Ph.D., Bellevue, Washington; and Avery Tung, M.D., Wilmette, Illinois.

Received from the American Society of Anesthesiologists, Park Ridge, Illinois. Submitted for publication October 20, 2011. Accepted for publication October 20, 2011. Supported by the American Society of Anesthesiologists and developed under the direction of the Committee on Standards and Practice Parameters, Jeffrey L. Apfelbaum, M.D. (Chair). Approved by the ASA House of Delegates on October 19, 2011. Endorsed by the Society of Cardiovascular Anesthesiologists, October 4, 2010; the Society of Critical Care Anesthesiologists March 16, 2011; the Society of Pediatric Anesthesia March 29, 2011. A complete list of references used to develop these updated Guidelines, arranged alphabetically by author, is available as Supplemental Digital Content 1, http://links.lww.com/ALN/A783.

Address correspondence to the American Society of Anesthesi- ologists: 520 North Northwest Highway, Park Ridge, Illinois 60068- 2573. These Practice Guidelines, as well as all ASA Practice Param- eters, may be obtained at no cost through the Journal Web site, www.anesthesiology.org.

* This description of the venous great vessels is consistent with the venous subset for central lines defined by the National Health- care Safety Network (NHSN).

 Anesthesiology 2012; 116:539–73

Hickman®, Quinton®, (6) methods of detection or treat- ment of infectious complications associated with central ve- nous catheterization, or (7) diagnosis and management of central venous catheter-associated trauma or injury (*e.g.*, pneumothorax or air embolism), with the exception of ca- rotid arterial injury.

D. Application

These Guidelines are intended for use by anesthesiologists and individuals who are under the supervision of an anes- thesiologist. They also may serve as a resource for other physicians (*e.g.*, surgeons, radiologists), nurses, or health care providers who manage patients with central venous catheters.

E. Task Force Members and Consultants

The ASA appointed a Task Force of 12 members, including anesthesiologists in both private and academic practice from various geographic areas of the United States and two con- sulting methodologists from the ASA Committee on Stan- dards and Practice Parameters.

The Task Force developed the Guidelines by means of a seven- step process. First, they reached consensus on the cri- teria for evidence. Second, original published research stud- ies from peer-reviewed journals relevant to central venous access were reviewed and evaluated. Third, expert consul- tants were asked to (1) participate in opinion surveys on the effectiveness of various central venous access recommenda- tions and (2) review and comment on a draft of the Guide- lines. Fourth, opinions about the Guideline recommenda- tions were solicited from a sample of active members of the ASA. Opinions on selected topics related to pediatric pa- tients were solicited from a sample of active members of the Society for Pediatric Anesthesia (SPA). Fifth, the Task Force held open forums at three major national meetings† to solicit input on its draft recommendations. Sixth, the consultants were surveyed to assess their opinions on the feasibility of implementing the Guidelines. Seventh, all available informa- tion was used to build consensus within the Task Force to finalize the Guidelines. A summary of recommendations may be found in appendix 1.

F. Availability and Strength of Evidence

Preparation of these Guidelines followed a rigorous meth- odologic process. Evidence was obtained from two principal sources: scientific evidence and opinion-based evidence.

Scientific Evidence

Study findings from published scientific literature were ag- gregated and are reported in summary form by evidence cat- egory, as described in the following paragraphs. All literature (*e.g.*, randomized controlled trials, observational studies, case reports) relevant to each topic was considered when evaluat- ing the findings. However, for reporting purposes in this document, only the highest level of evidence (*i.e.*, level 1, 2, or 3 within category A, B, or C, as identified in the following paragraphs) is included in the summary.

Category A: Supportive Literature

Randomized controlled trials report statistically significant ($P < 0.01$) differences between clinical interventions for a specified clinical outcome.

Level 1: The literature contains multiple randomized con- trolled trials, and aggregated findings are supported by meta- analysis.‡

Level 2: The literature contains multiple randomized con- trolled trials, but the number of studies is insuffi- cient to conduct a viable meta-analysis for the pur- pose of these Guidelines.

Level 3: The literature contains a single randomized con- trolled trial.

Category B: Suggestive Literature

Information from observational studies permits inference of beneficial or harmful relationships among clinical interven- tions and clinical outcomes.

Level 1: The literature contains observational comparisons (*e.g.*, cohort, case-control research designs) of clin- ical interventions or conditions and indicates statis- tically significant differences between clinical inter- ventions for a specified clinical outcome.

Level 2: The literature contains noncomparative observa- tional studies with associative (*e.g.*, relative risk, correlation) or descriptive statistics.

Level 3: The literature contains case reports.

Category C: Equivocal Literature

The literature cannot determine whether there are beneficial or harmful relationships among clinical interventions and clinical outcomes.

Level 1: Meta-analysis did not find significant differences ($P > 0.01$) among groups or conditions.

Level 2: The number of studies is insufficient to conduct meta-analysis, and (1) randomized controlled trials have not found significant differences among groups or conditions or (2) randomized controlled trials report inconsistent findings.

Level 3: Observational studies report inconsistent findings or do not permit inference of beneficial or harmful relationships.

† Society for Pediatric Anesthesia Winter Meeting, April 17, 2010, San Antonio, Texas; Society of Cardiovascular Anesthesia 32nd Annual Meeting, April 25, 2010, New Orleans, Louisiana, and Inter- national Anesthesia Research Society Annual Meeting, May 22, 2011, Vancouver, British Columbia, Canada.

‡ All meta-analyses are conducted by the ASA methodology group. Meta-analyses from other sources are reviewed but not included as evidence in this document.

Category D: Insufficient Evidence from Literature

The lack of scientific evidence in the literature is described by the following terms:

Inadequate: The available literature cannot be used to assess relationships among clinical interventions and clinical outcomes. The literature either does not meet the criteria for content as defined in the "Fo- cus" of the Guidelines or does not permit a clear interpretation of findings due to methodologic con- cerns (*e.g.*, confounding in study design or imple- mentation).

Silent: No identified studies address the specified relation- ships among interventions and outcomes.

Opinion-based Evidence

All opinion-based evidence relevant to each topic (*e.g.*, survey data, open-forum testimony, Internet-based comments, letters, editori- als) is considered in the development of these Guidelines. However, only the findings obtained from formal surveys are reported.

Opinion surveys were developed by the Task Force to address each clinical intervention identified in the docu- ment. Identical surveys were distributed to expert consul- tants and ASA members, and a survey addressing selected pediatric issues was distributed to SPA members.

Category A: Expert Opinion

Survey responses from Task Force-appointed expert consultants are reported in summary form in the text, with a complete listing of consultant survey responses reported in appendix 5.

Category B: Membership Opinion

Survey responses from active ASA and SPA members are reported in summary form in the text, with a complete listing of ASA and SPA member survey responses reported in appendix 5.

Survey responses are recorded using a 5-point scale and summarized based on median values.§

Strongly Agree. Median score of 5 (at least 50% of the responses are 5).

Agree. Median score of 4 (at least 50% of the responses are 4 or 4 and 5).

Equivocal. Median score of 3 (at least 50% of the responses are 3, or no other response category or com- bination of similar categories contain at least 50% of the responses).

Disagree. Median score of 2 (at least 50% of responses are 2 or 1 and 2).

Strongly Disagree. Median score of 1 (at least 50% of responses are 1).

Category C: Informal Opinion

Open-forum testimony, Internet-based comments, letters, and editorials are all informally evaluated and discussed dur- ing the development of Guideline recommendations. When warranted, the Task Force may add educational information or cautionary notes based on this information.

Guidelines

I. Resource Preparation

Resource preparation includes (1) assessing the physical environment where central venous catheterization is planned to determine the feasibility of using aseptic techniques, (2) availabil- ity of a standardized equipment set, (3) use of an assistant for central venous catheterization, and (4) use of a checklist or pro- tocol for central venous catheter placement and maintenance.

The literature is insufficient to specifically evaluate the effect of the physical environment for aseptic catheter inser- tion, availability of a standardized equipment set, or the use of an assistant on outcomes associated with central venous catheterization (*Category D evidence*). An observational study reports that the implementation of a trauma intensive care unit multidisciplinary checklist is associated with reduced catheter-related infection rates (*Category B2 evidence*).[1] Observational studies report reduced catheter-related bloodstream infection rates when intensive care unit-wide bundled protocols are implemented (*Category B2 evidence*).[2–7] These studies do not permit the assessment of the effect of any single component of a checklist or bundled protocol on outcome. The Task Force notes that the use of checklists in other specialties or professions has been effective in reducing the error rate for a complex series of activities.[8,9]

The consultants and ASA members strongly agree that cen- tral venous catheterization should be performed in a location that permits the use of aseptic techniques. The consultants and ASA members strongly agree that a standardized equipment set should be available for central venous access. The consultants and ASA members agree that a trained assistant should be used during the placement of a central venous catheter. The ASA members agree and the consultants strongly agree that a check- list or protocol should be used for the placement and mainte- nance of central venous catheters.

Recommendations for Resource Preparation. Central venous catheterization should be performed in an environment that permits use of aseptic techniques. A standardized equipment set should be available for central venous access.‖ A checklist or protocol should be used for placement and maintenance of central venous catheters.# An assistant should be used during placement of a central venous catheter.**

§ When an equal number of categorically distinct responses are obtained, the median value is determined by calculating the arith- metic mean of the two middle values. Ties are calculated by a predetermined formula.

‖ Refer to appendix 2 for an example of a list of standardized equipment for adult patients.

Refer to appendix 3 for an example of a checklist or protocol.

** Refer to appendix 4 for an example of a list of duties per- formed by an assistant.

II. Prevention of Infectious Complications

Interventions intended to prevent infectious complications associated with central venous access include, but are not limited to (1) intravenous antibiotic prophylaxis, (2) aseptic techniques (*i.e.*, practitioner aseptic preparation and patient skin preparation), (3) selection of coated or impregnated catheters, (4) selection of catheter insertion site, (5) catheter fixation method, (6) insertion site dressings, (7) catheter maintenance procedures, and (8) aseptic techniques using an existing central venous catheter for injection or aspiration.

Intravenous Antibiotic Prophylaxis. Randomized controlled trials indicate that catheter-related infections and sepsis are reduced when prophylactic intravenous antibiotics are administered to high-risk immunosuppressed cancer patients or neonates. (*Category A2 evidence*).[10,11] The literature is insufficient to evaluate outcomes associated with the routine use of intravenous antibiotics (*Category D evidence*).

The consultants and ASA members agree that intravenous antibiotic prophylaxis may be administered on a case-by-case basis for immunocompromised patients or high-risk neonates. The consultants and ASA members agree that intravenous antibiotic prophylaxis should not be administered routinely.

Recommendations for Intravenous Antibiotic Prophylaxis. For immunocompromised patients and high-risk neonates, administer intravenous antibiotic prophylaxis on a case-by-case basis. Intravenous antibiotic prophylaxis should not be administered routinely.

Aseptic Preparation and Selection of Antiseptic Solution

Aseptic preparation of practitioner, staff, and patients: A randomized controlled trial comparing maximal barrier precautions (*i.e.*, mask, cap, gloves, gown, large full-body drape) with a control group (*i.e.*, gloves and small drape) reported equivocal findings for reduced colonization (P 0.03) and catheter-related septicemia (P 0.06) (*Category C2 evidence*).[12] The literature is insufficient to evaluate the efficacy of specific aseptic activities (*e.g.*, hand washing) or barrier precautions (*e.g.*, sterile full-body drapes, sterile gown, gloves, mask, cap) (*Category D evidence*). Observational studies report hand washing, sterile full-body drapes, sterile gloves, caps, and masks as elements of care "bundles" that result in reduced catheter-related bloodstream infections (*Category B2 evidence*).[2–7] However, the degree to which each particular element contributed to improved outcomes could not be determined.

Most consultants and ASA members indicated that the following aseptic techniques should be used in preparation for the placement of central venous catheters: hand washing (100% and 96%); sterile full-body drapes (87.3% and 73.8%); sterile gowns (100% and 87.8%), gloves (100% and 100%), caps (100% and 94.7%), and masks covering both the mouth and nose (100% and 98.1%).

Selection of Antiseptic Solution

Chlorhexidine solutions: A randomized controlled trial comparing chlorhexidine (2% aqueous solution without alcohol) with 10% povidone iodine (without alcohol) for skin preparation reports equivocal findings regarding catheter colonization (P 0.013) and catheter-related bacteremia (P 0.28) (*Category C2 evidence*).[13] The literature is insufficient to evaluate chlorhexidine with alcohol compared with povidone-iodine with alcohol (*Category D evidence*). The literature is insufficient to evaluate the safety of antiseptic solutions containing chlorhexidine in neonates, infants and children (*Category D evidence*).

Solutions containing alcohol: Comparative studies are insufficient to evaluate the efficacy of chlorhexidine with alcohol in comparison with chlorhexidine without alcohol for skin preparation during central venous catheterization (*Category D evidence*). A randomized controlled trial of povidone-iodine with alcohol indicates that catheter tip colonization is reduced when compared with povidone-iodine alone (*Category A3 evidence*); equivocal findings are reported for catheter-related infection (P 0.04) and clinical signs of infection (P 0.09) (*Category C2 evidence*).[14]

The consultants and ASA members strongly agree that chlorhexidine with alcohol should be used for skin preparation. SPA members are equivocal regarding whether chlorhexidine-containing solutions should be used for skin preparation in neonates (younger than 44 gestational weeks); they agree with the use of chlorhexidine in infants (younger than 2 yr) and strongly agree with its use in children (2–16 yr).

Recommendations for Aseptic Preparation and Selection of Antiseptic Solution

In preparation for the placement of central venous catheters, use aseptic techniques (*e.g.*, hand washing) and maximal barrier precautions (*e.g.*, sterile gowns, sterile gloves, caps, masks covering both mouth and nose, and full-body patient drapes). A chlorhexidine-containing solution should be used for skin preparation in adults, infants, and children; for neonates, the use of a chlorhexidine-containing solution for skin preparation should be based on clinical judgment and institutional protocol. If there is a contraindication to chlorhexidine, povidone-iodine or alcohol may be used. Unless contraindicated, skin preparation solutions should contain alcohol.

Catheters Containing Antimicrobial Agents. Meta-analysis of randomized controlled trials[15–19] comparing antibiotic-coated with uncoated catheters indicates that antibiotic-coated catheters reduce catheter colonization (*Category A1 evidence*). Meta-analysis of randomized controlled trials[20–24]

comparing silver-impregnated catheters with uncoated cath- eters report equivocal findings for catheter-related blood- stream infection (*Category C1 evidence*); randomized con- trolled trials were equivocal regarding catheter colonization (P 0.16 – 0.82) (*Category C2 evidence*).[20–22,24] Meta-anal- yses of randomized controlled trials[25–36] demonstrate that catheters coated with chlorhexidine and silver sulfadiazine reduce catheter colonization (*Category A1 evidence*); equivo- cal findings are reported for catheter-related bloodstream in- fection (*i.e.,* catheter colonization and corresponding posi- tive blood culture) (*Category C1 evidence*).[25–27,29–35,37,38] Cases of anaphylactic shock are reported after placement of a catheter coated with chlorhexidine and silver sulfadiazine (*Category B3 evidence*).[39–41]

Consultants and ASA members agree that catheters coated with antibiotics or a combination of chlorhexidine and silver sulfadiazine may be used in selected patients based on infectious risk, cost, and anticipated duration of catheter use.

Recommendations for Use of Catheters Containing Antimicrobial Agents. Catheters coated with antibiotics or a combination of chlorhexidine and silver sulfadiazine should be used for selected patients based on infectious risk, cost, and anticipated duration of catheter use. The Task Force notes that catheters containing antimicrobial agents are not a substitute for additional infection precautions.

