

**POSITION PAPER:**

**Which ICU Patients Need Central Venous Catheterization?**

**Review of the Evidence**

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## **Abstract**

Central venous catheter (CVC) insertion is widely performed in critically ill patients but causes mechanical, thrombotic, or infectious adverse events in 15% of cases. Scant data are available on the risk/benefit ratio of central vs. peripheral venous catheter insertion. Although debate continues to surround the appropriateness of CVC use in many clinical situations, there is a consensus that a CVC is needed in patients with cardiac arrest, rapid fluid resuscitation, or parenteral nutrition. Daily assessments by physicians and nurses should be used to select the best option when peripheral venous access is difficult or the patient requires filling-pressure monitoring or infusion of irritant drugs.

When CVC insertion is needed, the risk/benefit ratio should be optimized by selecting the best insertion site, using Doppler-ultrasound guidance when appropriate, and switching to another operator after two failed attempts. Recent data on these measures are available and can be used to build a decision algorithm.

Studies evaluating the risk/benefit ratio of CVCs versus peripheral catheters are needed to develop a venous-access strategy for ICU patients.

Selecting the best venous access method for individual ICU patients is a daily challenge for intensivists. Although guidelines based on evidence or expert opinion exist for a number of situations, in most cases intensivists must rely on their experience and on local practice profiles to choose between a central venous catheter (CVC) and a peripheral venous catheter (PVC). The present article rests on a review of the literature about indications for CVC versus PVC use in ICU patients. The literature was reviewed by the authors then discussed at workshops by panels of intensivists.

## **I/ Venous access methods: current patterns of use (table 1)**

Of the 10,038 study patients included in a European survey of nosocomial infections in the ICU, 64% had CVCs.[1] In the German national database of nosocomial infections, CVCs were used for 75% of all ICU days (<http://www.medizin.fu-berlin.de/hygiene/nrz/>). An incidence study conducted in Finland in the early 1990s found that CVCs were used in 49.3% of the 14,951 study patients.[2] Few published data are available for France. In the 2000-2001 CUB-REA database established in 35 ICUs in the Ile de France region, 29.7% of the 40,413 patients had CVCs. No consistent relationships were found between CVC insertion and disease severity (as assessed by the SAPS II) (Figure 1) or standardized mortality ratios in study ICUs (CUB-REA database, 2001 report). CVC use was more common in patients who stayed in the ICU longer than 48 h and in surgical patients (<http://cclin-sudest.univ-lyon1.fr/reseaux/rea/Resrea/REA00.pdf>). These wide variations in CVC use rates are probably related not only to the diversity of indications for CVC insertion, but also to major differences in practice patterns and opinions across ICUs and countries. That decisions regarding CVC use are not primarily evidence-based is of some concern, as CVC insertion is associated with a substantial burden of adverse events. The risk/benefit ratio of CVC insertion

should be evaluated comparatively to PVC insertion, as a venous line is needed in virtually all ICU patients.

## **II/ Adverse events associated with venous access in ICU patients**

### *Adverse events related to central venous catheters*

CVCs can cause mechanical, infectious, and thrombotic adverse events. In a recent literature review,[3] 5% to 19% of patients experienced mechanical events, 5% to 26% infectious events, and 2% to 26% thrombotic events. Overall, 15% of ICU patients with CVCs experience at least one CVC-related adverse event. These events are usually minor, however. In a recent study comparing the femoral route to the subclavian route,[4] 6 of 52 patients experienced mechanical events requiring drainage or surgery, 8 of 33 patients with significant catheter colonization experienced catheter-related infection, and 7 of 27 patients diagnosed with thrombosis had complete vessel occlusion.

### *Adverse events related to peripheral venous catheters*

Data are scant. Bloodstream infection (BSI) rates have ranged from 0% to 0.3%.[5-7] Venous thrombophlebitis rates have varied widely, from 0.3% to 53%, a range that can only be explained by differences in definitions of this last event.[5-9] The main risk factors for peripheral vein thrombophlebitis identified in a recent review[10] were longer duration of catheterization, Teflon catheter, larger catheter diameter, characteristics of infusion solutions, and catheter-related infection. Half the patients with PVC-related septicaemia had thrombophlebitis.[10] PVC thrombophlebitis is associated with a 20-fold increase in the risk

of BSI (3.7% vs. 0.2%).[10] Table 2 lists the main measures for preventing PVC thrombophlebitis.

