Review Article

Clinical guidelines on central venous catheterisation

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Safe and reliable venous access is mandatory in modern health care, but central venous catheters (CVCs) are associated with significant morbidity and mortality, This paper describes current Swedish guidelines for clinical management of CVCs The guidelines supply updated recommendations that may be useful in other countries as well. Literature retrieval in the Cochrane and Pubmed databases, of papers written in English or Swedish and pertaining to CVC management, was done by members of a task force of the Swedish Society of Anaesthesiology and Intensive Care Medicine. Consensus meetings were held throughout the review process to allow all parts of the guidelines to be embraced by all contributors. All of the content was carefully scored according to criteria by the Oxford Centre for Evidence-Based Medicine. We aimed at producing useful and reliable guidelines on bleeding diathesis, vascular approach, ultrasonic guidance, catheter tip positioning, prevention and management of associated trauma and infection, and specific training and follow-up. A structured patient history focused on bleeding should be taken prior to insertion of a CVCs. The right internal jugular vein should primarily be chosen for insertion of a wide-bore CVC. Catheter tip positioning in the right atrium or lower third of the superior caval vein should be verified for long-term use. Ultrasonic guidance should be used for catheterisation by the internal jugular or femoral veins and may also be used for insertion via the subclavian veins or the veins of the upper limb. The operator inserting a CVC should wear cap, mask, and sterile gown and gloves. For long-term intravenous access, tunnelled CVC or subcutaneous venous ports are preferred. Intravenous position of the catheter tip should be verified by clinical or radiological methods after insertion and before each use. Simulator-assisted training of CVC insertion should precede bedside training in patients. Units inserting and managing CVC should have quality assertion programmes for implementation and follow-up of routines, teaching, training and clinical outcome. Clinical guidelines on a wide range of relevant topics have been introduced, based on extensive literature retrieval, to facilitate effective and safe management of CVCs.

S UBOPTIMAL clinical use of central venous catheters (CVCs), intended for safe and reliable vascular access, may influence patient morbidity and even mortality. Current guidelines by others on various aspects of vascular access have been limited to short-term access,[1] to the prevention of infection,[2] or to haematological[3] or renal[4] problems.

This paper, based on extended review of the literature, reports updated national guidelines for clinical management of CVC in adults set by a task force of the Swedish Society of Anaesthesiology and Intensive Care Medicine (SFAI) based on current scientific evidence and empirical experience regarding insertion and management of non-tunnelled CVC, tunnelled CVC with anchoring cuffs, dialysis catheters, implanted subcutaneous ports, and peripherally inserted CVCs (PICCs).

Methods

A task force was recently commissioned by the SFAI to design national guidelines for management of

CVC in Sweden based on current scientific and empirical knowledge (Table 1).

Literature retrieval, in the Cochrane and Pubmed database (Appendix 1), of papers written in English or Swedish, and pertaining to CVC management, was done by the members of the task force according to agreed individual responsibilities for specific relevant topics. After this initial screening of the literature, all articles considered relevant to key issues were objectively evaluated, while only those with the highest available evidence were subsequently included in the review.

Each subtopic was discussed during the task force meetings, and disagreements regarding evaluation of evidence and focus of the guidelines were handled by group discussions aiming at consensus.

Six consensus meetings were arranged during the 2-year working process to enable all parts of the guidelines to be embraced by all contributors. All of the content was carefully graded according to criteria by the Oxford Centre for Evidence-Based Medicine (Appendix 2). Expert opinion was considered as appropriate surrogate for low-grade scientific evidence (also indicated as evidence level 5, expert opinion).

Bleeding diathesis

Bleeding associated with CVC insertion has a reported incidence of 0.5–1.6%[5] but is rarely fatal. In case reports, fatal outcome due to bleeding is most often considered a consequence of inadequate technique or management rather than bleeding diathesis.[6,7]

Bleeding complications associated with CVC removal are rare[8,9] and have not been reported to be associated with moderately decreased platelet count and/or increased prothrombin time – international normalised ratio (PT-INR) levels.[10]

A structured assessment of bleeding diathesis (including heredity, history of bleeding, complications associated with previous surgery, and drugs affecting coagulation) should be made before CVC insertion. Laboratory tests should then be omitted if no coagulation disorder is suspected[11–13] (evidence level 3, recommendation grade B). Mechanical tests of bleeding time are unreliable and should not be used in this context.[14]

In patients with significantly abnormal coagulation tests or clinically suspected coagulation disorder, an easily compressible vessel should be chosen and the catheter inserted by an experienced operator using optimal techniques[6,7,15] (A. Larsson,

unpublished data, 2009) (evidence level 2a, recommendation grade B). There is no scientific evidence for preferring cut-down to percutaneous techniques in patients with coagulation disorders[16] (evidence level 2b, recommendation grade B).

Coagulation disorders should not be reversed routinely, e.g. by administration of fresh frozen plasma, tranexamic acid, desmopressin, vitamin K, or platelets, but pharmacological treatment may be considered in selected patients[11,17] (evidence level 2a, recommendation grade B).

For non-tunnelled catheters, platelet count levels below $50\ 10^9$/l have been reported to be associated with increased risk of bleeding or haematoma formation, and catheterisations should be done by experienced operators using optimal techniques[18,19] (evidence level 2a, recommendation grade B).