Selection of Catheter Insertion Site. A randomized con- trolled trial comparing the subclavian and femoral insertion sites report higher levels of catheter colonization with the femoral site (*Category A3 evidence*); equivocal findings are reported for catheter-related sepsis (P 0.07) (*Category C2 evidence*).[42] A randomized controlled trial comparing the in- ternal jugular insertion site with the femoral site reports no difference in catheter colonization (P 0.79) or catheter related bloodstream infections (P 0.42) (*Category C2 evi- dence*).[43] Prospective nonrandomized comparative studies are equivocal (*i.e.,* inconsistent) regarding catheter-related colonization[44–46] and catheter related bloodstream infec- tion[46–48] when the internal jugular site is compared with the subclavian site (*Category C3 evidence*). A nonrandomized comparative study of burn patients reports that catheter col- onization and bacteremia occur more frequently the closer the catheter insertion site is to the burn wound (*Category B1 evidence*).[49]

Most consultants indicate that the subclavian insertion site is preferred to minimize catheter-related risk of infec- tion. Most ASA members indicate that the internal jugular insertion site is preferred to minimize catheter-related risk of infection. The consultants and ASA members agree that femoral catheterization should be avoided when pos- sible to minimize the risk of infection. The consultants and ASA members strongly agree that an insertion site should be selected that is not contaminated or potentially contaminated.

Recommendations for Selection of Catheter Insertion Site. Catheter insertion site selection should be based on clinical need. An insertion site should be selected that is not contaminated or potentially contaminated (*e.g.,* burned or infected skin, inguinal area, adjacent to tracheostomy or open surgical wound). In adults, selection of an upper body insertion site should be considered to minimize the risk of infection.

Catheter Fixation. The literature is insufficient to evaluate whether catheter fixation with sutures, staples or tape is associated with a higher risk for catheter-related infections (*Category D evidence*).

Most consultants and ASA members indicate that use of sutures is the preferred catheter fixation technique to minimize catheter-related infection.

Recommendations for Catheter Fixation. The use of sutures, staples, or tape for catheter fixation should be determined on a local or institutional basis.

Insertion Site Dressings. The literature is insufficient to evaluate the efficacy of transparent bio-occlusive dressings to reduce the risk of infection (*Category D evidence*). Randomized controlled trials are equivocal (P 0.04–0.96) regarding catheter tip colonization[50,51] and inconsistent (P 0.004 – 0.96) regarding catheter-related blood- stream infection[50,52] when chlorhexidine sponge dressings are compared with standard polyurethane dressings (*Cate- gory C2 evidence*). A randomized controlled trial is also equiv- ocal regarding catheter tip colonization for silver-impreg- nated transparent dressings compared with standard dressings (P > 0.05) (*Category C2 evidence*).[53] A randomized controlled trial reports a greater frequency of severe localized contact dermatitis when neonates receive chlorhexidine-im- pregnated dressings compared with povidone-iodine impregnated dressings (*Category A3 evidence*).[54]

The ASA members agree and the consultants strongly agree that transparent bio-occlusive dressings should be used to protect the site of central venous catheter insertion from infection. The consultants and ASA members agree that dressings containing chlorhexidine may be used to reduce the risk of catheter-related infection. SPA members are equivocal regarding whether dressings containing chlorhexidine may be used for skin preparation in neonates (younger than 44 gestational weeks); they agree that the use of dressings containing chlorhexidine may be used in infants (younger than 2 yr) and children (2–16 yr).

Recommendations for Insertion Site Dressings. Transpar- ent bio-occlusive dressings should be used to protect the site of central venous catheter insertion from infection.

Unless contraindicated, dressings containing chlorhexidine may be used in adults, infants, and children. For neonates, the use of transparent or sponge dressings containing chlorhexidine should be based on clinical judgment and institutional protocol.

Catheter Maintenance. Catheter maintenance consists of (1) determining the optimal duration of catheterization, (2) conducting catheter site inspections, (3) periodically changing catheters, and (4) changing catheters using a guidewire instead of selecting a new insertion site.

Nonrandomized comparative studies indicate that longer catheterizations are associated with higher rates of catheter colonization, infection, and sepsis (*Category B2 evidence*).[45,55] The literature is insufficient to evaluate whether specified time intervals between catheter site inspections are associated with a higher risk for catheter-related infection (*Category D evidence*). Randomized controlled trials report equivocal findings (P 0.54 – 0.63) regarding differences in catheter tip colonizations when catheters are changed at 3- *versus* 7-day intervals (*Category C2 evidence*).[56,57] Meta-analysis of randomized controlled trials[58–62] report equivocal findings for catheter tip colonization when guidewires are used to change catheters compared with the use of new insertion sites (*Category C1 evidence*).

The ASA members agree and the consultants strongly agree that the duration of catheterization should be based on clinical need. The consultants and ASA members strongly agree that (1) the clinical need for keeping the catheter in place should be assessed daily; (2) catheters should be promptly removed when deemed no longer clinically necessary; (3) the catheter site should be inspected daily for signs of infection and changed when infection is suspected; and (4) when catheter infection is suspected, replacing the catheter using a new insertion site is preferable to changing the catheter over a guidewire.

Recommendations for Catheter Maintenance. The duration of catheterization should be based on clinical need. The clinical need for keeping the catheter in place should be assessed daily. Catheters should be removed promptly when no longer deemed clinically necessary. The catheter insertion site should be inspected daily for signs of infection, and the catheter should be changed or removed when catheter insertion site infection is suspected. When a catheter related infection is suspected, replacing the catheter using a new insertion site is preferable to changing the catheter over a guidewire.

Aseptic Techniques Using an Existing Central Venous Catheter for Injection or Aspiration

Aseptic techniques using an existing central venous catheter for injection or aspiration consist of (1) wiping the port with an appropriate antiseptic, (2) capping stopcocks or access ports, and (3) use of needleless catheter connectors or access ports.

The literature is insufficient to evaluate whether wiping ports or capping stopcocks when using an existing central venous catheter for injection or aspiration is associated with a reduced risk for catheter-related infections (*Category D evidence*). Randomized controlled trials comparing needleless connectors with standard caps indicate decreased levels of microbial contamination of stopcock entry ports with needleless connectors (*Category A2 evidence*);[63,64] no differences in catheter-related bloodstream infection are reported (P 0.3–0.9) (*Category C2 evidence*).[65,66]

The consultants and ASA members strongly agree that catheter access ports should be wiped with an appropriate antiseptic before each access. The consultants and ASA members agree that needleless ports may be used on a case-by-case basis. The consultants and ASA members strongly agree that central venous catheter stopcocks should be capped when not in use.

Recommendations for Aseptic Techniques Using an Existing Central Line. Catheter access ports should be wiped with an appropriate antiseptic before each access when using an existing central venous catheter for injection or aspiration. Central venous catheter stopcocks or access ports should be capped when not in use. Needleless catheter access ports may be used on a case-by-case basis.

III. Prevention of Mechanical Trauma or Injury

Interventions intended to prevent mechanical trauma or injury associated with central venous access include, but are not limited to (1) selection of catheter insertion site, (2) positioning the patient for needle insertion and catheter placement, (3) needle insertion and catheter placement, and (4) monitoring for needle, guidewire, and catheter placement.

1. Selection of Catheter Insertion Site. A randomized controlled trial comparing the subclavian and femoral insertion sites reports that the femoral site had a higher frequency of thrombotic complications in adult patients (*Category A3 evidence*).[42] A randomized controlled trial comparing the internal jugular insertion site with the femoral site reports equivocal findings for arterial puncture (P 0.35), deep venous thrombosis (P 0.62) or hematoma formation (P 0.47) (*Category C2 evidence*).[43] A randomized controlled trial comparing the internal jugular insertion site with the subclavian site reports equivocal findings for successful venipuncture (P 0.03) (*Category C2 evidence*).[67] Nonrandomized comparative studies report equivocal findings for arterial puncture, pneumothorax, hematoma, hemothorax, or arrhythmia when the internal jugular insertion site is compared with the subclavian insertion site (*Category C3 evidence*).[68–76]

Most consultants and ASA members indicate that the internal jugular insertion site is preferred to minimize catheter cannulation-related risk of injury or trauma. Most consultants and ASA members also indicate that the internal jugular insertion site is preferred to minimize catheter-related risk of thromboembolic injury or trauma.

Recommendations for Catheter Insertion Site Selection. Catheter insertion site selection should be based on clinical need and practitioner judgment, experience, and

skill. In adults, selection of an upper body insertion site should be considered to minimize the risk of thrombotic complications.

2. Positioning the Patient for Needle Insertion and Catheter Placement. Nonrandomized studies comparing the Trendelenburg (*i.e.*, head down) position with the normal supine position indicates that the right internal jugular vein increases in diameter and cross-sectional area to a greater extent when adult patients are placed in the Trendelenburg position (*Category B2 evidence*).[71–76] One nonrandomized study comparing the Trendelenburg position with the normal supine position in pediatric patients reports an increase in right internal jugular vein diam- eter only for patients older than 6 yr (*Category B2 evidence*).[77]

The consultants and ASA members strongly agree that, when clinically appropriate and feasible, central vascular ac- cess in the neck or chest should be performed with the patient in the Trendelenburg position.

Recommendations for Positioning the Patient for Needle Insertion and Catheter Placement

When clinically appropriate and feasible, central venous ac- cess in the neck or chest should be performed with the patient in the Trendelenburg position.

3. Needle Insertion, Wire Placement, and Catheter Placement. Needle insertion, wire placement, and catheter placement includes (1) selection of catheter size and type, (2) use of a wire-through-thin-wall needle technique (*i.e.*, Seldinger tech- nique) *versus* a catheter-over-the-needle-then-wire-through- the-catheter technique (*i.e.*, modified Seldinger technique), (3) limiting the number of insertion attempts, and (4) introducing two catheters in the same central vein.

Case reports describe severe injury (*e.g.*, hemorrhage, he- matoma, pseudoaneurysm, arteriovenous fistula, arterial dis- section, neurologic injury including stroke, and severe or lethal airway obstruction) when there is unintentional ar- terial cannulation with large bore catheters (*Category B3 evidence*).[78–88] The literature is insufficient to evaluate whether the risk of injury or trauma is associated with the use of a thin-wall needle technique *versus* a catheter-over- the needle technique (*Category D evidence*). The literature is insufficient to evaluate whether the risk of injury or trauma is related to the number of insertion attempts (*Category D evidence*). One nonrandomized comparative study reports a higher frequency of dysrhythmia when two central venous catheters are placed in the same vein (right internal jugular) compared with placement of one cathe- ter in the vein (*Category B2 evidence*); no differences in carotid artery puncture (P 0.65) or hematoma (P 0.48) were noted (*Category C3 evidence*).[89]

The consultants agree and the ASA members strongly agree that the selection of catheter type (*i.e.*, gauge, length, number of lumens) and composition (*e.g.*, poly- urethane, Teflon) should be based on the clinical situation, and the skill and experience of the operator. The consultants and ASA members agree that the selection of a modified Seldinger technique *versus* a Seldinger technique should be based on the clinical situation and the skill and experience of the operator. The consultants and ASA members agree that the number of insertion attempts should be based on clinical judgment. The ASA members agree and the consultants strongly agree that the decision to place two central catheters in a single vein should be made on a case-by-case basis.

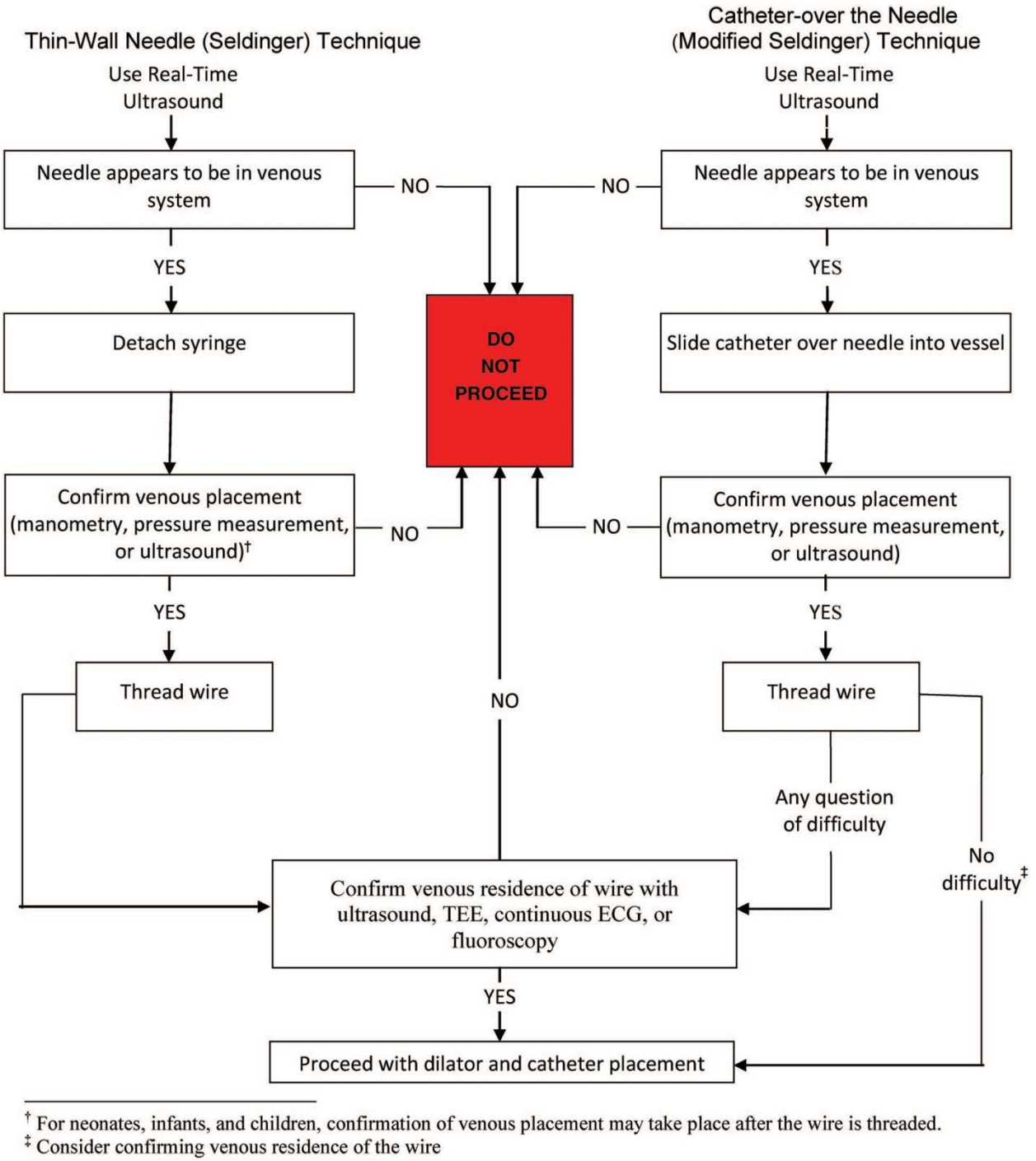
Recommendations for Needle Insertion, Wire Placement, and Catheter Placement. Selection of catheter size (*i.e.*, outside diameter) and type should be based on the clinical situation and skill/experience of the operator. Selection of the smallest size catheter appropriate for the clinical situation should be considered. Selection of a thin-wall needle (*i.e.*, Seldinger) technique *versus* a catheter-over-the-nee- dle (*i.e.*, modified Seldinger) technique should be based on the clinical situation and the skill/experience of the operator. The decision to use a thin-wall needle technique or a catheter-over-the-needle technique should be based at least in part on the method used to confirm that the wire resides in the vein before a dilator or large-bore catheter is threaded (fig. 1). The Task Force notes that the catheter- over-the-needle technique may provide more stable ve- nous access if manometry is used for venous confirmation. The number of insertion attempts should be based on clinical judgment. The decision to place two catheters in a single vein should be made on a case-by-case basis.

4. Guidance and Verification of Needle, Wire, and Catheter Placement. Guidance for needle, wire, and catheter placement includes ultrasound imaging for the purpose of prepuncture vessel localization (*i.e.*, static ultrasound) and ultrasound for vessel localization and guiding the needle to its intended venous location (*i.e.*, real time or dynamic ultrasound). Verification of needle, wire, or catheter location includes any one or more of the following methods: (1) ultrasound, (2) manometry, (3) pressure waveform analysis, (4) venous blood gas, (5) fluoroscopy, (6) continuous electrocardiography, (7) transesophageal echocardiography, and (8) chest radiography.

Guidance

Static Ultrasound. Randomized controlled trials comparing static ultrasound with the anatomic landmark approach for locating the internal jugular vein report a higher first insertion attempt success rate for static ultrasound (*Category A3 evidence*);[90] findings are equivocal regarding overall successful cannulation rates (P 0.025– 0.57) (*Category C2 evidence*).[90–92] In addition, the literature is equivocal regarding subclavian vein access (P 0.84) (*Category C2 evidence*) [93] and insufficient for femoral vein access (*Category D evidence*).