### ***Paucity of data comparing central to peripheral venous catheterization***

In a prevalence study done by the Paris-North University Nosocomial Infection Control Group, 28% of the 1512 recorded cases of BSI were due to catheter-related infection; 24% were related to CVCs and 4% to peripheral venous catheters. Similarly, Coello et al. showed that 23.8% of 3198 ICU-acquired cases of BSI were catheter-related; 19.3% were related to CVCs and 5.5% to peripheral venous catheters.[11] The main measures for preventing CVC-related infections are listed in Table 3.

There are no well-designed studies comparing thrombophlebitis rates associated with PVCs, peripherally inserted CVCs, and centrally-inserted CVCs. Nevertheless, thrombophlebitis seems less common with centrally inserted CVCs than with PVCs,[9] and the risk is intermediate with peripherally inserted CVCs.[9, 12]

## **III/ Indications for central venous catheter insertion in critically ill patients**

### ***No veins for peripheral access***

Absence of peripheral veins suitable for catheterization is a commonly reported reason for CVC insertion. Although a CVC is clearly needed when peripheral access is not available, this last point must be confirmed by a careful evaluation. Lefrant et al. [13] studied 101 patients for whom CVC insertion was requested because peripheral access was deemed unfeasible. In 14 patients, no attempt at venipuncture had been made, and in 94 patients a

PVC was successfully inserted by an anaesthesiologist (in an upper limb vein in 79 cases and the external jugular vein in 15 patients). This study establishes clearly that the need for CVC insertion must be evaluated with great care.

### ***Cardiac arrest***

The American Heart Association guidelines issued in 2000[14] recommend first-line use of a PVC (antecubital fossa or external jugular vein) in patients with cardiac arrest, both because the procedure is simple and because external cardiac massage can be continued during insertion. However, when resuscitation efforts are unsuccessful, CVC insertion (in the internal jugular vein or subclavian vein) should be considered, as the peak level of infused drugs in the systemic bloodstream is lower and delayed (by 1-2 minutes) with a PVC, as compared to a CVC.

### ***Monitoring filling pressures***

A discussion of the interpretation and relative value of the various methods used in the ICU to monitor filling pressures would be beyond the scope of this article. The advantages and disadvantages of these methods have been reviewed recently.[15] The respective roles for invasive versus non-invasive methods remain unclear. Pulmonary artery catheterization seemed associated with worse outcomes in an epidemiological study.[16] A recent randomized study,[17] however, found no difference in outcomes between haemodynamic monitoring by pulmonary arterial catheterization or by other methods in ICU patients with refractory shock or adult respiratory distress syndrome.

### ***High-rate fluid resuscitation***

Clinical practice guidelines encourage use of a PVC for high-rate fluid resuscitation in patients with relative or absolute hypovolemia.[18] PVC insertion requires less time and induces fewer complications. However, the diameter of the catheter should be sufficient to allow a high rate of infusion. Therefore, CVC insertion is warranted when peripheral access (including via a jugular vein) cannot be used. A large-calibre Vygon Desilet set may be useful, provided the patient has no injury to the inferior vena cava (abdominal trauma).

### ***Parenteral nutrition***

Malnutrition is not only common among inpatients, but also associated with increased morbidity and mortality rates. Consequently, parenteral nutrition is widely used. A CVC is often the preferred route of administration given the high calorie requirements and irritant effects of hypertonic solutions. However, perioperative parenteral nutrition was found useful only in the subset of patients with severe malnutrition[19, 20] and was associated with increased mortality in the subgroup of ICU patients.[19] Similarly, there is sound evidence that enteral nutrition is superior over parenteral nutrition, particularly when enteral nutrition is started early[21, 22] and even in patients with acute pancreatitis.[23] The indications for nutritional support in surgical patients were defined clearly by a consensus panel in 1994.[24] They include a need for major surgery and weight loss greater than 10% within the last 6 months or a serum albumin level lower than 35 g/L. A Buzby index lower than 83.5 may be the most reliable parameter for identifying patients likely to benefit from perioperative nutritional support. The duration of preoperative nutritional support should not exceed 1 week. The enteral route should be used whenever possible. In ICU patients without malnutrition, parenteral nutrition has not been shown to improve outcomes.[25] Nutritional

support seems beneficial in patients with multiple injuries, burns, or head injury.[21]