Moderately prolonged activated partial thromboplastin time (APTT) levels do not increase the risk of bleeding or haematoma formation. In our opinion, levels of up to 1.3 times the upper reference interval in the absence of other coagulation disorder do not increase the risk of bleeding and are acceptable for routine cannulation[12,18,20–24] (evidence level 4, recommendation grade C). In contrast, moderately increased APTT levels may indicate severe coagulation disorder in patients with haemophilia (evidence level 5, expert opinion, recommendation grade D).

Levels of PT-INR at or below 1.8 have not been reported to be associated with higher risk of bleeding or haematoma formation[11,18,19,21,23] (evidence level 3b, recommendation grade B).

Several drugs influencing haemostasis merit added vigilance. Routine procedures are adequate in patients on monotherapy with acetylsalicylic acid, non-steroidal anti-inflammatory drugs or prophylactic anticoagulants (e.g., low-dose heparin, low-molecular-weight heparin, pentasackarides, thrombin inhibitors) (recommendation grade D). However, if these drugs are combined, in particular clopidogrel and acetylsalicylic acid, patients should be catheterised by experienced operators using the safest possible techniques[25] (recommendation grade D).

Patients with haemophilia are often given factor concentrate before catheterisation despite weak evidence for this practice[26] (evidence level 5, expert opinion, recommendation grade D).

Vascular access site

CVCs are commonly inserted via the internal jugular, external jugular, subclavian, or femoral veins. There

Table 1

Summary of the National Guidelines for Central Venous Catheterisation in Sweden, based on current international scientific and empirical knowledge, and endorsed by the Swedish Society of Anaesthesiology and Intensive Care Medicine in 2010 for safer management of central venous catheters in Scandinavia.

National Guidelines for Central Venous Catheter (CVC) Management in Sweden

Bleeding diathesis
A structured patient history focused on bleeding should be taken prior to insertion of a central venous catheter (C).
Patients without a history of or symptoms of a coagulation disorder do not require coagulation tests prior to insertion of a CVC (B).
In patients with bleeding diathesis, CVC should be inserted by an experienced operator using optimal technique (B).
Reversal of coagulation disorders may be considered but should not be done routinely (B).
Platelet count $\geq 50 \cdot 10^9$/l, prothrombin time (PT-INR) $\leq 1,8$ or activated partial thromboplastin time (APTT) $\leq 1,3$ times the upper normal range are considered limits for routine CVC insertion in patients with no bleeding diathesis (B,C).
Routine CVC insertion may be done despite monotherapy with acetyl salicylic acid, a non-steroid anti-inflammatory drug or a prophylactic anticoagulant (heparins, pentasacharides, or thrombin inhibitors) (D).
Vascular access site
The right internal jugular vein should primarily be chosen for insertion of a wide-bore CVC (≥ 10 Fr) (B).
For long-term access, the subclavian veins and the veins of the arm should be avoided in patients requiring, or possibly requiring, haemodialysis, and in patients where ipsilateral mastectomy has been, or will be, carried out (B).
The subclavian veins should be avoided in patients with coagulopathy (D).
Catheter tip positioning
Catheter tip positioning in the right atrium or lower third of the superior caval vein should be verified for long-term use, haemofiltration/dialysis, central venous pressure measurement or infusion of tissue-toxic agents (e.g., chemotherapy) (C).
Control by chest X-ray should be done with the patient supine (C).
Pre-operative flouroscopy may be used to guide correct catheter positioning for long-term use and post-operative chest X-ray is then required only if complications are suspected (B).
Ultrasonic guidance
Ultrasonic guidance should be used for catheterisation by the internal jugular or femoral veins, and may also be used for insertion via the subclavian veins or the veins of the upper limb (B).
Associated infection
Central venous catheters should be inserted and managed under sterile conditions (A).
Pre-operative hair shortening may be done when indicated (D).
The operator inserting a CVC should wear cap, mask, and sterile gown and gloves (A).
Multiple lumen catheters may be used when indicated, but the number of lumens should be kept at a minimum (B).
For long-term intravenous access, tunnelled CVC or subcutaneous venous ports are preferred (A).
Clinical routines and the incidence of CVC-associated bacterial colonisation and infection should be monitored continuously (A).
Catheters with antimicrobial coating, and daily total-body desinfection with chlorhexidine in intensive care patients, may be considered to reduce unacceptably high CVC-associated infection rates despite correctly implemented hygiene routines (A).
Routine prophylactic antibiotic administration before catheterisation is not recommended (A)
A monofilament suture should be used for fixing catheters for short-term use (C), and a sterile cotton dressing or a semipermeable polyurethane film should cover the site (A).
The entry site should be inspected, and the patient should be evaluated for signs of infection, regularly (A).
Sterile dressings should be changed at least every seventh day and more often if indicated (B).
Dressings containing chlorhexidine sponges may be considered (A).
Needleless membranes should be connected to each CVC port (C) and be appropriately disinfected before each use (A).
Injectable membranes, connectors, and valves connected to the CVC should be changed every third day in in-hospital patients and at least weekly in outpatient care (C).
Heparin or antibiotic locks for the purpose of reducing the rate of CVC-related infection should be considered only for long-term access in immunocompromised patients (B).
Cultures from the blood and catheter tip should be obtained in suspected CVC-associated infection (C).
When a culture from the catheter tip is to be obtained, the skin around the CVC should be disinfected with chlorhexidine-ethanol solution and allowed to dry before CVC extraction (D).
Associated mechanical trauma
The decision to adjust the position of a CVC should be based on both clinical and radiological findings (C).
A chest X-ray should be made when pneumothorax or haemothorax is suspected (C).
Patients prone to cardiac dysrhythmia should be subjected to electrocardiogram monitoring during insertion, and neither the guidewire nor the catheter should be allowed to enter the heart (D).
In accidental arterial catheterisation regardless of catheter dimension at a non-compressible site and also for catheters > 7 Fr regardless of site, the catheter should be secured in place and a vascular surgeon be consulted (C).
To minimise the risk of nerve damage, multiple punctures should be minimised by using ultrasonic guidance when possible (D).
The risk of venous air embolism is minimised by head-down patient positioning during catheter insertion and extraction, and by applying a tight dressing immediately after extraction (D).
Associated venous thrombo-embolism
For long-term vascular access in patients undergoing haemodialysis, an arteriovenous fistula should be preferred to a CVC because of lower risks of dysfunction and associated infection and venous thrombosis (A).
Routine use of anticoagulants to prevent CVC-associated thrombosis is not recommended (D).
Routine treatment of asymptomatic CVC-associated thrombosis is not recommended (D).
Anticoagulants should be given to patients with symptomatic associated deep venous thrombosis (B).
Whether the CVC should be removed or not in a patient with symptomatic CVC-associated venous thrombosis depends on the need for continued central venous access and anticipated problems with recatheterisation (B).
Thrombolytic therapy should only be given to patients with life-threatening-associated deep venous thrombosis (B).
Catheter dysfunction
Intravenous position of the catheter tip should be verified by clinical or radiological methods after insertion and before each use (B).
Central venous catheters should be flushed with saline after each use (B).
Thrombolytic drugs may be used in thrombosis-related catheter occlusion (B).
Ethanol, hydrochloric acid or sodium hydroxide may be injected in catheter occlusion due to sedimentation of drugs or lipids (C).
Changing the CVC over a guidewire should be considered when the above measures have failed (B).
Patients with previous long-term central venous access should undergo mapping of the central venous system by computerised tomography or magnetic resonance imaging before recatheterisation, and endovascular expertise should be consulted in those with verified central venous stenosis (C).
Training and follow-up
Simulator-assisted training of CVC insertion should precede bedside training in patients (B).
Central venous catheterisation, with and without ultrasonic guidance, should be continuously practiced (D).
Units inserting and managing CVC should have quality assertion programmes for implementation and follow-up of routines, teaching, training, and clinical outcome (A).