The consultants and ASA members agree that static ultra- sound imaging should be used in elective situations for pre- puncture identification of anatomy and vessel localization



† For neonates, infants, and children, confirmation of venous placement may take place after the wire is threaded.
‡ Consider confirming venous residence of the wire

Fig. 1. Algorithm for central venous insertion and verification. This algorithm compares the thin-wall needle (*i.e.*, Seldinger) technique *versus* the catheter-over-the needle (*i.e.*, Modified-Seldinger) technique in critical safety steps to prevent uninten- tional arterial placement of a dilator or largebore catheter. The variation between the two techniques reflects mitigation steps for the risk that the thin-wall needle in the Seldinger technique could move out of the vein and into the wall of an artery between the manometry step and the threading of the wire step. ECG electrocardiography; TEE transesophageal echocardiography.

when the internal jugular vein is selected for cannulation; they are equivocal regarding whether static ultrasound imaging should be used when the subclavian vein is selected. The consultants agree and the ASA members are equivocal regarding the use of static ultrasound imaging when the femoral vein is selected.

Real-time Ultrasound. Meta-analysis of randomized controlled trials[94–104] indicates that, compared with the anatomic landmark approach, real-time ultrasound guided venipuncture of the internal jugular vein has a higher first insertion attempt success rate, reduced access time, higher overall successful cannulation rate, and decreased

rates of arterial puncture (*Category A1 evidence*). Randomized controlled trials report fewer number of insertion attempts with real-time ultrasound guided venipuncture of the internal jugular vein (*Category A2 evidence*).[97,99,103,104]

For the subclavian vein, randomized controlled trials report fewer insertion attempts with real-time ultrasound guided veni- puncture (*Category A2 evidence*),[105,106] and one randomized clinical trial indicates a higher success rate and reduced access time, with fewer arterial punctures and hematomas compared with the anatomic landmark approach (*Category A3 evi- dence*).[106]

For the femoral vein, a randomized controlled trial re- ports a higher first-attempt success rate and fewer needle passes with real-time ultrasound guided venipuncture com- pared with the anatomic landmark approach in pediatric patients (*Category A3 evidence*).[107]

The consultants agree and the ASA members are equivocal that, when available, real time ultrasound should be used for guidance during venous access when either the internal jugular or femoral veins are selected for cannulation. The consultants and ASA members are equivocal regarding the use of real time ultrasound when the subclavian vein is selected.

Verification

Confirming that the Catheter or Thin-wall Needle Resides in the Vein. A retrospective observational study reports that manometry can detect arterial punctures not identified by blood flow and color (*Category B2 evidence*).[108] The literature is insuf- ficient to address ultrasound, pressure-waveform analysis, blood gas analysis, blood color, or the absence of pulsatile flow as effective methods of confirming catheter or thin-wall needle venous access (*Category D evidence*).

Confirming Venous Residence of the Wire. An observational study indicates that ultrasound can be used to confirm venous placement of the wire before dilation or final catheterization (*Category B2 evidence*).[109] Case reports indicate that transesoph- ageal echocardiography was used to identify guidewire position (*Category B3 evidence*).[110–112] The literature is insufficient to evaluate the efficacy of continuous electrocardiography in con- firming venous residence of the wire (*Category D evidence*), al- though narrow complex electrocardiographic ectopy is recog- nized by the Task Force as an indicator of venous location of the wire. The literature is insufficient to address fluoroscopy as an effective method to confirm venous residence of the wire (*Cat- egory D evidence*); the Task Force believes that fluoroscopy may be used.

Confirming Residence of the Catheter in the Venous Sys- tem. Studies with observational findings indicate that fluo- roscopy[113,115] and chest radiography[115–125] are useful in identifying the position of the catheter tip (*Category B2 evi- dence*). Randomized controlled trials indicate that continu- ous electrocardiography is effective in identifying proper catheter tip placement compared with not using electrocar- diography (*Category A2 evidence*).[115,126,127]

The consultants and ASA members strongly agree that before insertion of a dilator or large- bore catheter over a wire, venous access should be confirmed for the catheter or thin- wall needle that accesses the vein. The Task Force be- lieves that blood color or absence of pulsatile flow should not be relied upon to confirm venous access. The consultants agree and ASA members are equivocal that venous access should be confirmed for the wire that subsequently resides in the vein after traveling through a catheter or thin-wall needle before insertion of a dilator or large-bore catheter over a wire. The consultants and ASA members agree that, when feasible, both the location of the catheter or thin-wall needle and wire should be confirmed.

The consultants and ASA members agree that a chest radiograph should be performed to confirm the location of the catheter tip as soon after catheterization as clinically ap- propriate. They also agree that, for central venous catheters placed in the operating room, a confirmatory chest radio- graph may be performed in the early postoperative period. The ASA members agree and the consultants strongly agree that, if a chest radiograph is deferred to the postoperative period, pressure waveform analysis, blood gas analysis, ultra- sound, or fluoroscopy should be used to confirm venous positioning of the catheter before use.

Recommendations for Guidance and Verification of Needle, Wire, and Catheter Placement

The following steps are recommended for prevention of me- chanical trauma during needle, wire, and catheter placement in elective situations:

- Use static ultrasound imaging before prepping and draping for prepuncture identification of anatomy to determine vessel localization and patency when the in- ternal jugular vein is selected for cannulation. Static ultrasound may be used when the subclavian or femoral vein is selected.
- Use real time ultrasound guidance for vessel localization and venipuncture when the internal jugular vein is selected for cannulation (see fig. 1). Real-time ultrasound may be used when the subclavian or femoral vein is selected. The Task Force recognizes that this approach may not be fea- sible in emergency circumstances or in the presence of other clinical constraints.
- After insertion of a catheter that went over the needle or a thin-wall needle, confirm venous access.†† Methods for confirming that the catheter or thin-wall needle resides in the vein include, but are not limited to, ultrasound, ma- nometry, pressure-waveform analysis, or venous blood gas measurement. Blood color or absence of pulsatile flow

†† For neonates, infants, and children, confirmation of venous placement may take place after the wire is threaded.

should not be relied upon for confirming that the catheter or thin-wall needle resides in the vein.

- When using the thin-wall needle technique, confirm venous residence of the wire after the wire is threaded. When using the catheter-over-the-needle technique, confirmation that the wire resides in the vein may not be needed (1) when the catheter enters the vein easily and manometry or pressure waveform measurement provides unambiguous confirmation of venous location of the catheter; and (2) when the wire passes through the catheter and enters the vein without difficulty. If there is any uncertainty that the catheter or wire resides in the vein, confirm venous residence of the wire after the wire is threaded. Insertion of a dilator or large-bore catheter may then proceed. Methods for confirming that the wire resides in the vein include, but are not limited to, ultrasound (identification of the wire in the vein) or transesophageal echocardiography (identification of the wire in the superior vena cava or right atrium), continuous electrocardiography (identification of narrow-complex ectopy), or fluoroscopy.
- After final catheterization and before use, confirm residence of the catheter in the venous system as soon as clinically appropriate. Methods for confirming that the catheter is still in the venous system after catheterization and before use include manometry or pressure waveform measurement.
- Confirm the final position of the catheter tip as soon as clinically appropriate. Methods for confirming the position of the catheter tip include chest radiography, fluoroscopy, or continuous electrocardiography. For central venous catheters placed in the operating room, perform the chest radiograph no later than the early postoperative period to confirm the position of the catheter tip.

IV. Management of Arterial Trauma or Injury Arising from Central Venous Catheterization

Case reports of adult patients with arterial puncture by a large bore catheter/vessel dilator during attempted central venous catheterization indicate severe complications (*e.g.*, cerebral infarction, arteriovenous fistula, hemothorax) after immediate catheter removal; no such complications were reported for adult patients whose catheters were left in place before surgical consultation and repair (*Category B3 evidence*).[80,86]

The consultants and ASA members agree that, when unintended cannulation of an arterial vessel with a large-bore catheter occurs, the catheter should be left in place and a general surgeon or vascular surgeon should be consulted. When unintended cannulation of an arterial vessel with a large-bore catheter occurs, the SPA members indicate that the catheter should be left in place and a general surgeon, vascular surgeon, or interventional radiologist should be immediately consulted before deciding on whether to remove the catheter, either surgically or nonsurgically, as follows: 54.9% (for neonates), 43.8% (for infants), and 30.0% (for children). SPA members indicating that the catheter may be nonsurgically removed without consultation is as follows: 45.1% (for neonates), 56.2% (for infants), and 70.0% (for children). The Task Force agrees that the anesthesiologist and surgeon should confer regarding the relative risks and benefits of proceeding with elective surgery after an arterial vessel has sustained unintended injury by a dilator or large-bore catheter.

Recommendations for Management of Arterial Trauma or Injury Arising from Central Venous Access. When unintended cannulation of an arterial vessel with a dilator or large-bore catheter occurs, the dilator or catheter should be left in place and a general surgeon, a vascular surgeon, or an interventional radiologist should be immediately consulted regarding surgical or nonsurgical catheter removal for adults. For neonates, infants, and children the decision to leave the catheter in place and obtain consultation or to remove the catheter nonsurgically should be based on practitioner judgment and experience. After the injury has been evaluated and a treatment plan has been executed, the anesthesiologist and surgeon should confer regarding relative risks and benefits of proceeding with the elective surgery *versus* deferring surgery to allow for a period of patient observation.

Appendix 1: Summary of Recommendations

Resource Preparation

- Central venous catheterization should be performed in an environment that permits use of aseptic techniques.
- A standardized equipment set should be available for central venous access.
- A checklist or protocol should be used for placement and maintenance of central venous catheters.
- An assistant should be used during placement of a central venous catheter.

Prevention of Infectious Complications

- For immunocompromised patients and high-risk neonates, administer intravenous antibiotic prophylaxis on a case-by-case basis.
  - Intravenous antibiotic prophylaxis should not be administered routinely.
- In preparation for the placement of central venous catheters, use aseptic techniques (*e.g.*, hand washing) and maximal barrier precautions (*e.g.*, sterile gowns, sterile gloves, caps, masks covering both mouth and nose, and full-body patient drapes).
- A chlorhexidine-containing solution should be used for skin preparation in adults, infants, and children.
  - For neonates, the use of a chlorhexidine-containing solution for skin preparation should be based on clinical judgment and institutional protocol.

- If there is a contraindication to chlorhexidine, povidone-iodine or alcohol may be used as alternatives.
- Unless contraindicated, skin preparation solutions should contain alcohol.

- If there is a contraindication to chlorhexidine, povidone-iodine or alcohol may be used. Unless contraindicated, skin preparation solutions should contain alcohol.
- Catheters coated with antibiotics or a combination of chlorhexidine and silver sulfadiazine should be used for selected patients based on infectious risk, cost, and anticipated duration of catheter use.
  - Catheters containing antimicrobial agents are not a substitute for additional infection precautions.
- Catheter insertion site selection should be based on clinical need.
  - An insertion site should be selected that is not contaminated or potentially contaminated (*e.g.*, burned or infected skin, inguinal area, adjacent to tracheostomy or open surgical wound).
  - In adults, selection of an upper body insertion site should be considered to minimize the risk of infection.
- The use of sutures, staples, or tape for catheter fixation should be determined on a local or institutional basis.
- Transparent bio-occlusive dressings should be used to protect the site of central venous catheter insertion from infection.
  - Unless contraindicated, dressings containing chlorhexidine may be used in adults, infants, and children.
  - For neonates, the use of transparent or sponge dressings containing chlorhexidine should be based on clinical judgment and institutional protocol.
- The duration of catheterization should be based on clinical need.
  - The clinical need for keeping the catheter in place should be assessed daily.
  - Catheters should be removed promptly when no longer deemed clinically necessary.
- The catheter insertion site should be inspected daily for signs of infection.
  - The catheter should be changed or removed when catheter insertion site infection is suspected.
- When a catheter-related infection is suspected, replacing the catheter using a new insertion site is preferable to changing the catheter over a guidewire.
- Catheter access ports should be wiped with an appropriate antiseptic before each access when using an existing central venous catheter for injection or aspiration.
- Central venous catheter stopcocks or access ports should be capped when not in use.
- Needleless catheter access ports may be used on a case-by-case basis.

Prevention of Mechanical Trauma or Injury

- Catheter insertion site selection should be based on clinical need and practitioner judgment, experience, and skill.
  - In adults, selection of an upper body insertion site should be considered to minimize the risk of thrombotic complications.
- When clinically appropriate and feasible, central venous access in the neck or chest should be performed with the patient in the Trendelenburg position.
- Selection of catheter size (*i.e.*, outside diameter) and type should be based on the clinical situation and skill/experience of the operator.
  - Selection of the smallest size catheter appropriate for the clinical situation should be considered.
- Selection of a thin-wall needle (a wire-through-thin-wall-needle, or Seldinger) technique *versus* a catheter-over-the-needle (a catheter-over-the-needle-then-wire-through-the-catheter, or Modified Seldinger) technique should be based on the clinical situation and the skill/experience of the operator.
  - The decision to use a thin-wall needle technique or a catheter-over-the-needle technique should be based at least in part on the method used to confirm that the wire resides in the vein before a dilator or large-bore catheter is threaded.
  - The catheter-over-the-needle technique may provide more stable venous access if manometry is used for venous confirmation.
- The number of insertion attempts should be based on clinical judgment.
- The decision to place two catheters in a single vein should be made on a case-by-case basis.
- Use static ultrasound imaging in elective situations before prepping and draping for prepuncture identification of anatomy to determine vessel localization and patency when the internal jugular vein is selected for cannulation.
  - Static ultrasound may be used when the subclavian or femoral vein is selected.
- Use real-time ultrasound guidance for vessel localization and venipuncture when the internal jugular vein is selected for cannulation.
  - Real-time ultrasound may be used when the subclavian or femoral vein is selected.
  - Real-time ultrasound may not be feasible in emergency circumstances or in the presence of other clinical constraints.
- After insertion of a catheter that went over the needle or a thin-wall needle, confirm venous access.††
  - Methods for confirming that the catheter or thin-wall needle resides in the vein include, but are not limited to: ultrasound, manometry, pressure-waveform analysis, or venous blood gas measurement.
  - Blood color or absence of pulsatile flow should not be relied upon for confirming that the catheter or thin-wall needle resides in the vein.
- When using the thin-wall needle technique, confirm venous residence of the wire after the wire is threaded.
- When using the catheter-over-the-needle technique, confirmation that the wire resides in the vein may not be needed (1) when the catheter enters the vein easily and manometry or pressure waveform measurement provides unambiguous con-

firmation of venous location of the catheter, and (2) when the wire passes through the catheter and enters the vein without difficulty.

- If there is any uncertainty that the catheter or wire resides in the vein, confirm venous residence of the wire after the wire is threaded. Insertion of a dilator or large-bore catheter may then proceed.

- Methods for confirming that the wire resides in the vein include, but are not limited to surface ultrasound (identifi- cation of the wire in the vein) or transesophageal echocar- diography (identification of the wire in the superior vena cava or right atrium), continuous electrocardiography (identification of narrow-complex ectopy), or fluoroscopy.

- After final catheterization and before use, confirm residence of the catheter in the venous system as soon as clinically appropriate.
  - Methods for confirming that the catheter is still in the venous system after catheterization and before use include waveform manometry or pressure measurement.
- Confirm the final position of the catheter tip as soon as clinically appropriate.
  - Methods for confirming the position of the catheter tip include chest radiography, fluoroscopy, or continuous electrocardiography.
- For central venous catheters placed in the operating room, perform the chest radiograph no later than the early postoperative period to confirm the position of the catheter tip.

Management of Arterial Trauma or Injury Arising from Central Venous Catheterization

- When unintended cannulation of an arterial vessel with a dilator or large-bore catheter occurs, the dilator or catheter should be left in place and a general surgeon, a vascular surgeon, or an interventional radiologist should be immediately consulted regarding surgical or nonsurgical catheter removal for adults.
  - For neonates, infants, and children, the decision to leave the catheter in place and obtain consultation or to remove the catheter nonsurgically should be based on practitioner judgment and experience.
- After the injury has been evaluated and a treatment plan has been executed, the anesthesiologist and surgeon should confer regarding relative risks and benefits of proceeding with the elective surgery *versus* deferring surgery for a period of patient observation.