Nutritional support, via the enteral route if possible, is recommended in ICU patients who receive no food by mouth for longer than 7 days.[26]

In practice, in ICU patients whose nutritional status is normal but whose gastrointestinal tract is transiently non-functional, a 5% or 10% glucose solution infused into a peripheral vein is sufficient, and parenteral nutrition requiring CVC insertion does not need to be considered for the first 7 days.[27]

### ***Infusion of vein irritants***

No studies have compared the risk/benefit ratios of peripheral vs. central infusion of vein irritants. However, the characteristics of infused solutions are among the main risk factors for peripheral thrombophlebitis. Hyperosmolar solutions with a low pH, such as hypertonic glucose solutions, carry a high risk of thrombophlebitis. A number of other drugs have been incriminated, including potassium chloride, barbiturates, phenytoin, and most of the cancer chemotherapy agents. A 2-fold increase in the risk of thrombophlebitis has been reported with intravenous antibiotics such as vancomycin, amphotericin B, dalfopristin-quinupristin, and most of the beta-lactams.[10] Adding heparin to the solution reduces the risk of venous irritation (relative risk, 0.6; 95% confidence interval, 0.4-0.8)[28] and may be an alternative to routine CVC use.

Clearly, this contraindication does not apply to extreme emergencies, such as hypoglycaemia requiring a 30% or 50% glucose solution, hyperkalaemia requiring 42% or 84% bicarbonate solution, or cardiocirculatory collapse requiring vasopressors. In these situations, the risk of vein irritation should be weighed against the risk of immediate adverse events caused by CVC insertion and the risk related to the time needed for CVC insertion.

Chronic infusion of potent vasopressors (noradrenaline, adrenaline, vasopressin) requires CVC insertion, given the high risk of cutaneous necrosis with peripheral administration.[29] In addition, drugs such as dobutamine or dopamine, whose vasopressive effects are marked only with rates above 10 µg/kg/min, are often given via a CVC, despite the absence of studies comparing risk/benefit ratios with central versus peripheral administration. The same applies to a number of antimicrobials (amphotericin B, dalfopristin-quinupristin, and vancomycin) and to amiodarone, which can probably be given peripherally for a few days until the patient can be switched to the oral route or the need for longer term intravenous therapy requiring CVC insertion becomes clear.

#### **IV/ Optimizing the risk/benefit ratio in patients who must receive a central venous catheter**

Recommendations for preventing CVC-related infection and thrombosis were developed worldwide[30, 31]. Although a detailed description of these recommendations is not appropriate here, a number of points related to preventing mechanical adverse events deserve discussion.

##### ***Selecting the insertion site***

According to recent recommendations issued in the US[30] and in France,[31] the insertion site should be selected after weighing the risk of infection against the risk of mechanical complications and, in the absence of contraindications, the subclavian route should be given preference over the internal jugular vein and femoral vein. The French consensus conference also gives a prominent place to the predicted duration of