Capitals in parentheses (A–D) indicate grades of clinical recommendation according to criteria set by the Oxford Centre for Evidence-Based Medicine, revised in 2009.

Table 2

Clinical aspects considered relevant for central venous catheterisation of specific veins.

Vein	Clinical aspects	
	Supporting choice of vein for vascular access	Discouraging choice of vein for vascular access
Internal jugular	Ultrasonic guidance easier External compression possible Lower risk of mechanical complications Lower risk of thrombosis or stenosis	Patient discomfort
Subclavian	Patient comfort	Ultrasonic guidance more difficult External compression difficult or even impossible Higher risk of pneumothorax/haemothorax Higher risk of thrombosis or stenosis (particularly during long-term use) Risk of pinch-off syndrome (during long-term use)
Femoral	Ultrasonic guidance easier External compression possible	Higher risk of thrombosis Patient discomfort

Individual patient- (e.g., venous thrombosis, coagulopathy, vascular anatomy) and operator- (e.g. clinical skills, experience) associated issues should also be considered.

is no unequivocal evidence, based on controlled, randomised trials, for choosing particular locations under specific clinical conditions (Table 2).

Aspects on associated mechanical trauma

Cannulation of the internal jugular veins is associated with lower incidence of pneumothorax than of the subclavian veins.[27] A randomised study of dialysis catheters reported similar incidences of associated infection, but more associated bleeding, in internal jugular compared with femoral cannulations[28] (evidence level 1b). The risk of malfunction was found to be higher in dialysis catheters inserted via the left internal jugular vein compared with the right internal jugular vein or the femoral veins[29] (evidence level 2b). Cannulation-induced bleeding with haematoma formation is uncommon but has been reported to have compromised the upper airway after jugular or (particularly) carotid puncture, and to be difficult to manage by external compression after subclavian puncture.[30]

Aspects on associated infection

For short-term use, the subclavian veins have been reported to be associated with lower incidence of associated infection than the internal jugular or femoral veins.[31,32] However, according to a recent meta-analysis, there is no difference in the incidence of catheter-associated blood-borne infection between those three sites of vascular access, probably as a result of the implementation of new procedures and techniques for prevention[33] (evidence level 1b). Furthermore, possible benefits of a lower risk of infection associated with subclavian cannulation should be weighed against a higher

risk of mechanical complications, e.g., pneumothorax or bleeding[31,32,34–39] (evidence level 2b). In intensive care settings, the risk of CVC-associated infection seems to be similar in internal jugular and femoral cannulations[28] (evidence level 1b). The basilic and cephalic veins are commonly used for introduction of PICC. Their risks of cannulation-associated infection may be similar to those of the subclavian and internal jugular veins[40,41] (evidence level 2b).