Appendix 2. Example of a Standardized Equipment Cart for Central Venous Catheterization for Adult Patients

Item Description	Quantity
First Drawer	
Bottles Alcohol-based Hand Cleanser	2
Transparent bio-occlusive dressings with catheter stabilizer devices	2
Transducer kit: NaCL 0.9% 500 ml bag; single-line transducer, pressure bag	1
Needle Holder, Webster Disposable 5 inch	1
Scissors, 4 1/2 inchSterile	1
Vascular Access Tray(Chloraprep, Sponges, Labels)	1
Disposable pen with sterile labels	4
Sterile tubing, arterial line pressure-rated (for manometry)	2
Intravenous connector with needleless valve	4
Second Drawer	
Ultrasound Probe Cover, Sterile 3x96	2
Applicator, chloraprep 10.5 ml	3
Surgical hair clipper blade	3
Solution, NaCl bacteriostatic 30 ml	2
Third Drawer	
Cap, Nurses Bouffant	3
Surgeon hats	6
Goggles	2
Mask, surgical fluidshield	2
Gloves, sterile sizes 6.0–8.0 (2 each size)	10
Packs, sterile gowns	2
Fourth Drawer	
Drape, Total Body (with Femoral Window)	1
Sheet, central line total body (no window)	1
Fifth Drawer	
Dressing, Sterile Sponge Packages	4
Catheter kit, central venous pressure single lumen14 gauge	1
Catheter kits, central venous pressure two lumens 16 cm 7 French	2
Sixth Drawer	
Triple Lumen Centravel Venous Catheter Sets, 7 French Antimicrobial Impregnated	2
Introducer catheter sets, 9 French with sideport	2

Appendix 3. Example of a Central Venous Catheterization Checklist

Central Line Insertion Standard Work & Safety (Bundle) Checklist for OR and CCU

Date: _____ **Start Time:** _____ **End Time:** _____

Procedure Operator: _____ **Person Completing Form:** _____

Catheter Type: D Central Venous D PA/Swan-Ganz

French Size of catheter: _____ **Catheter lot number:** _____

Number of Lumens: D 1 D 2 D 3 D 4

Insertion Site: D Jugular D Upper Arm D Subclavian D Femoral

Side of Body: D Left D Right D Bilateral

Clinical Setting: D Elective D Emergent

BEFORE	**1. Consent form complete and in chart** Exception: Emergent procedure	D
	2. Patient's Allergy Assessed (especially to Lidocaine or Heparin)	D
	3. Patient's Latex Allergy Assessed (modify supplies)	D
	4. Hand Hygiene: D Operator and Assistant cleanse hands (ASK, if not witnessed)	D
	5. Optimal Catheter Site Selection: D In adults, Consider Upper Body Site D Check / explain why femoral site used: _____ D Anatomy – distorted, prior surgery/rad. Scar D Chest wall infection or burn D Coagulopathy D COPD severe/ lung disease D Emergency / CPR D Pediatric	D D **OR** Exception(s) checked to left
	6. Pre-procedure Ultrasound Check of internal jugular location and patency if IJ	D
	7. Skin Prep Performed (Skin Antisepsis): D **Chloraprep** 10.5 ml applicator used D **Dry technique (normal, unbroken skin):** 30 second scrub + 30 second dry time D **Wet technique (abnormal or broken skin):** 2 minute scrub + 1 minute dry time	D D DRY D WET
	8. MAXIMUM Sterile Barriers: D **Operator wearing hat, mask, sterile gloves, and sterile gown** D **Others** in room, (except patient) **wearing mask** D **Patient's body covered by sterile drape**	D D D
	9. Procedural "Time out" performed: D Patient ID X 2 D Procedure to be performed has been announced D Insertion site marked D Patient positioned correctly for procedure (Supine or Trendelenburg) D Assembled equipment/ supplies including venous confirmation method verified D Labels on all medication & syringes are verified	D D D D D D

(*continued*)

Appendix 3. Continued

DURING	**10. Ultrasound Guidance Used for Elective Internal Jugular insertions (sterile probe cover in place)**	D Used for IJ D Not used (Other site used)
	11. Confirmation of Venous Placement of Access Needle or Catheter: (do not rely on blood color or presence/absence of pulsatility)	D Manometry D Ultrasound D Transducer D Blood Gas
	12. Confirmation of Venous Placement of the Wire: D Access catheter easily in vein & confirmed (catheter-over needle technique) D Access *via* thin-wall needle (confirmation of wire recommended) D *or* ambiguous catheter or wire placement when using catheter-over-the-needle technique	D Not Needed D Ultrasound D TEE D Fluoroscopy D ECG
	13. Confirmation of Final Catheter in Venous System Prior to Use:	D Manometry D Transducer
	14. Final steps: D **Verify guidewire not retained** D **Type and Dosage** (ml / units) **of Flush: _____** D **Catheter Caps Placed on Lumens** D Tip position confirmation: **Fluoroscopy** **Chest radiograph ordered** D **Catheter Secured / Sutured in place**	D D D D D D

AFTER	**15. Transparent Bio-occlusive dressing applied**	D
	16. Sterile Technique Maintained when applying dressing	D
	17. Dressing Dated	D
	18. Confirm Final Location of Catheter Tip	D CXR D Fluoroscopy D Continuous ECG
	19. After tip location confirmed, "Approved for use" Written on Dressing	D
	20. Central line (maintenance) Order Placed	D

Comments:
Tip location:

Appendix 4. Example Duties Performed by an Assistant for Central Venous Catheterization

Reads prompts on checklist to ensure that no safety step is forgotten or missed. Completes checklist as task is completed
Verbally alerts anesthesiologist if a potential error or mistake is about to be made.
Gathers equipment/supplies or brings standardized supply cart.
Brings the ultrasound machine, positions it, turns it on, makes adjustments as needed.
Provides moderate sedation (if registered nurse) if needed.
Participates in "time-out" before procedure.
Washes hands and wears mask, cap, and nonsterile gloves (scrubs or cover gown required if in the sterile envelope).
Attends to patient requests if patient awake during procedure.
Assists with patient positioning. Assists with draping.
Assists with sterile field setup; drops sterile items into field as needed.
Assists with sterile ultrasound sleeve application to ultrasound probe.
Assists with attachment of intravenous lines or pressure lines if needed.
Assists with application of a sterile bandage at the end of the procedure.
Assists with clean-up of patient, equipment, and supply cart; returns items to their proper location.

Appendix 5: Methods and Analyses

State of the Literature

For these Guidelines, a literature review was used in combination with opinions obtained from expert consultants and other sources (*e.g.*, ASA members, SPA members, open forums, Internet post- ings). Both the literature review and opinion data were based on evidence linkages, or statements regarding potential relationships between clinical interventions and outcomes. The interventions listed below were examined to assess their effect on a variety of outcomes related to central venous catheterization.

Resource Preparation
Selection of a Sterile Environment Availability of a standardized equipment set
Use of a checklist or protocol for placement and maintenance Use of an assistant for placement

Prevention of Infectious Complications
Intravenous antibiotic prophylaxis Aseptic techniques
Aseptic preparation
Hand washing, sterile full-body drapes, sterile gown, gloves, mask, cap Skin preparation
Chlorhexidine *versus* povidone-iodine Aseptic preparation with *versus* without alcohol Selection of catheter coatings or impregnation
Antibiotic-coated catheters *versus* no coating
Silver-impregnated catheters *versus* no coating
Chlorhexidine combined with silver sulfadiazine catheter coating *versus* no coating
Selection of catheter insertion site Internal jugular
Subclavian Femoral
Selecting a potentially uncontaminated insertion site Catheter fixation
Suture, staple, or tape Insertion site dressings
Clear plastic, chlorhexidine, gauze and tape, cyanoacrylate, antimicrobial dressings, patch, antibiotic ointment
Catheter maintenance
Long-term *versus* short-term catheterization
Frequency of insertion site inspection for signs of infection Changing catheters
Specified time intervals
Specified time interval *versus* no specified time interval (*i.e.*, as needed)
One specified time interval *versus* another specified time interval Changing a catheter over a wire *versus* a new site
Aseptic techniques using an existing central line for injection or aspiration
Wiping ports with alcohol Capping stopcocks
Needleless connectors or access ports

Prevention of Mechanical Trauma or Injury
Selection of catheter insertion site Internal jugular
Subclavian Femoral
Trendelenburg *versus* supine position Needle insertion and catheter placement
Selection of catheter type (*e.g.*, double lumen, triple lumen, Cordis)
Selection of a large-bore catheter
Placement of two catheters in the same vein
Use of a Seldinger technique *versus* a modified Seldinger technique
Limiting number of insertion attempts Guidance of needle, wire and catheter placement
Static ultrasound *versus* no ultrasound (*i.e.*, anatomic landmarks)
Real-time ultrasound guidance *versus* no ultrasound Verification of placement
Manometry *versus* direct pressure measurement (*via* pressure transducer)
Continuous electrocardiogram
Fluoroscopy
Venous blood gas
Transesophageal echocardiography Chest radiography

Management of Trauma or Injury Arising from Central Venous Catheterization
Not removing *versus* removing central venous catheter on evidence of arterial puncture.

For the literature review, potentially relevant clinical studies were identified *via* electronic and manual searches of the literature. The electronic and manual searches covered a 44-yr period from 1968 through 2011. More than 2,000 citations were initially identified, yielding a total of 671 nonoverlapping articles that addressed topics related to the evidence linkages. After review of the articles, 383 studies did not provide direct evidence, and were subsequently eliminated. A total of 288 articles contained direct linkage-related evidence. A complete bibliography used to develop these Guide- lines, organized by section, is available as Supplemental Digital Content 2, http://links.lww.com/ALN/A784.

Initially, each pertinent outcome reported in a study was classi- fied as supporting an evidence linkage, refuting a linkage, or equiv- ocal. The results were then summarized to obtain a directional assessment for each evidence linkage before conducting formal meta-analyses. Literature pertaining to five evidence linkages con- tained enough studies with well-defined experimental designs and statistical information sufficient for meta-analyses (table 1). These linkages were (1) antimicrobial catheters, (2) silver sulfadiazine catheter coatings, (3) chlorhexidine and silver sulfadiazine catheter coatings, (4) changing a catheter over a wire *versus* a new site, and (5) ultrasound guidance for venipuncture.

General variance-based effect-size estimates or combined prob- ability tests were obtained for continuous outcome measures, and Mantel-Haenszel odds-ratios were obtained for dichotomous out- come measures. Two combined probability tests were employed as follows: (1) the Fisher combined test, producing chi-square values based on logarithmic transformations of the reported *P* values from the independent studies, and (2) the Stouffer combined test, pro- viding weighted representation of the studies by weighting each of the standard normal deviates by the size of the sample. An odds- ratio procedure based on the Mantel-Haenszel method for combin- ing study results using 2 × 2 tables was used with outcome fre- quency information. An acceptable significance level was set at $P <$ 0.01 (one-tailed). Tests for heterogeneity of the independent stud- ies were conducted to assure consistency among the study results. DerSimonian-Laird random-effects odds ratios were obtained when significant heterogeneity was found ($P < 0.01$). To control for potential publishing bias, a "fail-safe n " value was calculated. No search for unpublished studies was conducted, and no reliability tests for locating research results were done. To be accepted as significant findings, Mantel-Haenszel odds ratios must agree with combined test results whenever both types of data are assessed. In the absence of Mantel-Haenszel odds-ratios, findings from both the Fisher and weighted Stouffer combined tests must agree with each other to be acceptable as significant.

Interobserver agreement among Task Force members and two methodologists was established by interrater reliability testing. Agreement levels using a kappa (K) statistic for two-rater agreement pairs were as follows: (1) type of study design, K 0.70 –1.00l; (2) type of analysis, K 0.60 – 0.84; (3) evidence linkage assignment, K 0.91– 1.00; and (4) literature inclusion for database, K 0.65– 1.00. Three-rater chance-corrected agreement values were (1) study design, Sav 0.80, Var (Sav) 0.006; (2) type of analysis, Sav 0.70, Var (Sav) 0.016; (3) linkage assignment, Sav 0.94, Var (Sav) 0.002; (4) literature database inclusion, Sav 0.65, Var (Sav) 0.034. These values represent moderate to high levels of agreement.

Consensus-based Evidence

Consensus was obtained from multiple sources, including (1) sur- vey opinion from consultants who were selected based on their knowledge or expertise in central venous access, (2) survey opinions solicited from active members of the ASA and SPA, (3) testimony from attendees of publicly-held open forums at two national anes- thesia meetings, (4) Internet commentary, and (5) task force opin- ion and interpretation. The survey rate of return was 41.0% (n 55 of 134) for the consultants (table 2), 530 surveys were received from active ASA members (table 3), and 251 surveys were received from active SPA members (table 4).

An additional survey was sent to the expert consultants asking them to indicate which, if any, of the evidence linkages would change their clinical practices if the Guidelines were instituted. The rate of return was 16% (n 22 of 134). The percentage of respond- ing consultants expecting no change associated with each linkage were as follows: (1) availability of a standardized equipment set 91.8%, (2) use of a trained assistant 83.7%, (3) use of a checklist or protocol for placement and maintenance 75.5%, (4) use of bundles that include a checklist or protocol 87.8%, (5) intravenous antibiotic prophylaxis 93.9%, (6) aseptic preparation (*e.g.*, hand washing, caps, masks) 98.0%, (8) skin preparation 98.0%, (9) selection of cath- eters with antibiotic or antiseptic coatings/impregnation 89.8%, (10) selection of catheter insertion site for prevention of infection 100%, (11) catheter fixation methods 89.8%, (12) insertion site dressings 100%, (13) catheter maintenance 100%, (14) aseptic techniques using an existing central line for injection or aspiration 95.9%, (15) selection of catheter insertion site for prevention of me- chanical trauma or injury 100%, (16) Trendelenburg *versus* supine patient positioning for neck or chest venous access 100%, (17) needle insertion and catheter placement 100%, (18) guidance of needle, wire, and catheter placement 89.8%, (19) verification of needle puncture and placement 98.0%, (20) management of trauma or injury 100%.

Fifty-seven percent of the respondents indicated that the Guide- lines would have no effect on the amount of time spent on a typical case, and 43% indicated that there would be an increase of the amount of time spent on a typical case with the implementation of these Guidelines. Seventy-four percent indicated that new equip- ment, supplies, or training would not be needed to implement the Guidelines, and 78% indicated that implementation of the Guide- lines would not require changes in practice that would affect costs.

Combined Sources of Evidence

Evidence for these Guidelines was formally collected from multiple sources, including randomized controlled trials, observational liter- ature, surveys of expert consultants, and randomly selected samples of ASA and SPA members. This information is summarized in table 5, with a brief description of each corresponding recommendation.

Table 1. Meta-analysis Summary

Evidence Linkages	N	Fisher Chi-square	*P* Value	Weighted Stouffer Zc	Heterogeneity *P* Value	Heterogeneity Effect Size	Odds Ratio	Confidence Interval	*P* Values	Effect Size
Antibiotic-coated catheters *vs*. no coating										
Catheter colonization	5						0.35	0.23–0.55		ns
Silver sulfadiazine catheter coating *vs*. no coating										
Catheter-related bloodstream infection	5						0.70	0.45–1.10		ns
Chlorhexidine + silver sulfadiazine catheter coating *vs*. no coating										
Catheter colonization	12						0.43	0.34–0.54		ns
Catheter-related bloodstream infection	12						0.70	0.47–1.03		ns
Changing a catheter over a wire *vs.* a new site										
Catheter colonization	5						1.18	0.66–2.09		ns
Real-time ultrasound guidance *vs*. no ultrasound*										
Successful insertion/ cannulation	11						7.15†	1.33–18.27		0.005
First attempt success	5						3.24	1.93–5.45		ns
Time to insertion	6	70.67	0.001	-7.15	0.001	-0.23			ns	ns
Arterial puncture	10						0.24	0.15–0.38		ns

* Findings represent studies addressing internal jugular access. † Random-effects odds ratio.
ns *P* > 0.01.