catheterization. The overwhelming majority of infectious events occur after 5 to 7 days of catheterization, so that there is less reason to prefer the subclavian route for shorter catheterization durations. When a short duration is predicted, the jugular or femoral vein should be given preference in patients with risk factors for bleeding or barotrauma. On the opposite, in patients who are expected to need a catheter for more than 5-7 days and who are free of major contraindications to subclavian insertion, this last site should be used. Data on practice patterns regarding site selection have been obtained. The 2001-2002 database established by the REACAT network of the Paris North University Nosocomial Infection Control Group contains data on over 4000 CVCs inserted in 64 ICUs in patients expected to require catheterization for longer than 48 h. Insertion sites were as follows: subclavian vein, 48% (mean duration, 11.8 days), internal jugular vein, 39% (mean duration, 9.5 days), and femoral vein, 13% (mean duration, 8.3 days). The duration of jugular and femoral vein catheterization far exceeded the recommended 5 to 7 days, suggesting underutilization of the subclavian site. Possible explanations include habits, ease of jugular vein insertion in the operating room, or perceptions regarding responsibility for potential adverse events. Operators are more likely to feel directly responsible for immediate mechanical events than for infectious or thrombotic events that occur several days after insertion. This factor probably causes excessive concern about mechanical events as compared to infection and thrombosis, thereby possibly leading to underutilization of the subclavian site. However, in terms of public health, the number of serious mechanical events (life-threatening or potentially responsible for a considerable increase in ICU stay length) is small compared to the number of cases of CVC-related BSI, which carries an estimated 11% mortality rate[32] and 9.5-day increase in ICU stay length. In a study by Giraud et al.,[33] pneumothorax was common but rarely serious. In the French multicenter Outcomerea database, the 30-day incidence of pneumothorax is 3%, and one-third of cases are related to CVC insertion [34].

Among these last, 10% were associated with cardiocirculatory arrest indicating tension pneumothorax.

### ***When should the operator let someone else try?***

After two failed attempts at subclavian CVC insertion, the risk of mechanical complications related to further attempts by the same operator increases sharply. In two studies conducted in ICU patients, the increase was 4.3% to 24%[35] and 5% to 20%, [36] respectively. Similarly, an insertion time greater than 1 minute was associated with a 1.05 odds ratio for each additional minute (95%CI, 1.03-1.08).[4] Therefore, after two failed attempts, the operator should let another experienced physician take over.

CVC insertion by the night-duty physician is associated with a significantly greater risk of mechanical complications (OR, 2.06; 95% CI, 1.04-4.08).[4] Therefore, CVC insertion while on duty should be carefully weighed against insertion the following morning (which also allows re-evaluation of the need for a CVC) in patients who do not immediately require a CVC.

### ***When and how should ultrasound guidance be used?***

A study in 821 patients[35] found no benefits from ultrasound guidance for subclavian CVC insertion. However, venipuncture was not performed at the same time as ultrasonography, and several operators each inserted a single CVC during the study period. The earliest meta-analysis was done in 1996 and indicated that real-time Doppler guidance decreased the adverse event rate and increased the rate of successful CVC insertion.[37] In ICU patients, obtaining a good Doppler signal modulated by ventilation ensured a greater than

99% success rate.[38] The effectiveness of real-time Doppler ultrasonography guidance may be heavily operator-dependent,[39] although this technique has been reported to increase the success rate for less experienced operators.[40] In a recent meta-analysis,[41] available data were stratified according to the ultrasound method used (real-time Doppler ultrasonography guidance or 2D ultrasonography) and to the insertion site. The results suggest that 2D ultrasonography may be better than the conventional method for internal jugular vein catheterization (RR, 0.14; 95%CI, 0.06-0.33); for the subclavian and femoral veins, the differences in favour of 2D ultrasonography were smaller, probably because of the limited number of studies. Doppler ultrasonography guidance was more effective than the conventional method for internal jugular catheterization (RR, 0.39; 95%CI, 0.17-0.92) but less effective for subclavian vein catheterization (RR, 1.48; 95%CI, 1.03-2.14). An indirect comparison of the relative risks of insertion failure with the two methods of ultrasound-guided subclavian CVC insertion militated in favour of 2D ultrasonography (RR, 0.09; 95%CI, 0.02-0.38). Although these ultrasound methods are appealing, their cost and the likely need for specific training limit their use.

### ***Duration of central venous catheterization***

Infection and perhaps thrombosis are closely related to the duration of catheterization. Venous catheters should be used only as long as needed, since each additional day increases the likelihood of adverse events. A recent study[42] suggests that 4.6% of CVC days may be unnecessary overall and 8.5% outside the ICU. However, most patients on wards with CVCs had the catheters inserted in the ICU, suggesting that CVC removal prior to ICU discharge may deserve consideration.