Aspects on associated thromboembolism

Dialysis catheters have been reported to be associated with higher incidence of thrombosis or stenosis in the subclavian than in the internal jugular veins[42,43] (evidence level 2b), and the incidence is even higher in the femoral veins[31,44] (evidence level 1b). Two studies have reported higher incidences of thrombosis after CVC insertion by the left compared with the right, internal jugular, or subclavian veins in patients with malignant disease[45,46] (evidence level 4), but no difference between the left and right sides was found in a later prospective study[47] (evidence level 2c). The risk of thromboembolic complications for small-bore catheters, including those inserted by peripheral routes, is not well defined, but PICC inserted via arm veins have been reported to be associated with more local and central venous thrombosis.[41] Because thromboses in subclavian and/or arm veins may render future establishment of arteriovenous fistulas for haemodialysis more difficult, these veins should be avoided for long-term central venous access in patients who might require future haemodialysis[4,48,49] (evidence level 2a, recommendation grade B).

Catheter tip positioning

There are no conclusive studies on optimal catheter tip positioning.[4,50–54] Radiographic verification of the catheter tip position is influenced by the position of the patient,[55,56] but anatomical variation[57] (evidence level 4) and radiological landmarks may also influence radiographic interpretation of the catheter tip position[50,57] (evidence level 2b).

With respect to the risk of complications or catheter dysfunction, optimal tip positioning of catheters inserted via jugular, subclavian, or arm veins has been suggested to be within the inferior part of the superior caval vein[58,59] or within the right atrium[4] (evidence level 5, expert opinion). Nevertheless, cases of perforation,[50,60] thrombosis,[61–64] and catheter dysfunction[65] have been reported regardless of the initial catheter position (evidence level 4).

Case reports of cardiac tamponade associated with catheter tips positioned within the right atrium[66] have led the American Federal Drug Administration to recommend right atrial tip positioning to be avoided. However, erosive perforation has almost exclusively been described for rigid catheter materials[67,68] (evidence level 4). In clinical practice, those materials have gradually been replaced by more flexible ones, e.g., silicone or polyurethane.

Five[69–73] out of seven[46,69–74] non-randomised, retrospective studies in patients with known malignant disease have reported increased risk of symptomatic venous thrombosis to be associated with tip positioning peripherally to the right atrium (evidence level 4). The remaining two studies[46,74] were inconclusive in this respect.

For intermittent haemodialysis, right atrial catheter tip positioning may be necessary to maintain high blood flow, which is also why the American National Kidney Foundation recommends the catheter tip to be placed within or close to the right atrium.[4,52] For continuous haemodialysis, calling for lower rates of blood flow, a position in the superior caval vein is often adequate.[75]

Optimal catheter tip positioning via the femoral veins has not been well elucidated, but for long-term use, the catheter tip should probably be positioned above the inferior caval entry points of the renal veins[76] (evidence level 4).

No association with vascular perforation, severe cardiac arrhythmias, local venous thrombosis, or clinical dysfunction of the central nervous system has been shown for short-term use of extrathoracically positioned catheters made of modern softer materials[27] (evidence level 2c).

Pre-operative fluoroscopy is useful to facilitate optimal long-term catheter tip positioning,[77] and chest X-ray is then required only when clinical complications are obvious or suspected[78–81] (evidence level 2c).

Ultrasonic guidance

There is compelling evidence that ultrasound-guided CVC insertion via the internal jugular veins is associated with higher success rate and fewer mechanical complications compared with traditional techniques based on external anatomical landmarks[47,82,83] (evidence level 1a, recommendation grade A). Additionally, the femoral veins are suitable for ultrasound-guided puncture[83,84] (evidence level 2a, recommendation grade B) as are the subclavian and axillary veins[85,86] (evidence level 2a, recommendation grade B). Ultrasonic guidance has also made the deep veins of the upper arm more available for PICC insertion, which may have reduced the complication rate, but randomised controlled studies are still lacking.

Associated infection

Prevention

Catheter-associated infection is an important cause of morbidity and mortality,[87,88] particularly in severely ill or injured patients. The incidence varies between countries and hospitals from 0 to 30 per 1000 catheter days.[34,89] These infections prolong individual hospital stay by 10–20 days and are estimated to correspond to 12% of all infections in intensive care patients.[89–91] The mortality of CVC-associated infection has been estimated to be up to 25%.[92] Available studies on mortality are more than 10 years old, and the wide range quoted may reflect differences in practice and settings. Notwithstanding, since the risk of CVC-associated infection increases over time, any CVC should be removed as soon as it is no longer required for safe individual patient care.

Continuous follow-up of clinical routines and staff awareness by designated CVC teams has been reported to reduce CVC-associated infection rates[93–96] (evidence level 1a).