Table 2. Consultant Survey Responses*

	Percent Responding to Each Item					
	N	Strongly Agree	Agree	Equivocal	Disagree	Strongly Disagree
I. Resource preparation						
1. Central venous catheterization should be performed in a location that permits the use of aseptic techniques	54	92.6*	7.4	0.0	0.0	0.0
2. A standardized equipment set should be available for central venous access	55	78.2*	16.4	5.4	0.0	0.0
3. A trained assistant should be present during placement of a central venous catheter	54	33.3	29.6*	16.7	18.4	1.9
4. A checklist or protocol should be used for the placement and maintenance of central venous catheters	54	59.3*	20.4	9.3	9.3	1.8
II. Prevention of infectious complications						
5. Intravenous antibiotic prophylaxis should not be administered routinely	55	43.6	32.7*	12.7	7.3	3.6
6. For immunocompromised patients and high-risk neonates, intravenous antibiotic prophylaxis may be administered on a case-by-case basis	55	23.6	36.4*	27.3	10.9	1.8
7. The practitioner should use the following aseptic techniques in preparation for the placement of central venous catheters (check all that apply)	55	Percentage				
Hand washing		100.0				
Sterile full-body drapes		87.3				
Sterile gowns		100.0				
Gloves		100.0				
Caps		100.0				
Masks covering both mouth and nose		100.0				

(*continued*)

Table 2. Continued

Percent Responding to Each Item

		N	Strongly Agree	Agree	Equivocal	Disagree	Strongly Disagree
8.	Chlorhexidine with alcohol should be used for skin preparation	55	72.7*	27.3	0.0	0.0	0.0
9.	Catheters coated with antibiotics or a combination of chlorhexidine and silver sulfadiazine may be used in selected patients based on infectious risk, cost, and anticipated duration of catheter use	55	38.2	45.5*	16.3	0.0	0.0
10.	Please indicate your preferred central venous catheter insertion site to minimize catheter-related risk of infection (check one)	55	Percentage				
	Internal jugular		41.8				
	Subclavian		52.7				
	Femoral		0.0				
	No preference		5.5				
11.	Femoral catheterization should be avoided when possible to minimize the risk of infection	54	37.0	53.7*	3.7	3.7	1.9
12.	An insertion site should be selected that is not contaminated or potentially contaminated (*e.g.*, burned or infected skin, inguinal area, adjacent to tracheostomy or open surgical wound)	53	71.7*	24.5	7.8	0.0	0.0
13.	Please indicate your preferred catheter fixation technique to minimize catheter-related risk of infection (check one)	54	Percentage				
	Sutures		70.4				
	Staples		3.7				
	Tape		5.5				
	No preference		20.4				
14.	Transparent bio-occlusive dressings should be used to protect the site of central venous catheter insertion from infection	55	52.7*	41.8	3.6	1.8	0.0
15.	Dressings containing chlorhexidine may be used to reduce the risk of catheter-related infection	55	20.0	34.6*	45.4	0.0	0.0
16.	The duration of catheterization should be based on clinical need	55	61.8*	30.9	0.0	7.3	0.0
17.	The clinical need for keeping a catheter in place should be assessed daily	53	90.6*	9.4	0.0	0.0	0.0
18.	Catheters should be promptly removed when deemed no longer clinically necessary	54	88.9*	11.1	0.0	0.0	0.0
19.	The catheter site should be inspected daily for signs of infection	54	88.9*	11.1	0.0	0.0	0.0
20.	The catheter should be changed or removed when infection is suspected	55	74.6*	20.0	3.6	1.8	0.0
21.	When catheter-related infection is suspected, replacing the catheter using a new insertion site is preferable to changing the catheter over a guidewire	55	70.9*	27.3	1.8	0.0	0.0
22.	Catheter access ports should be wiped with an appropriate antiseptic before each access	55	69.1*	21.8	7.3	1.8	0.0
23.	Needleless catheter access ports may be used on a case-by-case basis	55	30.9	47.3*	12.7	3.6	5.5
24.	Central venous catheter stopcocks should be capped when not in use	54	81.5*	18.5	0.0	0.0	0.0

(*continued*)

Table 2. Continued

		Percent Responding to Each Item					
		N	Strongly Agree	Agree	Equivocal	Disagree	Strongly Disagree
III.	Prevention of mechanical trauma or injury						
25.	Please indicate your preferred central venous catheter insertion site to minimize catheter cannulation-related risk of injury or trauma (check one)	55	Percentage				
	Internal jugular		81.8				
	Subclavian		9.1				
	Femoral		3.6				
	No preference		5.6				
26.	Please indicate your preferred central venous catheter insertion site to minimize catheter-related risk of thromboembolic injury or trauma (check one)	55	Percentage				
	Internal jugular		76.4				
	Subclavian		7.3				
	Femoral		0.0				
	No preference		16.3				
27.	When clinically appropriate and feasible, central venous access in the neck or chest should be performed in the Trendelenburg position	54	51.9*	33.3	9.6	5.6	0.0
28.	Selection of catheter type (*i.e.,* gauge, length, number of lumens) and composition (*e.g.*, polyurethane, Teflon) should be based on the clinical situation and skill/experience of the operator	55	49.1	38.2*	9.1	3.6	0.0
29.	Selection of a modified Seldinger technique *vs.* a Seldinger technique should be based on the clinical situation and the skill/experience of the operator	55	36.4	49.1*	5.4	7.3	1.8
30.	The number of insertion attempts should be based on clinical judgment	55	45.5	32.7*	3.6	16.4	1.8
31.	The decision to place two catheters in a single vein should be made on a case-by-case basis	55	55.6*	40.0	3.6	1.8	0.0
32.	Ultrasound imaging (*i.e.*, static) should be used in elective situations for pre-puncture identification of anatomy and vessel localization when the internal jugular vein is selected for cannulation	53	49.1	26.4*	11.3	9.4	3.8
33.	Ultrasound imaging (*i.e.*, static) should be used in elective situations for pre-puncture identification of anatomy and vessel localization when the subclavian vein is selected for cannulation	55	12.7	18.2	32.7*	25.5	10.9
34.	Ultrasound imaging (*i.e.*, static) should be used in elective situations for pre-puncture identification of anatomy and vessel localization when the femoral vein is selected for cannulation	55	18.2	32.7*	21.8	23.6	3.6
35.	When available, real-time ultrasound should be used for guidance during venous access when the internal jugular vein is selected for cannulation	54	44.4	33.3*	13.0	9.3	0.0
36.	When available, real-time ultrasound should be used for guidance during venous access when the subclavian vein is selected for cannulation	53	11.3	17.0	37.7*	28.3	5.7

(*continued*)

Table 2. Continued

	Percent Responding to Each Item						
		N	Strongly Agree	Agree	Equivocal	Disagree	Strongly Disagree
37.	When available, real-time ultrasound should be used for guidance during venous access when the femoral vein is selected for cannulation	54	14.8	35.2*	33.3	14.8	1.9
38.	Before insertion of a dilator or large bore catheter over a wire, venous access should be confirmed for the catheter or thin-wall needle that accesses the vein	54	57.4*	25.9	7.4	9.3	0.0
39.	Before insertion of a dilator or large bore catheter over a wire, venous access should be confirmed for the wire that subsequently resides in the vein after traveling through a catheter or thin-wall needle	55	29.1	29.1*	25.5	12.7	3.6
40.	When feasible, both the location of the catheter or thin-wall needle *and* wire should be confirmed	55	25.4	38.2*	18.2	15.6	3.6
41.	A chest radiograph should be performed to confirm the location of the catheter tip as soon after catheterization as clinically appropriate	55	30.9	41.8*	9.1	14.5	3.6
42.	For central venous catheters placed in the operating room, a confirmatory chest radiograph may be performed in the early postoperative period	55	47.3	50.9*	0.0	1.8	0.0
43.	If a chest radiograph will be deferred to the postoperative period, pressure/waveform analysis, blood gas analysis, ultrasound or fluoroscopy should be used to confirm venous positioning of the catheter before use	55	56.4*	30.9	5.4	7.3	0.0
IV.	Management of arterial trauma or injury arising from central venous						
44.	When unintended cannulation of an arterial vessel with a large bore catheter occurs, the catheter should be left in place and a general or vascular surgeon should be consulted	55	45.4	36.4*	7.3	9.1	1.8

* N number of consultants who responded to each item. An asterisk next to a percentage score indicates the median.

Table 3. ASA Member Survey Responses*

	N	Percent Responding to Each Item				
		Strongly Agree	Agree	Equivocal	Disagree	Strongly Disagree
I. Resource preparation						
1. Central venous catheterization should be performed in a location that permits the use of aseptic techniques	529	78.1*	19.1	2.1	0.8	0.0
2. A standardized equipment set should be available for central venous access	530	64.5*	30.0	4.2	0.9	0.4
3. A trained assistant should be present during placement of a central venous catheter	526	24.1	35.6*	24.0	13.1	3.2
4. A checklist or protocol should be used for The placement and maintenance of central venous catheters	528	35.6	37.5*	16.3	8.9	1.7
II. Prevention of infectious complications						
5. Intravenous antibiotic prophylaxis should not be administered routinely	526	29.7	44.5*	16.9	7.0	1.9
6. For immunocompromised patients and high-risk neonates, intravenous antibiotic prophylaxis may be administered on a case-by-case basis	523	25.0	54.1*	15.9	4.2	0.8
7. The practitioner should use the following aseptic techniques in preparation for the placement of central venous catheters (check all that apply)	524	Percentage				
Hand washing		96.0				
Sterile full-body drapes		73.8				
Sterile gowns		87.8				
Gloves		100.0				
Caps		94.7				
Masks covering both mouth and nose		98.1				
8. Chlorhexidine with alcohol should be used for skin preparation	522	57.3*	34.1	7.8	0.8	0.0
9. Catheters coated with antibiotics or a combination of chlorhexidine and silver sulfadiazine may be used in selected patients based on infectious risk, cost, and anticipated duration of catheter use	526	24.3	54.8*	19.2	1.7	0.0
10. Please indicate your preferred central venous catheter insertion site to minimize catheter-related risk of infection (check one)	524	Percentage				
Internal jugular		51.3				
Subclavian		44.3				
Femoral		0.0				
No preference		4.4				
11. Femoral catheterization should be avoided when possible to minimize the risk of infection	525	33.9	49.7*	9.3	4.7	2.3
12. An insertion site should be selected that is not contaminated or potentially contaminated (*e.g.*, burned or infected skin, inguinal area, adjacent to tracheostomy or open surgical wound)	523	58.9*	37.9	2.5	0.7	0.0

(*continued*)

Table 3. Continued

Percent Responding to Each Item	N	Strongly Agree	Agree	Equivocal	Disagree	Strongly Disagree
13. Please indicate your preferred catheter fixation technique to minimize catheter-related risk of infection (check one)	524	Percentage				
Sutures		80.2				
Staples		5.7				
Tape		3.6				
No preference		10.5				
14. Transparent bio-occlusive dressings should be used to protect the site of central venous catheter insertion from infection	522	46.9	44.4*	6.5	1.3	0.8
15. Dressings containing chlorhexidine may be used to reduce the risk of catheter-related infection	525	18.7	37.9*	41.3	1.9	0.2
16. The duration of catheterization should be based on clinical need	523	49.5	44.5*	3.1	2.5	0.4
17. The clinical need for keeping a catheter in place should be assessed daily	523	65.8*	32.5	1.3	0.4	0.0
18. Catheters should be promptly removed when deemed no longer clinically necessary	521	78.7*	20.9	0.4	0.0	0.0
19. The catheter site should be inspected daily for signs of infection	521	79.1*	19.6	1.1	0.2	0.0
20. The catheter should be changed or removed when infection is suspected	524	72.7*	24.4	2.5	0.2	0.2
21. When catheter-related infection is suspected, replacing the catheter using a new insertion site is preferable to changing the catheter over a guidewire	525	64.8*	30.7	3.8	0.8	0.0
22. Catheter access ports should be wiped with an appropriate antiseptic before each access	522	64.6*	31.0	3.4	1.0	0.0
23. Needleless catheter access ports may be used on a case-by-case basis	522	33.9	51.3*	12.3	1.7	0.8
24. Central venous catheter stopcocks should be capped when not in use	527	70.6*	26.2	2.6	0.6	0.0
III. Prevention of mechanical trauma or injury						
25. Please indicate your preferred central venous catheter insertion site to minimize catheter cannulation-related risk of injury or trauma (check one)	525	Percentage				
Internal jugular		79.4				
Subclavian		10.7				
Femoral		2.7				
No preference		7.2				
26. Please indicate your preferred central venous catheter insertion site to minimize catheter-related risk of thromboembolic injury or trauma (check one)	525	Percentage				
Internal jugular		67.6				
Subclavian		12.8				
Femoral		1.9				
No preference		17.7				

(*continued*)

Table 3. Continued

Percent Responding to Each Item

		N	Strongly Agree	Agree	Equivocal	Disagree	Strongly Disagree
27.	When clinically appropriate and feasible, central venous access in the neck or chest should be performed in the Trendelenburg position	528	57.0*	37.7	3.0	1.9	0.4
28.	Selection of catheter type (*i.e.*, gauge, length, number of lumens) and composition (*e.g.*, polyurethane, Teflon) should be based on the clinical situation and skill/experience of the operator	530	52.1*	38.1	6.2	3.4	0.0
29.	Selection of a modified Seldinger technique *vs.* a Seldinger technique should be based on the clinical situation and the skill/experience of the operator	531	47.8	36.9*	9.8	4.7	0.8
30.	The number of insertion attempts should be based on clinical judgment	528	47.3	43.6*	4.2	3.8	1.1
31.	The decision to place two catheters in a single vein should be made on a case-by-case basis	527	45.9	36.2*	12.1	4.4	1.3
32.	Ultrasound imaging (*i.e.*, static) should be used in elective situations for pre-puncture identification of anatomy and vessel localization when the internal jugular vein is selected for cannulation	526	28.9	25.1*	21.3	18.8	5.9
33.	Ultrasound imaging (*i.e.*, static) should be used in elective situations for pre-puncture identification of anatomy and vessel localization when the subclavian vein is selected for cannulation	528	9.7	14.2	41.5*	26.5	8.1
34.	Ultrasound imaging (*i.e.*, static) should be used in elective situations for pre-puncture identification of anatomy and vessel localization when the femoral vein is selected for cannulation	527	11.9	29.8	30.6*	21.4	6.3
35.	When available, *real time* ultrasound should be used for guidance during venous access when the *internal jugular* vein is selected for cannulation	525	24.0	24.2	23.2*	21.5	7.1
36.	When available, *real time* ultrasound should be used for guidance during venous access when the *subclavian* vein is selected for cannulation	530	8.1	13.4	42.1*	27.9	8.5
37.	When available, real-time ultrasound should be used for guidance during venous access when the femoral vein is selected for cannulation	528	13.5	23.5	31.4*	25.0	6.6
38.	Before insertion of a dilator or large bore catheter over a wire, venous access should be confirmed for the catheter or thin-wall needle that accesses the vein	524	52.9*	32.1	8.4	6.3	0.4
39.	Before insertion of a dilator or large bore catheter over a wire, venous access should be confirmed for the *wire* that subsequently resides in the vein after traveling through a catheter or thin-wall needle	524	24.0	25.4	25.6*	22.9	2.1

(*continued*)

Table 3. Continued

Percent Responding to Each Item	N	Strongly Agree	Agree	Equivocal	Disagree	Strongly Disagree
40. When feasible, *both* the location of the catheter or thin-wall needle *and* wire should be confirmed	526	23.8	32.5*	22.1	19.4	2.3
41. A chest radiograph should be performed to confirm the location of the catheter tip as soon following catheterization as clinically appropriate	525	39.8	45.5*	7.1	7.0	0.6
42. For central venous catheters placed in the operating room, a confirmatory chest radiograph may be performed in the early postoperative period	524	46.8	48.1*	2.5	1.9	0.8
43. If a chest radiograph will be deferred to the postoperative period, pressure/waveform analysis, blood gas analysis, ultrasound or fluoroscopy should be used to confirm venous positioning of the catheter before use	527	33.0	35.3*	12.7	16.7	2.3
IV. Management of arterial trauma or injury arising from central venous						
44. When unintended cannulation of an arterial vessel with a large bore catheter occurs, the catheter should be left in place and a general or vascular surgeon should be consulted	526	28.5	35.6*	16.3	17.9	1.7

* Number of ASA members who responded to each item. An asterisk next to a percentage score indicates the median.

Table 4. SPA Member Survey Responses*

Percent Responding to Each Item

	N	Strongly Agree	Agree	Equivocal	Disagree	Strongly Disagree
1. A chlorhexidine-containing solution should be used for skin preparation in neonates†	250	17.2	26.0	31.6*	17.2	8.0
2. A chlorhexidine-containing solution should be used for skin preparation in infants‡	248	46.0	40.3*	11.3	2.4	0.0
3. A chlorhexidine-containing solution should be used for skin preparation in children§	249	62.7*	30.9	5.2	1.2	0.0
4. Dressings containing chlorhexidine may be used in neonates	243	7.0	14.0	52.2*	20.2	6.6
5. Dressings containing chlorhexidine may be used in infants	249	22.5	36.6*	35.3	4.8	0.8
6. Dressings containing chlorhexidine may be used in children	249	38.6	35.3*	24.5	1.2	0.4
7. When unintended cannulation of an arterial vessel with a large bore catheter occurs in neonates (check one)	244	Percentage				
The catheter should be left in place[5]		54.9				
The catheter may be nonsurgically removedI		45.1				
8. When unintended cannulation of an arterial vessel with a large-bore catheter occurs in infants (check one)	249	Percentage				
The catheter should be left in place		43.8				
The catheter may be nonsurgically removed		56.2				
9. When unintended cannulation of an arterial vessel with a large bore catheter occurs in children (check one)	244	Percentage				
The catheter should be left in place		30.0				
The catheter may be nonsurgically removed		70.0				

* Number of SPA members who responded to each item. An asterisk beside a percentage score indicates the median response. † Younger than 44 gestational weeks. ‡ Younger than 2 yr. § 2–16 yr of age. I The complete wording of the response category is: The catheter should be left in place and a general surgeon, vascular surgeon, or interventional radiologist should be immediately consulted before deciding on whether to remove the catheter, either surgically or nonsurgically. # The complete wording of the response category is: The catheter may be nonsurgically removed without consulting a general surgeon, vascular surgeon, or interventional radiologist.

Table 5. Evidence Summary*

Interventions	Evidence Category[1]	Consultant Survey[2]	ASA Member Survey[2]	SPA Member Survey[2]	Guideline Recommendation
I. Resource preparation					
Catheterization in environment that permits use of aseptic techniques	D	Strongly agree	Strongly agree		Should be performed
Standardized equipment set	D	Strongly agree	Strongly agree		Should be available
An assistant	D	Agree (trained)	Agree (trained)		Should be used
A checklist or protocol	B2[3]	Strongly agree	Agree		Should be used
II. Prevention of infectious complications					
Intravenous antibiotic prophylaxis					
Prophylactic intravenous antibiotics should not be administered routinely	D	Agree	Agree		Should not be routinely administered
Prophylactic intravenous antibiotics should be administered to immunocompromised patients and high- risk neonates	A2[4]	Agree	Agree		Administer on a case-by-case basis
Aseptic techniques and barrier precautions:					
Maximal barrier *vs.* gloves and small drape only					
"Bundled" elements: hand-washing, sterile full body drapes, sterile, gloves, caps, and masks	C2[5,6]				
Specific activities:					
	B2[3]				
Hand washing	D	100% agreement	96% agreement		Use
Sterile full-body drape	D	87% agreement	74% agreement		Use
Sterile gown	D	100% agreement	88% agreement		Use
Sterile gloves	D	100% agreement	100% agreement		Use
Caps	D	100% agreement	95% agreement		Use
Masks covering both mouth and nose	D	100% agreement	98% agreement		Use
Skin preparation:					
Solutions containing chlorhexidine:					
Chlorhexidine with alcohol (patient age not specified)	D	Strongly agree	Strongly agree		Should be used for adults, infants and children
Antiseptic solutions containing chlorhexidine for:					
Neonates	D			Equivocal	Should be based on clinical judgment and Institutional protocol
Infants	D			Agree	Should be used
Children	D		Strongly agree		Should be used
Solutions containing alcohol:					
Chlorhexidine *without* alcohol *vs.* povidone-iodine without alcohol	C2[5,7]				
Chlorhexidine *with* alcohol *vs.* Povidone-iodine with alcohol					
Skin preparation solutions with vs. without alcohol:	D				
Chlorhexidine	D				

(*continued*)

Table 5. Continued

Interventions	Evidence Category[1]	Consultant Survey[2]	ASA Member Survey[2]	SPA Member Survey[2]	Guideline Recommendation
Povidone-iodine	A3[5]/C2[8]				
Skin preparation solutions containing alcohol					Use unless contraindicated
Catheters containing antimicrobial agents:					
Antibiotic-coated catheters	A1[5]	Agree (selected pts)	Agree (selected pts)		Should be used for selected patients
Silver-impregnated catheters	C1[3]/C2[5]				No recommendation
Chlorhexidine and silver sulfadiazine coated catheters	A1[5]/B3[9]/C1[3]	Agree (selected pts)	Agree (selected pts)		Should be used for selected patients
Selection of catheter insertion site:					
Internal jugular *vs.* subclavian	C2[3,5]/C3[3,5] subclavian site	Majority prefer	Majority prefer internal jugular site		Site selection should be based on clinical need to minimize risk of catheter- related infection
Subclavian *vs.* femoral femoral)	A3[5]/C2[4]	Agree (avoid	Agree (avoid femoral)		Site selection should be based on clinical need. In adults, upper body site should be considered to minimize risk of infection
Catheter fixation:					
Risk of catheter-related infections with suture, staple, tape	D	Majority prefer suture	Majority prefer suture		Should be determined on a local or institutional basis
Catheter insertion site dressings:					
Transparent bio-occlusive	D	Strongly agree	Strongly agree		Should be used
Chlorhexidine sponge dressings (patient age not specified)	C2[3,5]	Agree	Agree		May be used unless contraindicated
Chlorhexidine-impregnated transparent dressings for neonates	A3[10] judgment and institutional protocol				Should be based on clinical
Chlorhexidine sponge dressings					
For neonates judgment and institutional protocol				Equivocal	Should be based on clinical
For infants				Agree	May be used, unless contraindicated
For children				Agree	May be used, unless contraindicated
Silver-impregnated transparent dressings	C2[5]				No recommendation
Catheter maintenance:					
Duration of catheterization related to higher colonization/infection rates	B2[4,5]				
Duration of catheterization should be based on clinical need					
Specific time intervals between insertion site inspections	Strongly agree		Agree		Duration should be based
Catheter change interval 3-days *vs.* 7-days	on clinical need				
Daily assessment of clinical need for continuing catheterization	D				
	C2[5]				
	Strongly agree		Strongly agree		Clinical need for keeping
	catheter in place should be assessed daily				

(*continued*)

Table 5. Continued

Interventions	Evidence Category[1]	Consultant Survey[2]	ASA Member Survey[2]	SPA Member Survey[2]	Guideline Recommendation
Conduct daily catheter site inspections		Strongly agree	Strongly agree		Catheter insertion site should be inspected daily for signs of infection
Change or remove catheter when infection is suspected		Strongly agree	Strongly agree		Catheter should be changed or removed when Catheter insertion site infection is suspected
When catheter-related infection is suspected, replace catheter using new insertion site *vs.* catheter change over a guidewire	C1[5]	Strongly agree (Suspected infection)	Strongly agree (Suspected infection)		When catheter-related infection is suspected, replacing the catheter using a new insertion site is preferred
Promptly remove catheter when deemed no longer clinically necessary		Strongly agree	Strongly agree		Promptly remove catheter when deemed no longer clinically necessary
Aseptic techniques using an existing central venous catheter:					
Wipe port with an appropriate antiseptic before access	D	Strongly agree	Strongly agree		Catheter access ports should be wiped with an appropriate antiseptic before each access
Cap stopcocks or access ports when not in use		Strongly agree	Strongly agree		Central venous catheter stopcocks or access ports should be capped when not in use
Needleless catheter connectors/access ports *vs.* standard caps					
Needleless catheter connectors/ports *vs.* standard caps	A2[11]/C2[3] (case-by case basis)	Agree	Agree (case-by case basis)		Needless catheter access ports may be used on a case-by-case basis
III. Prevention of mechanical trauma or injury					
Selection of catheter insertion site:					
Internal jugular *vs.* subclavian	C2[13,14,15,16]/C3[17]				
Subclavian *vs.* femoral	A3[12]				
Preferred catheter insertion site		Majority prefer internal jugular	Majority prefer internal jugular		Insertion site selection should be based on clinical need and practitioner judgment, experience and skill. In adults, selection of an upper body insertion site should be considered to minimize the risk of thromboembolic injury or trauma
Positioning the patient for needle insertion and catheter placement:					
Trendelenburg *vs.* normal supine	B2[18]	Strongly agree	Strongly agree		When clinically appropriate and feasible, central venous access in the neck or chest should be performed with the patient in the Trendelenburg position

(*continued*)

Table 5. Continued

Interventions	Evidence Category[1]	Consultant Survey[2]	ASA Member Survey[2]	SPA Member Survey[2]	Guideline Recommendation
Needle insertion, wire and catheter placement:					
Selection of catheter size and type	Strongly agree		Strongly agree		Should be based on the clinical situation and the skill and experience of the practitioner; selection of the smallest size catheter appropriate for the clinical situation should be considered
	B3[19]				Select the smallest size catheter appropriate for the clinical situation
Large-bore catheters associated with unintentional arterial cannulation	D	Agree	Agree		Should be based on the clinical situation and the skill and experience of the operator; the decision to use a catheter-over-the- needle (modified Seldinger) technique or a thin-wall needle (Seldinger) technique should be based at least in part on the method used to confirm that the wire resides in the vein before a dilator or large-bore catheter is threaded
Modified Seldinger *vs.* Seldinger technique	D	Agree	Agree		Should be based on clinical judgment
Limiting the number of insertion attempts					
Introducing two catheters in the same central vein	B2[20]/C3[13,15]	Strongly agree (case-by-case)	Agree (case-by-case)		Should be decided on a case-by-case basis
Guidance of needle placement in elective situations:					
Static ultrasound for preprocedural vessel localization *vs.* landmark approach:					
Internal jugular vein access	A3[21]/C2[22] (elective situations)	Agree	Agree (elective situations)		Use
Subclavian vein access	C2[22]	Equivocal (elective situations)	Equivocal (elective situations)		May be used
Femoral vein access	D	Agree (elective situations)	Equivocal (elective situations)		May be used
Real-time ultrasound for guiding needle *vs.* landmark approach:					
Internal jugular vein access	A1[13,21,22,23]/A2[24] (when available)	Agree	Equivocal (when available)		Use
Subclavian vein access	A2[24]/A3[13,15,16,23]	Equivocal (when available)	Equivocal (when available)		May be used May be used
Femoral vein access	A3[21,24]	Agree (when available)	Equivocal (when available)		

(*continued*)

Table 5. Continued

Interventions	Evidence Category[1]	Consultant Survey[2]	ASA Member Survey[2]	SPA Member Survey[2]	Guideline Recommendation
Verification of venous access:					
Confirm that catheter or thin-wall needle is in a vein		Strongly agree	Strongly agree		Confirm venous access after insertion of catheter that went over the needle or a thin-wall needle
Ultrasound	D				An identified method
Manometry	B2[13]				An identified method
Pressure waveform analysis	D				An identified method
Venous blood gas	D				An identified method
Absence of pulsatility, blood color	D				Should not be relied upon to confirm venous access (based on Task Force opinion)
Confirm venous residence of the wire		Agree	Equivocal		When using the thin-wall needle technique, confirm venous residence of the wire after the wire is threaded
Ultrasound	B2[25]				An identified method
Transesophageal ultrasound	B3[25]				An identified method
Continuous electrocardiography	D				An identified method (based on Task Force opinion)
Fluoroscopy	D				An identified method (based on Task Force opinion)
Confirm both the location of the catheter or thin-wall needle and wire		Agree (when feasible)	Agree (when feasible)		Confirm if there is any uncertainty that the catheter or wire resides in the vein
Verification of catheter placement:					
Confirmation of final position of tip of catheter					Confirm the final position of the catheter tip as soon as clinically appropriate (based on Task Force opinion)
Fluoroscopy	B2[26]	Strongly agree	Agree		An identified method
Chest radiograph	B2[26]	Agree	Agree		An identified method
Continuous electrocardiography	A2[26]				An identified method
Unintended cannulation of an arterial vessel with a large bore catheter:					
Leave catheter in place (patient age not specified)	B3[27]	Agree	Agree		For adults, the catheter should be left in place and a general surgeon, a vascular surgeon, or an interventional radiologist should be immediately consulted
For neonates				Majority prefer leaving in place	Should be based on clinical judgment
For infants				Majority prefer nonsurgical removal	Should be based on clinical judgment

(*continued*)

Table 5. Continued

Interventions	Evidence Category[1]	Consultant Survey[2]	ASA Member Survey[2]	SPA Member Survey[2]	Guideline Recommendation
For children				Majority prefer Nonsurgical removal	Should be based on clinical judgment

* Categories of evidence for literature: Category A: Supportive Literature. Randomized controlled trials report statistically significant ($P < 0.01$) differences between clinical interventions for a specified clinical outcome. Level 1: The literature contains multiple randomized controlled trials, and aggregated findings are supported by meta-analysis. † Level 2: The literature contains multiple randomized controlled trials, but the number of studies is insufficient to conduct a viable meta-analysis for the purpose of these Guidelines. Level 3: The literature contains a single randomized controlled trial. Category B: Suggestive Literature. Information from observational studies permits inference of beneficial or harmful relationships among clinical interventions and clinical outcomes. Level 1: The literature contains observational comparisons (*e.g.*, cohort, case-control research designs) of clinical interventions or conditions and indicates statistically significant differences between clinical interventions for a specified clinical outcome. Level 2: The literature contains noncomparative observational studies with associative (*e.g.*, relative risk, correlation) or descriptive statistics. Level 3: The literature contains case reports. Category C: Equivocal Literature. The literature cannot determine whether there are beneficial or harmful relationships among clinical interventions and clinical outcomes. Level 1: Meta-analysis did not find significant differences ($P > 0.01$) among groups or conditions. Level 2: The number of studies is insufficient to conduct meta-analysis, and (1) randomized controlled trials have not found significant differences among groups or conditions or (2) randomized controlled trials report inconsistent findings. Level 3: Observational studies report inconsistent findings or do not permit inference of beneficial or harmful relationships. Category D: Insufficient Evidence from Literature. The lack of scientific evidence in the literature is described by the following terms. Inadequate: The available literature cannot be used to assess relationships among clinical interventions and clinical outcomes. The literature either does not meet the criteria for content as defined in the "Focus" of the Guidelines or does not permit a clear interpretation of findings due to methodological concerns (*e.g.*, confounding in study design or implementation). Silent: No identified studies address the specified relationships among interventions and outcomes. [1] All meta-analyses are conducted by the ASA methodology group. Meta-analyses from other sources are reviewed but not included as evidence in this document. [2] Survey data recorded on a 5-point scale: strongly agree - agree - equivocal - disagree - strongly disagree; reported findings represent the median survey response. [3] Catheter-related bloodstream infection. [4] Catheter-related infection and sepsis. [5] Catheter colonization. [6] Catheter-related septice- mia. [7] Catheter-related bacteremia. [8] Catheter-related infection and clinical signs of infection. [9] Anaphylactic shock. [10] Localized contact dermatitis. [11] Microbial contamination of stopcock entry ports. [12] Thrombotic complications. [13] Arterial puncture. [14] Deep vein thrombosis. [15] Hematoma. [16] Successful venipuncture. [17] Pneumothorax, hemothorax, or arrhythmia. [18] Diameter and cross sectional area of right internal jugular vein for patients older than 6 yr. [19] Severe injury (*e.g.*, hemorrhage, hematoma, pseudoaneurysm, arteriovenous fistula, arterial dissection, neurologic injury including stroke, and severe or lethal airway obstruction) may occur. [20] Dysrhythmia. [21] First insertion attempt success rate. [22] Overall successful cannulation rate. [23] Access time. [24] Number of insertion attempts. [25] Confirmation of venous placement of wire. [26] Identifying the position of the catheter tip. [27] Fewer severe complications in adult patients.