The physician inserting a CVC should wear cap, mask, sterile gown, and sterile gloves. The cannulation area should be disinfected by thorough application of a mixture of chlorhexidine and ethanol, which is then left to evaporate, and the patient should be completely covered with sterile drapes[97–102] (evidence level 1a).

Pre-operative hair shortening, but not shaving, may be considered[103] (evidence level 2b). Large randomised controlled studies on catheter materials vs. infection risks are lacking.[104] Clinical use of multiple-lumen catheters is considered to increase the risk of infection[105] (evidence level 2b).

For more than 3–4 weeks of clinical use, a cuffed tunnelled CVC or a subcutaneous venous port (SVP) should be chosen[90,106] (evidence level 1a).

PICCs are increasingly used for long-term access. There is no high-grade evidence to support long-term use of PICC over tunnelled CVC or SVPs regarding overall complication rates[40,41] (evidence level 5, expert opinion).

For short-term use, antibiotic coating of non-tunnelled CVC with chlorhexidine/silversulfadiazine or minicycline/rifampicine reduces infection rates more effectively than tunnelling with conventional catheters[107] (evidence level 2b).

Systemic prophylactic antibiotics should not be given routinely for CVC insertion[89,108–110] (evidence level 1a) but may be considered in patients with increased risk of infection[111–113] (evidence level 4).

The rates of infection and colonisation with multiresistant bacteria in intensive care patients are lower during daily whole-body chlorhexidine disinfection than with soap-and-water washing[114–117] (evidence level 2b). This measure may be considered as an adjunct to correctly implemented hygiene routines when CVC-associated infection rates remain unacceptably high (recommendation grade B).

Exchange over guidewire may be considered in catheter dysfunction or when a change of the type of catheter is indicated. This procedure is associated with lower risk of mechanical complications but with higher risk of associated infection compared with conventional insertion at a fresh site[89,118] (evidence level 2a).

Fixation with monofilament sutures is recommended. Staples or suture-less anchoring devices may reduce the risk of local infection but increase that of accidental catheter extraction[119–122] (evidence level 4).

Dressings should be changed with sterile techniques including use of clean or sterile gloves[89] (evidence level 1a). The skin and catheter should be disinfected with chlorhexidine-ethanol solution and left to dry[123] (evidence level 1a). The cannulation site should then be covered with sterile gauze or highly permeable polyurethane film[124,125] (evidence level 2). Dressing with a chlorhexidine-containing sponge may be effective, but there is a risk of skin rash[126–130] (evidence level 1b). Dressings should be changed once to seven times a week depending on the setting[131] (evidence level 2b). For cuffed or tunnelled CVC, dressings should be changed as described earlier until the cuff is anchored, after which they may probably be omitted[89] (evidence level 4).

Most studies report clinical use of needleless membranes to be associated with lower rates of CVC-associated infection[132–139] (evidence level 4). Together with connectors and valves, needleless membranes should be changed every third day to prevent colonisation and infection, and even longer (4- to 7-day) intervals have been proposed to be safe[140–143] (evidence level 2b).

The working group recommends CVCs to be consistently flushed with saline after each injection or sampling of blood (evidence level 5, expert opinion). No significant difference has been shown between flushing and instillation of heparin compared with saline regarding rates of infection or occlusion[144–149] (evidence level 3), but immune-deficient patients may benefit from instillation of heparin.[150] Regular flushing of resting long-term systems is not well studied and does not seem to reduce the risk of occlusion.[151] Antibacterial locks may reduce the incidence of CVC-associated infection, but the risk of increased bacterial resistance to antibiotics has not been elucidated[152] and should be considered.

Management
Various sets of diagnostic criteria have been proposed for associated infection. The core temperature should be measured, and basic laboratory tests for analysis of blood cell count and C-reactive protein be obtained together with cultures from the catheter tip, insertion site, and blood[106,153] (evidence level 2c-4). Blood cultures should be taken from all CVC lumens and a peripheral vein simultaneously, and should be evaluated including differential time to positivity.[154] Before a CVC is removed, if a culture from the tip is planned, the skin around the cannulation site should be disinfected with chlorhexidine-ethanol solution and left to dry.[155]

Empirical antibiotic therapy should cover Gram-positive (including coagulase-negative staphylococci) and Gram-negative pathogens before narrowing the antibiotic spectrum in response to microbiology reports. Antimycotic drugs should be added in patients with critical illness, neutropenia, or parenteral nutrition. See also Figs 1–2.
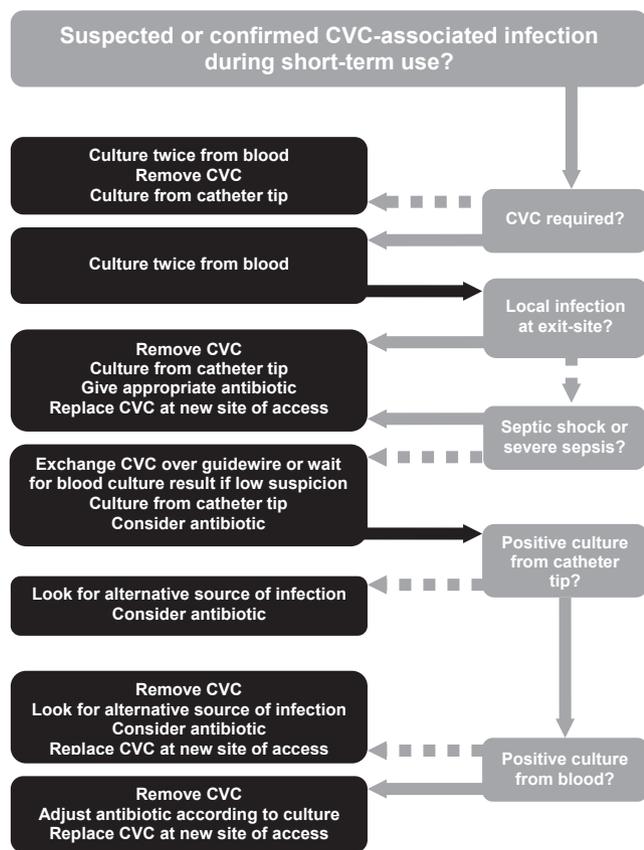
Fig. 1. Proposed clinical management of infections associated with short-term use of central venous catheters (CVCs).

Fig. 2. Proposed clinical management of infections associated with long-term use of central venous catheters (CVCs).

Associated mechanical trauma

During the cannulation procedure and before subsequent clinical use of the CVC, appropriate catheter position should be verified by aspiration of venous blood, by backflow into an intravenous fluid bag, or, in case of ambiguity, by chest X-ray with infusion of contrast via the catheter[27,156–158] (evidence level 2b). During insertion, the catheter tip position may also be adjusted according to electrocardiogram[159] or central venous pressure patterns[160] (evidence level 5, expert opinion).

The incidences of pneumothorax after CVC insertion via the internal jugular and subclavian veins are 0.3–1.0% and 1.6–2.3%, respectively.[158,161] Patients with pneumothorax requiring pleural drainage may show dyspnoea, tachypnoea, cough, or peripheral oxygen saturation < 90% at an early stage,[158] whereas a pneumothorax corresponding to approximately 30% or less of the pleural cavity is associated with few clinical signs and usually requires no drainage.[158,162]

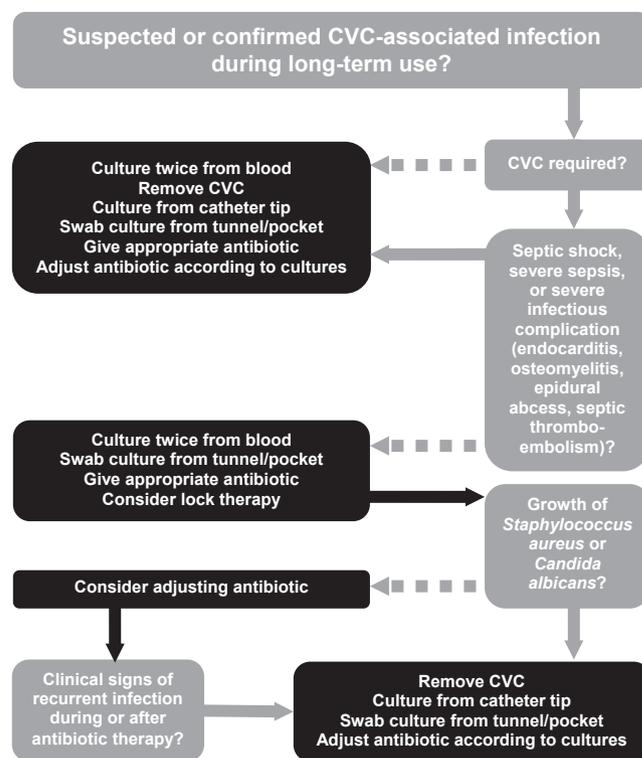A normal chest X-ray immediately after catheterisation does not exclude pneumothorax, which may develop insidiously.[163–165] Radiographic control is recommended if pneumothorax is suspected during catheterisation or if the patient has onset of respiratory symptoms, or is hypoxic, after the cannulation procedure (evidence level 4, recommendation grade C).

Traumatic injury to catheters or vessels during insertion or clinical use may cause subcutaneous spread of intravenous fluid to form local tissue oedema.[166] Extravasation of intravenously infused fluid may also lead to hydrothorax[167] or, if the perforation is located within the pericardial folds,[168] to cardiac tamponade with high mortality.[169] Vascular perforation has been reported to be more common in left-sided approaches possibly because of the more acute angle between the guidewire and catheter, and the superior caval wall,[59,170] but damage to the vein from catheter erosion is less common with modern pliant catheter materials.[67,68]

Benignant cardiac dysrhythmia resulting from a guidewire or catheter tip in the atrium or the ventricle, particularly during the cannulation procedure, is usually transient[171,172] (evidence level 3b). However, severe arrhythmias have been reported during catheter insertion[173–175] or use[173–175] (evidence level 4).

The incidence of accidental arterial puncture is approximately 6%,[176] while arterial catheterisation has been reported in 0.1–1.0% of CVC insertion procedures.[177] Serious complications, such as haematoma, pseudo-aneurysm with or without neural compression, arterial thrombosis or dissection, stroke, arteriovenous fistula, haemothorax, haemomediastinum, or cardiac tamponade, may occur.[30,178–184] Systematic efforts directed at their prevention by adopting safe ultrasound-guided techniques are mandatory.