References‡‡

1. Chua C, Wisniewski T, Ramos A, Schlepp M, Fildes JJ, Kuhls DA: Multidisciplinary trauma intensive care unit checklist: Impact on infection rates. J Trauma Nurs 2010; 17: 163–6
2. Berenholtz SM, Pronovost PJ, Lipsett PA, Hobson D, Earsing K, Farley JE, Milanovich S, Garrett-Mayer E, Winters BD, Rubin HR, Dorman T, Perl TM: Eliminating catheter-related bloodstream infections in the intensive care unit. Crit Care Med 2004; 32:2014–20
3. Higuera F, Rosenthal VD, Duarte P, Ruiz J, Franco G, Safdar N: The effect of process control on the incidence of central venous catheter-associated bloodstream infections and mortality in intensive care units in Mexico. Crit Care Med 2005; 33:2022–7
4. Miller MR, Griswold M, Harris JM 2nd, Yenokyan G, Huskins WC, Moss M, Rice TB, Ridling D, Campbell D, Margolis P, Muething S, Brilli RJ: Decreasing PICU catheter-associated bloodstream infections: NACHRI's quality transformation efforts. Pediatrics 2010; 125:206–13
5. Pronovost P, Needham D, Berenholtz S, Sinopoli D, Chu H, Cosgrove S, Sexton B, Hyzy R, Welsh R, Roth G, Bander J, Kepros J, Goeschel C: An intervention to decrease catheter-related bloodstream infections in the ICU. N Engl J Med 2006; 355:2725–32
6. Schulman J, Stricof R, Stevens TP, Horgan M, Gase K, Holzman IR, Koppel RI, Nafday S, Gibbs K, Angert R, Simmonds A, Furdon SA, Saiman L, New York State Regional Perinatal Care Centers: Statewide NICU central-line-associated bloodstream infection rates decline after bundles and checklists. Pediatrics 2011; 127:436–44
7. Warren DK, Cosgrove SE, Diekema DJ, Zuccotti G, Climo MW, Bolon MK, Tokars JI, Noskin GA, Wong ES, Sepkowitz KA, Herwaldt LA, Perl TM, Solomon SL, Fraser VJ, Prevension Epicenter Program: A multicenter intervention to prevent catheter-associated bloodstream infections. Infect Control Hosp Epidemiol 2006; 27:662–9
8. Boorman D: Today's electronic checklists reduce likelihood of crew errors and help prevent mishaps. ICAO J 2001: 17–20-36
9. Karl R: Briefings, checklists, geese, and surgical safety. Ann Surg Oncol 2010; 17:8–11
10. Spafford PS, Sinkin RA, Cox C, Reubens L, Powell KR: Prevention of central venous catheter-related coagulase-negative staphylococcal sepsis in neonates. J Pediatr 1994; 125:259–63
11. Vassilomanolakis M, Plataniotis G, Koumakis G, Hajichrastou H, Skouteri H, Dova H, Efremidis AP: Central venous catheter-related infections after bone marrow transplantation in patients with malignancies: A prospective study of short-course vancomycin prophylaxis. Bone Marrow Transplant 1995; 15:77–80
12. Raad II, Hohn DC, Gilbreath BJ, Suleiman N, Hill LA, Bruso PA, Marts K, Mansfield PF, Bodey GP: Prevention of central venous catheter-related infections by using maximal sterile barrier precautions during insertion. Infect Control Hosp Epidemiol 1994; 15:231–8
13. Maki DG, Ringer M, Alvarado CJ: Prospective randomised trial of povidone-iodine, alcohol, and chlorhexidine for prevention of infection associated with central venous and arterial catheters. Lancet 1991; 338:339–43

‡‡ A complete bibliography used to develop these Guidelines, arranged alphabetically by author, is available as Supplemental Digital Content 1, http://links.lww.com/ALN/A783.

14. Parienti JJ, du Cheyron D, Ramakers M, Malbruny B, Leclercq R, Le Coutour X, Charbonneau P, Members of the NACRE Study Group: Alcoholic providone-iodine to prevent central venous catheter colonization: A randomized unit crossover study. Crit Care Med 2004; 32:708–13
15. Bach A, Darby D, Böttiger B, Böhrer H, Motsch J, Martin E: Retention of the antibiotic teicoplanin on a hydromer-coated central venous catheter to prevent bacterial colonization in postoperative surgical patients. Intensive Care Med 1996; 22:1066–9
16. Kamal GD, Pfaller MA, Rempe LE, Jebson PJ: Reduced intravascular catheter infection by antibiotic bonding: A prospective, randomized, controlled trial. JAMA 1991; 265: 2364 – 8
17. Len C, Ruiz-Santana S, Rello J, de la Torre MV, Valls J, Alvarez-Lerma F, Sierra R, Saavedra P, Alvarez-Salgado F: Benefits of minocycline and rifampin-impregnated central venous catheters: A prospective, randomized, double-blind, controlled, multicenter trial. Intensive Care Med 2004; 30:1891–9
18. Thornton J, Todd NJ, Webster NR: Central venous line sepsis in the intensive care unit: A study comparing antibiotic coated catheters with plain catheters. Anaesthesia 1996; 51:1018–20
19. Raad I, Darouiche R, Dupuis J, Abi-Said D, Gabrielli A, Hachem R, Wall M, Harris R, Jones J, Buzaid A, Robertson C, Shenaq S, Curling P, Burke T, Ericsson C: Central venous catheters coated with minocycline and rifampin for the prevention of catheter-related colonization and bloodstream infections: A randomized, double-blind trial. The Texas Medical Center Catheter Study Group. Ann Intern Med 1997;127:267–74
20. Bong JJ, Kite P, Wilco MH, McMahon MJ: Prevention of catheter related bloodstream infection by silver iontophoretic central venous catheters: A randomised controlled trial. J Clin Pathol 2003; 56:731–5
21. Boswald M, Lugauer S, Regenfus A, Braun GG, Martus P, Geis C, Scharf J, Bechert T, Greil J, Guggenbichler J-P: Reduced rates of catheter-associated infection by use of a new silver-impregnated central venous catheter. Infection 1999;27:56 – 60
22. Hagau N, Studnicska D, Gavrus RL, Csipak G, Hagau R, Slavcovici AV: Central venous catheter colonization and catheter-related bloodstream infections in critically ill patients: A comparison between standard and silver-integrated catheters. Eur J Anaesthesiol 2009; 26:752–8
23. Harter C, Salwender HJ, Bach A, Egerer G, Goldschmidt H, Ho AD: Catheter-related infection and thrombosis of the internal jugular vein in hematologic-oncologic patients undergoing chemotherapy: A prospective comparison of silver-coated and uncoated catheters. Cancer 2002; 94:245–51
24. Kalfon P, de Vaumas C, Samba D, Boulet E, Lefrant JY, Eyraud D, Lherm T, Santoli F, Naija W, Riou B: Comparison of silver-impregnated with standard multi-lumen central venous catheters in critically ill patients. Crit Care Med 2007; 35:1032–9
25. Bach A, Schmidt H, Bttiger B, Schreiber B, Bhrer H, Motsch J, Martin E, Sonntag HG: Retention of antibacterial activity and bacterial colonization of antiseptic-bonded central venous catheters. J Antimicrob Chemother 1996; 37:315–22
26. Brun-Buisson C, Doyon F, Sollet JP, Cochard JF, Cohen Y, Nitenberg G: Prevention of intravascular catheter-related infection with newer chlorhexidine-silver sulfadiazine-coated catheters: A randomized controlled trial. Intensive Care Med 2004; 30:837–43
27. Ciresi DL, Albrecht RM, Volkers PA, Scholten DJ: Failure of antiseptic bonding to prevent central venous catheter-related infection and sepsis. Am Surg 1996; 62:641–6
28. Collin GR: Decreasing catheter colonization through the use of an antiseptic-impregnated catheter: A continuous quality improvement project. Chest 1999; 115:1632–40
29. George SJ, Vuddamalay P, Boscoe MJ: Antiseptic-impregnated central venous catheters reduce the incidence of bacterial colonization and associated infection in immunocompromised transplant patients. Eur J Anaesthesiol 1997; 14:428 –31
30. Hannan M, Juste RN, Umasanker S, Glendenning A, Nightingale C, Azadian B, Soni N: Antiseptic-bonded central venous catheters and bacterial colonisation. Anaesthesia 1999; 54:868 –72
31. Heard SO, Wagle M, Vijayakumar E, McLean S, Brueggemann A, Napolitano LM, Edwards LP, O'Connell FM, Puyana JC, Doern GV: Influence of triple-lumen central venous catheters coated with chlorhexidine and silver sulfadiazine on the incidence of catheter-related bacteremia. Arch Intern Med 1998; 158:81–7
32. Maki DG, Stolz SM, Wheeler S, Mermel LA: Prevention of central venous catheter-related bloodstream infection by use of an antiseptic-impregnated catheter. A randomized, controlled trial. Ann Intern Med 1997; 127:257–66
33. Ostendorf T, Meinhold A, Harter C, Salwender H, Egerer G, Geiss HK, Ho AD, Goldschmidt H: Chlorhexidine and silver-sulfadiazine coated central venous catheters in haematological patients–a double-blind, randomised, prospective, controlled trial. Support Care Cancer 2005; 13:993–1000
34. Rupp ME, Lisco SJ, Lipsett PA, Perl TM, Keating K, Civetta JM, Mermel LA, Lee D, Dellinger EP, Donahoe M, Giles D, Pfaller MA, Maki DG, Sherertz R: Effect of a second-generation venous catheter impregnated with chlorhexidine and silver sulfadiazine on central catheter-related infections: A randomized, controlled trial. Ann Intern Med 2005; 143: 570–80
35. Tennenberg S, Lieser M, McCurdy B, Boomer G, Howington E, Newman C, Wolf I: A prospective randomized trial of an antibiotic- and antiseptic-coated central venous catheter in the prevention of catheter-related infections. Arch Surg 1997; 132:1348 –51
36. van Heerden PV, Webb SAR, Fong S, Golledge CL, Roberts BL: Central venous catheters revisited: Infection rates and an assessment of the new fibrin analysing system brush. Anaesth Intens Care 1996; 24:330–3
37. Logghe C, Van Ossel C, D'Hoore W, Ezzedine H, Wauters G, Haxhe JJ: Evaluation of chlorhexidine and silver-sulfadiazine impregnated central venous catheters for the prevention of bloodstream infection in leukaemic patients: A randomized controlled trial. J Hosp Infect 1997; 37:145–56
38. Pemberton LB, Ross V, Cuddy P, Kremer H, Fessler T, McGurk E: No difference in catheter sepsis between standard and antiseptic central venous catheters. A prospective randomized trial. Arch Surg 1996; 131:986 –9
39. Oda T, Hamasaki J, Kanda N, Mikami K: Anaphylactic shock induced by an antiseptic-coated central venous catheter. ANESTHESIOLOGY 1997; 87:1242–4
40. Stephens R, Mythen M, Kallis P, Davies DW, Egner W, Rickards A: Two episodes of life-threatening anaphylaxis in the same patient to a chlorhexidine-sulphadiazine-coated central venous catheter. Br J Anaesth 2001; 87:306–8
41. Terazawa E, Shimonaka H, Nagase K, Masue T, Dohi S: Severe anaphylactic reaction due to a chlorhexidine-impregnated central venous catheter. ANESTHESIOLOGY 1998; 89:1296 – 8
42. Merrer J, De Jonghe B, Golliot F, Lefrant JY, Raffy B, Barre E, Rigaud JP, Casciani D, Misset B, Bosquet C, Outin H, Brun-Buisson C, Nitenberg G, French Catheter Study Group in Intensive Care: Complications of femoral and subclavian venous catheterization in critically ill patients: A randomized controlled trial. JAMA 2001; 286:700–7
43. Parienti JJ, Thirion M, Mégarbane B, Souweine B, Ouchikhe A, Polito A, Forel JM, Marqué S, Misset B, Airapetian N, Daurel C, Mira JP, Ramakers M, du Cheyron D, Le Coutour X, Daubin C, Charbonneau P, Members of the Cathedia

Study Group: Femoral *vs* jugular venous catheterization and risk of nosocomial events in adults requiring acute renal replacement therapy: A randomized controlled trial. JAMA 2008;299:2413–22

44. Collignon P, Soni N, Pearson I, Sorrell T, Woods P: Sepsis associated with central vein catheters in critically ill patients. Intensive Care Med 1988; 14:227–31
45. Gil RT, Kruse JA, Thill-Baharozian MC, Carlson RW: Triple- *vs* single-lumen central venous catheters: A prospective study in a critically ill population. Arch Intern Med 1989; 149:1139 – 43
46. Gowardman JR, Robertson IK, Parkes S, Rickard CM: Influence of insertion site on central venous catheter colonization and bloodstream infection rates. Intensive Care Med 2008; 34:1038 – 45
47. Lorente L, Henry C, Martín MM, Jiménez A, Mora ML: Central venous catheter-related infection in a prospective and observational study of 2,595 catheters. Crit Care 2005; 9:R631–5
48. McKinley S, Mackenzie A, Finfer S, Ward R, Penfold J: Incidence and predictors of central venous catheter related infection in intensive care patients. Anaesth Intensive Care 1999; 27:164 –9
49. Ramos GE, Bolgiani AN, Patio O, Prezzavento GE, Guastavino P, Durlach R, Fernandez Canigia LB, Benaim F: Catheter infection risk related to the distance between insertion site and burned area. J Burn Care Rehabil 2002; 23:266 –71
50. Levy I, Katz J, Solter E, Samra Z, Vidne B, Birk E, Ashkenazi S, Dagan O: Chlorhexidine-impregnated dressing for prevention of colonization of central venous catheters in infants and children: A randomized controlled study. Pediatr Infect Dis J 2005; 24:676 –9
51. Roberts B, Cheung D: Biopatch: A new concept in antimicrobial dressings for invasive devices. Aust Crit Care 1998; 11:16 –9
52. Timsit JF, Schwebel C, Bouadma L, Geffroy A, Garrouste-Orgeas M, Pease S, Herault MC, Haouache H, Calvino-Gunther S, Gestin B, Armand-Lefevre L, Leflon V, Chaplain C, Benali A, Francais A, Adrie C, Zahar JR, Thuong M, Arrault X, Croize J, Lucet JC, Dressing Study Group: Chlorhexidine-impregnated sponges and less frequent dressing changes for prevention of catheter-related infections in critically ill adults: A randomized controlled trial. JAMA 2009; 301:1231– 41
53. Madeo M, Martin CR, Turner C, Kirkby V, Thompson DR: A randomized trial comparing Arglaes (a transparent dressing containing silver ions) to Tegaderm (a transparent polyurethane dressing) for dressing peripheral arterial catheters and central vascular catheters. Intensive Crit Care Nurs 1998; 14:187–91
54. Garland JS, Alex CP, Mueller CD, Otten D, Shivpuri C, Harris MC, Naples M, Pellegrini J, Buck RK, McAuliffe TL, Goldmann DA, Maki DG: A randomized trial comparing povidone-iodine to a chlorhexidine gluconate-impregnated dressing for prevention of central venous catheter infections in neonates. Pediatrics 2001; 107:1431– 6
55. Moro ML, Viganò EF, Cozzi Lepri A: Risk factors for central venous catheter-related infections in surgical and intensive care units: The Central Venous Catheter-Related Infections Study Group. Infect Control Hosp Epidemiol 1994; 15: 253– 64
56. Bonawitz SC, Hammell EJ, Kirkpatrick JR: Prevention of central venous catheter sepsis: A prospective randomized trial. Am Surg 1991; 57:618 –23
57. Kowalewska-Grochowska K, Richards R, Moysa GL, Lam K, Costerton JW, King EG: Guidewire catheter change in central venous catheter biofilm formation in a burn population. Chest 1991; 100:1090 –5
58. Cobb DK, High KP, Sawyer RG, Sable CA, Adams RB, Lindley DA, Pruett TL, Schwenzer KJ, Farr BM: A controlled trial of scheduled replacement of central venous and pulmonary-ar- tery catheters. N Engl J Med 1992; 327:1062– 8
59. Eyer S, Brummitt C, Crossley K, Siegel R, Cerra F: Catheter-related sepsis: Prospective, randomized study of three methods of long-term catheter maintenance. Crit Care Med 1990; 18:1073–9
60. Kealey GP, Chang P, Heinle J, Rosenquist MD, Lewis RW: Prospective comparison of two management strategies of central venous catheters in burn patients. J Trauma 1995; 38:344 –9
61. Michel LA, Bradpiece HA, Randour P, Pouthier F: Safety of central venous catheter change over guidewire for suspected catheter-related sepsis. A prospective randomized trial. Int Surg 1988; 73:180 – 6
62. Snyder RH, Archer FJ, Endy T, Allen TW, Condon B, Kaiser J, Whatmore D, Harrington G, McDermott CJ: Catheter infection: A comparison of two catheter maintenance techniques. Ann Surg 1988; 208:651–3
63. Casey AL, Burnell S, Whinn H, Worthington T, Faroqui MH, Elliott TS: A prospective clinical trial to evaluate the microbial barrier of a needleless connector. J Hosp Infect 2007; 65:212– 8
64. Casey AL, Worthington T, Lambert PA, Quinn D, Faroqui MH, Elliott TS: A randomized, prospective clinical trial to assess the potential infection risk associated with the PosiFlow needleless connector. J Hosp Infect 2003; 54:288–93
65. Lucet JC, Hayon J, Bruneel F, Dumoulin JL, Joly-Guillou ML: Microbiological evaluation of central venous catheter administration hubs. Infect Control Hosp Epidemiol 2000; 21:40 –2
66. Ybenes JC, Vidaur L, Serra-Prat M, Sirvent JM, Batlle J, Motje M, Bonet A, Palomar M: Prevention of catheter-related bloodstream infection in critically ill patients using a disinfectable, needle-free connector: A randomized controlled trial. Am J Infect Control 2004; 32:291–5
67. Kaiser CW, Koornick AR, Smith N, Soroff HS: Choice of route for central venous cannulation: Subclavian or internal jugular vein? A prospective randomized study. J Surg Oncol 1981; 17:345–54
68. Eisenhauer ED, Derveloy RJ, Hastings PR: Prospective evaluation of central venous pressure (CVP) catheters in a large city-county hospital. Ann Surg 1982; 196:560
69. Molgaard O, Nielsen MS, Handberg BB, Jensen JM, Kjaergaard J, Juul N: Routine X-ray control of upper central venous lines: Is it necessary? Acta Anaesthesiol Scand 2004; 48:685–9
70. Sznajder JI, Zveibil FR, Bitterman H, Weiner P, Bursztein S: Central vein catheterization: Failure and complication rates by three percutaneous approaches. Arch Intern Med 1986; 146:259 – 61
71. Armstrong PJ, Sutherland R, Scott DH: The effect of position and different manoeuvres on the internal jugular vein diameter size. Acta Anaesth Scand 1994; 38:229 –31
72. Bellazzini MA, Rankin PM, Gangnon RE, Bjoernsen LP: Ultrasound validation of maneuvers to increase internal jugular vein cross-sectional area and decrease compressibility. Am J Emerg Med 2009; 27:454 –9
73. Modeliar SS, Sevestre MA, de Cagny B, Slama M: Ultrasound evaluation of central veins in the intensive care unit: Effects of dynamic manoeuvres. Intensive Care Med 2008; 34:333– 8
74. Parry G: Trendelenburg position, head elevation and a midline position optimize right internal jugular vein diameter. Can J Anaesth 2004; 51:379 – 81
75. Suarez T, Baerwald JP, Kraus C: Central venous access: The effects of approach, position, and head rotation on internal jugular vein cross-sectional area. Anesth Analg 2002; 95: 1519 –24
76. Tugrul M, Camci E, Pembeci K, Al-Darsani A, Telci L: Relation-

ship between peripheral and central venous pressures in dif- ferent patient positions, catheter sizes, and insertion sites. J Cardiothorac Vasc Anesthesia 2004; 18:446–50

77. Sayin MM, Mercan A, Koner O, Ture H, Celebi S, Sozubir S, Aykac B: Internal jugular vein diameter in pediatric patients: Are the J-shaped guidewire diameters bigger than internal jugular vein? An evaluation with ultrasound Paediatr Anaesth 2008; 18:745–51
78. Brown CQ: Inadvertent prolonged cannulation of the carotid artery. Anesth Analg 1982; 61:150–2
79. Digby S: Fatal respiratory obstruction following insertion of a central venous line. Anaesthesia 1994; 49:1013–4
80. Guilbert MC, Elkouri S, Bracco D, Corriveau MM, Beaudoin N, Dubois MJ, Bruneau L, Blair JF: Arterial trauma during central venous catheter insertion: Case series, review and proposed algorithm. J Vasc Surg 2008; 48:918–25, discussion 925
81. Farhat K, Nakhjavan K, Cope C, Yazdanfar S, Fernandez J, Gooch A, Goldberg H: Iatrogenic arteriovenous fistula: A complicaton of percutaneous subclavian vein puncture. Chest 1975; 67:480–2
82. Kulvatunyou N, Heard SO, Bankey PE: A subclavian artery injury, secondary to internal jugular vein cannulation, is a predictable right-sided phenomenon. Anesth Analg 2002; 95:564–6
83. Maschke SP, Rogove HJ: Cardiac tamponade associated with a multilumen central venous catheter. Crit Care Med 1984; 12:611–3
84. Nicholson T, Ettles D, Robinson G: Managing inadvertent arterial catheterization during central venous access procedures. Cardiovasc Intervent Radiol 2004; 27:21–5
85. Powell H, Beechey AP: Internal jugular catheterisation: Case report of a potentially fatal hazard. Anaesthesia 1990; 45:458–9
86. Shah PM, Babu SC, Goyal A, Mateo RB, Madden RE: Arterial misplacement of large-caliber cannulas during jugular vein catheterization: Case for surgical management. Am Coll Surg 2004; 198:939–44
87. Sloan MA, Mueller JD, Adelman LS, Caplan LR: Fatal brainstem stroke following internal jugular vein catheterization. Neurology 1991; 41:1092–5
88. Zaidi NA, Khan M, Naqvi HI, Kamal RS: Cerebral infarct following central venous cannulation. Anaesthesia 1998; 53:186–91
89. Reeves ST, Roy RC, Dorman BH, Fishman RL, Pinosky ML: The incidence of complications after the double-catheter technique for cannulation of the right internal jugular vein in a university teaching hospital. Anesth Analg 1995; 81:1073–6
90. Milling TJ Jr., Rose J, Briggs WM, Birkhahn R, Gaeta TJ, Bove JJ, Melniker LA: 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 2005; 33:1764–9
91. Alderson PJ, Burrows FA, Stemp LI, Holtby HM: Use of ultrasound to evaluate internal jugular vein anatomy and to facilitate central venous cannulation in paediatric patients. Br J Anaesth 1993; 70:145–8
92. Hayashi H, Amano M: Does ultrasound imaging before puncture facilitate internal jugular vein cannulation? Prospective randomized comparison with landmark-guided puncture in ventilated patients. J Cardiothorac Vasc Anesth 2002; 16:572–5
93. Mansfield PF, Hohn DC, Fornage BD, Gregurich MA, Ota DM: Complications and failures of subclavian-vein catheterization. N Engl J Med 1994; 331:1735–8
94. Bansal R, Agarwal SK, Tiwari SC, Dash SC: A prospective randomized study to compare ultrasound-guided with non-ultrasound-guided double lumen internal jugular catheter insertion as a temporary hemodialysis access. Ren Fail 2005; 27:561–4
95. Cajozzo M, Quintini G, Cocchiera G, Greco G, Vaglica R, Pezzano G, Barbera V, Modica G: Comparison of central venous catheterization with and without ultrasound guide. Transfus Apher Sci 2004; 31:199–202
96. Grebenik CR, Boyce A, Sinclair ME, Evans RD, Mason DG, Martin B: NICE guidelines for central venous catheterization in children. Is the evidence base sufficient? Br J Anaesth 2004; 92:827–30
97. Karakitsos D, Labropoulos N, De Groot E, Patrianakos AP, Kouraklis G, Poularas J, Samonis G, Tsoutsos DA, Konstadoulakis MM, Karabinis A: Real-time ultrasound-guided catheterisation of the internal jugular vein: A prospective comparison with the landmark technique in critical care patients. Crit Care 2006; 10:R162
98. Koroglu M, Demir M, Koroglu BK, Sezer MT, Akhan O, Yildiz H, Yavuz L, Baykal B, Oyar O: Percutaneous placement of central venous catheters: Comparing the anatomical landmark method with the radiologically guided technique for central venous catheterization through the internal jugular vein in emergency hemodialysis patients. Acta Radiol 2006; 47:43–7
99. Mallory DL, McGee WT, Shawker TH, Brenner M, Bailey KR, Evans RG, Parker MM, Farmer JC, Parillo JE: Ultrasound guidance improves the success rate of internal jugular vein cannulation: A prospective, randomized trial. Chest 1990; 98:157–60
100. Slama M, Novara A, Safavian A, Ossart M, Safar M, Fagon JY: Improvement of internal jugular vein cannulation using an ultrasound-guided technique. Intensive Care Med 1997; 23: 916–9
101. Teichgrber UKM, Benter T, Gebel M, Manns MP: A sonographically guided technique for central venous access. AJR Am J Roentgenol 1997; 169:731–3
102. Troianos CA, Jobes DR, Ellison N: Ultrasound-guided cannulation of the internal jugular vein: A prospective, randomized study. Anesth Analg 1991; 72:823–6
103. Verghese ST, McGill WA, Patel RI, Sell JE, Midgley FM, Ruttimann UE: Comparison of three techniques for internal jugular vein cannulation in infants. Paediatr Anaesth 2000; 10:505–11
104. Verghese ST, McGill WA, Patel RI, Sell JE, Midgley FM, Ruttimann UE: Ultrasound-guided internal jugular venous cannulation in infants: A prospective comparison with the traditional palpation method. ANESTHESIOLOGY 1999; 91:71–7
105. Gualtieri E, Deppe SA, Sipperly ME, Thompson DR: Subclavian venous catheterization: Greater success rate for less experienced operators using ultrasound guidance. Crit Care Med 1995; 23:692–7
106. Fragou M, Gravvanis A, Dimitriou V, Papalois A, Kouraklis G, Karabinis A, Saranteas T, Poularas J, Papanikolaou J, Davlouros P, Labropoulos N, Karakitsos D: Real-time ultrasound-guided subclavian vein cannulation versus the landmark method in critical care patients: A propsective randomized study. Crit Care Med 2011; 39:1607–12
107. Aouad MT, Kanazi GE, Abdallah FW, Moukaddem FH, Turbay MJ, Obeid MY, Siddik-Sayyid SM: Femoral vein cannulation performed by residents: A comparison between ultrasound-guided and landmark technique in infants and children undergoing cardiac surgery. Anesth Analg 2010; 111:724–8
108. Ezaru CS, Mangione MP, Oravitz TM, Ibinson JW, Bjerke RJ: Eliminating arterial injury during central venous catheterization using manometry. Anesth Analg 2009; 109:130–4
109. Gillman LM, Blaivas M, Lord J, Al-Kadi A, Kirkpatrick W: Ultrasound confirmation of guidewire position may eliminate accidental arterial dilatation during central venous cannulation. Scand J Trauma 2010; 18:39
110. Gu X, Paulsen W, Tisnado J, He Y, Li Z, Nixon JV: Malpo-

sition of a central venous catheter in the right main pulmo- nary artery detected by transesophageal echocardiography. J Am Soc Echocardiogr 2009; 22:1420

111. Mahmood F, Sundar S, Khabbaz K: Misplacement of a guide- wire diagnosed by transesophageal echocardiography. J Cardiothorac Vasc Anesth 2007; 21:420–1
112. Sawchuk C, Fayad A: Confirmation of internal jugular guide wire position utilizing transesophageal echocardiography. Can J Anaesth 2001; 48:688–90
113. Janik JE, Cothren CC, Janik JS, Hendrickson RJ, Bensard DD, Partrick DA, Karrer FM: Is a routine chest x-ray necessary for children after fluoroscopically assisted central venous access? J Pediatr Surg 2003; 38:1199–202
114. Lucey B, Varghese JC, Haslam P, Lee MJ: Routine chest radiographs after central line insertion: Mandatory postpro- cedural evaluation or unnecessary waste of resources? Car- diovasc Intervent Radiol 1999; 22:381–4
115. Gebhard RE, Szmuk P, Pivalizza EG, Melnikov V, Vogt C, Warters RD: The accuracy of electrocardiogram-controlled central line placement. Anesth Analg 2007; 104:65–70
116. Abood GJ, Davis KA, Esposito TJ, Luchette FA, Gamelli RL: Comparison of routine chest radiograph *versus* clinician judgment to determine adequate central line placement in critically ill patients. J Trauma 2007; 63:50–6
117. Amshel CE, Palesty JA, Dudrick SJ: Are chest X-rays mandatory following central venous recatheterization over a wire? Am Surg 1998; 64:499–501; discussion 501–2
118. Bailey SH, Shapiro SB, Mone MC, Saffle JR, Morris SE, Barton RG: Is immediate chest radiograph necessary after central venous catheter placement in a surgical intensive care unit? Am J Surg 2000; 180:517–21; discussion 521–2
119. Cullinane DC, Parkus DE, Reddy VS, Nunn CR, Rutherford EJ: The futility of chest roentgenograms following routine central venous line changes. Am J Surg 1998; 176:283–5
120. Frassinelli P, Pasquale MD, Cipolle MD, Rhodes M: Utility of chest radiographs after guidewire exchanges of central venous catheters. Crit Care Med 1998; 26:611–5
121. Lessnau KD: Is chest radiography necessary after uncom- plicated insertion of a triple-lumen catheter in the right internal jugular vein, using the anterior approach? Chest 2005; 127:220–3
122. Maury E, Guglielminotti J, Alzieu M, Guidet B, Offenstadt G: Ultrasonic examination: An alternative to chest radiography after central venous catheter insertion? Am J Respir Crit Care Med 2001; 164:403–5
123. Riblet JL, Shillinglaw W, Goldberg AJ, Mitchell K, Sedani KH, Davis FE, Reynolds HN: Utility of the routine chest X-ray after "over-wire" venous catheter changes. Am Surg 1996; 62:1064–5
124. Weil BR, Ladd AP, Yoder K: Pericardial effusion and cardiac tamponade associated with central venous catheters in chil- dren: An uncommon but serious and treatable condition. J Pediatr Surg 2010; 45:1687–92
125. Wirsing M, Schummer C, Neumann R, Steenbeck J, Schmidt P, Schummer W: Is traditional reading of the bedside chest radiograph appropriate to detect intraatrial central ve- nous catheter position? Chest 2008; 134:527–33
126. Francis KR, Picard DL, Fajardo MA, Pizzi WF: Avoiding complications and decreasing costs of central venous cath- eter placement utilizing electrocardiographic guidance. Surg Gynecol Obstet 1992; 175:208–11
127. McGee WT, Ackerman BL, Rouben LR, Prasad VM, Bandi V, Mallory DL: Accurate placement of central venous cathe- ters: A prospective, randomized, multicenter trial. Crit Care Med 1993; 21:1118–23
128. O'Grady NP, Alexander M, Burns LA, Dellinger EP, Garland J, Heard SO, Lipsett PA, Masur H, Mermel LA, Pearson ML, Raad II, Randolph AG, Rupp ME, Saint S, Healthcare Infection Con- trol Practices Advisory Committee. Guidelines for the preven- tion of intravascular catheter related infections. Am J Infect Control 2011; 39(4 Suppl 1):S1–34
129. Marschall J, Mermel LA, Classen D, Arias KM, Podgorny K, An- derson DJ, Burstin H, Calfee DP, Coffin SE, Dubberke ER, Fraser V, Gerding DN, Griffin FA, Gross P, Kaye KS, Klompas M, Lo E, Nicolle L, Pegues DA, Perl TM, Saint S, Salgado CD, Weinstein RA, Wise R, Yokoe DS: Strategies to prevent central line-associated bloodstream infections in acute care hospitals. Infect Control Hosp Epidemiol 2008; 29(Suppl 1):S22–30
130. Institute for Healthcare Improvement: Prevent Central Line Infections How-to Guide. Cambridge, MA; 2008
131. The Joint Commission Accreditation Program: Hospital: Na- tional patient safety goals. http://www.jointcommission. org/assets/1/6/2011_NPSGs_HAP.pdf. Accessed January 1, 2011
132. National Institute for Clinical Excellence: Guidance on the use of ultrasound locating devices for placing central venous catheters. http://www.nice.org.uk/nicemedia/pdf/49_English_patient. pdf. Accessed September 2012