Case series indicate that an arterial catheter of 7 Fr or less, accidentally inserted at a compressible site, may be safely extracted followed by external compression for 10 min.[30] In contrast, a vascular surgeon should be consulted for safe removal of any arterial catheter larger than 7 Fr or placed at a non-compressible site. A closure device, with endovascular or open techniques, may be used[30,180] (evidence level 4).

Local neural damage associated with catheter insertion may result from mechanical trauma, neural compression by haematoma, or extravasation of cytotoxic drugs. Neurological clinical signs are usually transient, but occasionally, the damage may induce permanent sequelae.[185]

Venous air embolism may be associated with CVC insertion, CVC extraction, or exchange of infusion tubing.[186,187] The mortality rate in massive air embolism is high,[188] but massive embolisation associated with catheter insertion or extraction is likely to be prevented by a head-down patient position (particularly during introduction over guidewire) and by an air-tight dressing after extraction[188] (evidence level 5, expert opinion).

Catheters inadvertently directed cranially in the internal jugular vein are often removed or redirected to avoid local thrombosis or retrograde injection into the cerebral circulation.[189] The latter is however unlikely due to the high venous flow in this vessel, and a cranially directed CVC for short-term use may thus be left in place[63] (evidence level 5, expert opinion).

Associated venous thromboembolism

Heparin may decrease the risk of associated venous thromboembolism,[190–193] but because it also considerably increases the risk of bleeding, prophylactic heparin cannot be recommended in patients with CVC (evidence level 1a, recommendation grade A). Nor is routine anticoagulant therapy indicated in patients with asymptomatic venous thrombosis (recommendation grade D). The use of prophylactic anticoagulants in catheterised patients with known inborn hypercoagulability has not been studied.[194]

No randomised studies on the treatment of symptomatic associated venous thrombosis have been published. However, several cohort studies have shown safe and successful treatment of deep venous thromboses in the upper extremities with regimens similar to those recommended for venous thromboses in the lower extremities[195–197] (evidence level 4). Optimal durations of treatment vary considerably, depending on individual clinical factors, and have not been well elucidated[198–201] (evidence level 4).

Catheter dysfunction

Catheter occlusion may result from intraluminal or extraluminal thrombosis, deposition of residues of lipids, precipitation (e.g., of calcium phosphate) by simultaneous infusion of solutions with low and high pH, angulation or folding of the catheter, pinch-off syndrome (compression of the catheter between the clavicle and first rib, mainly during long-term use), or intramural migration of the catheter tip.

The aetiology should be sought by considering how the catheter has been used before the occlusion[199] (evidence level 2b). Occlusion induced by intraluminal thrombosis or non-symptomatic venous thrombosis may be treated with systemic or local administration of thrombolytic drugs[199,202] (evidence level 2b, recommendation grade B). In catheters blocked by fibrin sheath or thrombosis, a stripping procedure may be considered if thrombolytic therapy fails[49,203] (evidence level 4). Asymptomatic fibrin sheath and/or thrombosis formation around the catheter tip is common but has little clinical implication for short-term use.[204–209]

Ethanol or sodium hydroxide may be instilled to remove lipid deposits, but it should be considered that ethanol may damage polyurethane catheters[210,211] (evidence level 4, recommendation grade C). Intraluminal deposits from acid solutions, e.g., of calcium phosphate, may be cleared by careful local instillation of hydrochloric acid[212] and those from alkaline solutions by instillation of sodium hydroxide or bicarbonate.[211] Catheter exchange over a guidewire may be considered for any type of occlusion.[199]

In patients with renal failure in need of long-term vascular access for haemodialysis and parenteral

nutrition, central dialysis catheters should not be the first choice because of increased risk of thrombosis and infectious complications[213,214] (evidence level 2c, recommendation grade B). Accordingly, PICC should not be chosen in patients with potential future need of a brachial arteriovenous fistula for haemodialysis[215] (evidence level 2c, recommendation grade B).

The incidence of associated venous stenosis increases with the number of catheters, the total duration of CVC use, and associated infections or thrombosis.[216–218] For patients with those risk factors and for patients with a verified central venous stenosis, mapping of the central venous system by computerised tomography or magnetic resonance tomography scanning should be considered, and endovascular expertise be consulted before de novo CVC insertion[214,219] (evidence level 4, recommendation grade C).

Training and follow-up

Several manikins or dummies for simulation training of central venous cannulation, with or without ultrasonic guidance, are available.[220] Such training should precede bedside practice[220–228] (evidence level 2a, recommendation grade B).

Continuous training of all clinically active CVC operators, regardless of level of experience, has been reported to reduce the risk of complications (recommendation grade D).[229–231]

All health-care units involved in CVC insertion and use should have quality assertion programmes for implementation and follow-up of routines, teaching, training, and clinical outcome (recommendation grade A).[93]

Concluding remarks

Based on extensive literature retrieval, thousands of scientific papers on central venous catheterisation have been systematically reviewed by a Swedish task force, commissioned by the Swedish Society of Anaesthesiology and Intensive Care Medicine, to produce relevant, useful, and reliable national CVC guidelines. Endorsed by the Swedish Society in 2010 to facilitate safer management of CVC in Scandinavia, these guidelines are considered to cover a wide range of key topics, including bleeding diathesis, vascular approach, ultrasonic guidance, catheter positioning, prevention and management of mechanical trauma or infection, and specific training and follow-up.

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Appendix 1. Literature retrieval strategies for the major topics addressed in the Swedish guidelines on clinical management of central venous catheters. For each retrieval process, we report the total number of papers initially obtained, the number of papers subjected to screening based on the title and/or abstract, and the number of papers read and evaluated by the authors

Bleeding diathesis
Search pattern: ('Catheterization, Central Venous') AND ('Blood Coagulation Tests'[Mesh]) OR (blood coagulation disorders) OR ('Anticoagulants'[Pharmacological Action] OR ('Fibrinolytic Agents'[Pharmacological Action]) OR ('Platelet Aggregation Inhibitors'[Pharmacological Action]) OR ('bleeding time').

Hits: 900; screened: 50; evaluated: 23.

Vascular access site
Search pattern: ('Catheterization, Central Venous/adverse effects')[Mesh] AND (('Jugular Veins')[Mesh] OR ('Subclavian Vein')[Mesh] OR ('Femoral Vein'))[Mesh]) AND (('Venous Thrombosis')[Mesh] OR ('Upper Extremity Deep Vein Thrombosis')[Mesh] OR ('Catheter-Related Infections')[Mesh] OR ('Pneumothorax')[Mesh] OR ('Hemothorax')[Mesh]))

Hits: 202; screened: 79; evaluated: 29. Additional studies from reference lists: 15.

Catheter tip positioning
Search pattern: ('Catheterization, Central Venous/adverse effects')[Mesh] AND (('Renal Dialysis')[Mesh] OR ('Vascular System Injuries')[Mesh] OR ('Central Venous Pressure')[Mesh] OR ('Extravasation of Diagnostic and Therapeutic Materials')[Mesh] OR ('Radiography')[Mesh])

Hits: 1358; screened: 200; evaluated: 44.

Infection
Search pattern: (('central venous catheters'[MeSH Terms] OR ('central'[All Fields] AND 'venous'[All Fields] AND 'catheters'[All Fields]) OR 'central venous catheters'[All Fields] OR ('central'[All Fields] AND 'venous'[All Fields] AND 'catheter'[All Fields]) OR 'central venous catheter'[All Fields]) AND ('infection'[MeSH Terms] OR 'infection'[All Fields] OR 'communicable diseases'[MeSH Terms] OR ('communicable'

[All Fields] AND 'diseases'[All Fields]) OR 'communicable diseases'[All Fields])) AND (('0001/01/01'[PDAT] : '1999/12/31'[PDAT]) AND English[lang])

Hits: >4000, evaluated: 148.

Associated mechanical complications

Search pattern: ('Catheterization, Central Venous')[Mesh] AND (('Extravasation of Diagnostic and Therapeutic Materials')[Mesh] OR ('Postoperative Complications')[Mesh] OR ('Pneumothorax')[Mesh] OR ('Hemothorax')[Mesh] OR ('Arrhythmias, Cardiac')[Mesh] OR ('Hematoma')[Mesh] OR ('Arteries')[Mesh] OR ('Peripheral Nerve Injuries')[Mesh] OR ('Embolism, Air')[Mesh])

Hits: 1849; screened: 248; evaluated: 35.

Thromboembolism

Search pattern: ('Catheterization, Central Venous') [Mesh] AND ('Occlusion') OR ('Thrombosis') [Mesh] OR ('Constriction, Pathologic')[Mesh] OR ('Stenosis') OR ('Pulmonary Embolism') [Mesh] OR ('Thrombolytic Therapy')[Mesh] OR ('Radiography')[Mesh] OR ('Magnetic Resonance Imaging')[Mesh]))

Hits: 2883; screened: 400; evaluated: 29.

Training and follow-up

Search pattern: (('Learning') OR ('Teaching') OR ('Education')) AND ('Catheterization, Central Venous')

Hits: 787; screened: 29; evaluated: 29.

Appendix 2. Levels of evidence and grades of recommendation according to the Oxford Centre for Evidence-Based Medicine (revised in March 2009)

Level of evidence

1 a	Systematic analysis (with homogeneity) of randomised controlled studies
1 b	Individual randomised controlled study (with narrow confidence interval)
1 c	All-or-none-criterium (applicable when all (or some) patients died before the studied treatment was available and some (or all) survive with the studied treatment)
2 a	Systematic analysis (with homogeneity) of cohort studies
2 b	Individual cohort study (including randomised controlled studies with low quality)
2 c	'Outcomes' research
3 a	Systematic analysis (with homogeneity) of case-control studies
3 b	Individual case-control study
4	Case-series (and poor quality cohort and case-control studies)
5	Expert opinion without explicit critical appraisal, or based on physiology, bench research or 'first principles'

Grade of recommendation

A	Consistent level 1 studies
B	Consistent level 2 or 3 studies OR extrapolations from level 1 studies
C	Level 4 studies OR extrapolations from level 2 or 3 studies
D	Level 5, expert opinion evidence OR troublingly inconsistent or inconclusive studies of any level