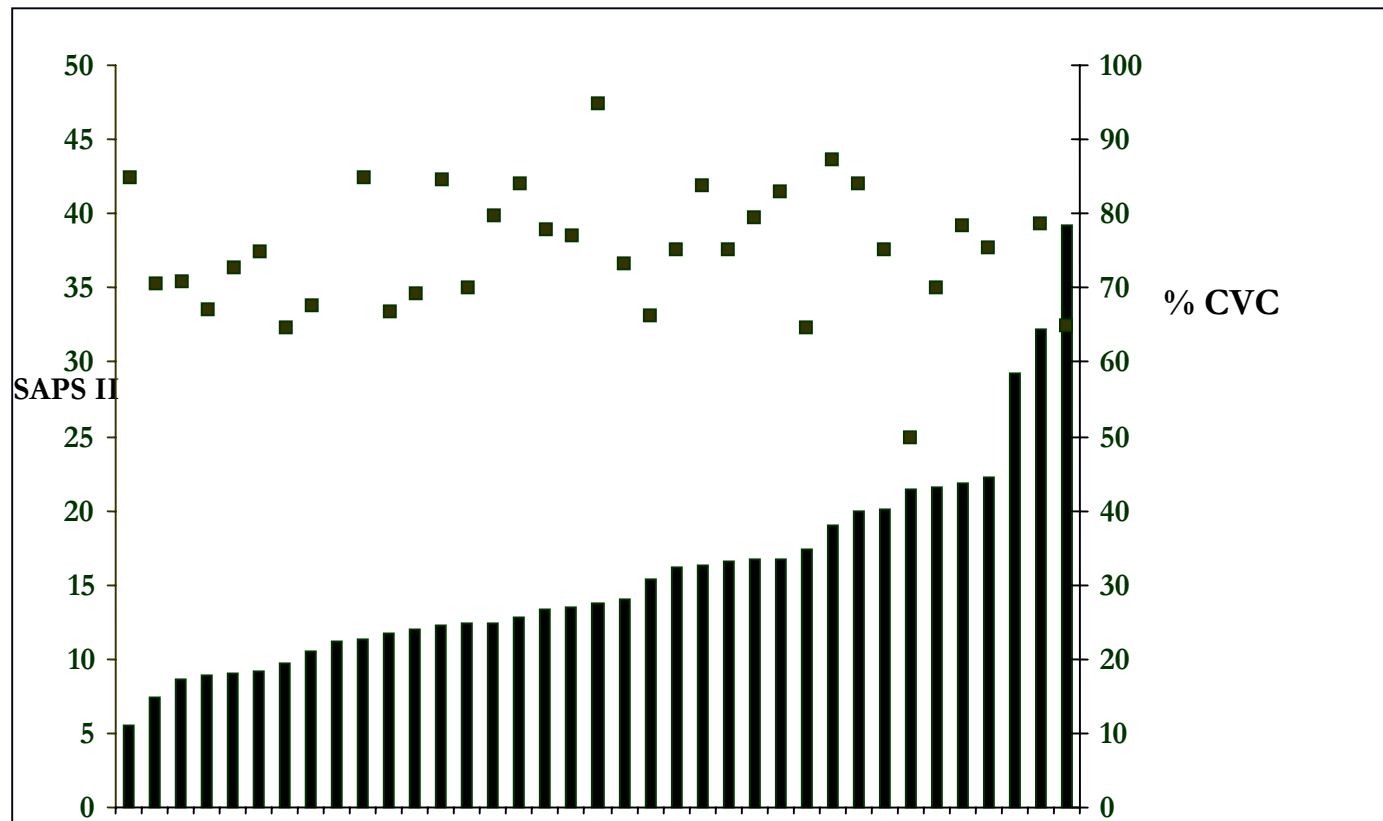
## ***Conclusion***

The results of work done over the last 10 years to investigate CVC use in the ICU can be used to develop a decision algorithm for selecting the insertion site and technique based on the predicted duration of catheterization and on each patient's risk factors.[43] However, the indications for CVC use in the ICU have received very little research attention, leaving intensivists with limited data to determine which patients really need CVC insertion. Whereas the adverse events associated with CVCs have been extensively documented, PVC use has not been adequately compared to CVC use, although in ICU patients there is usually a need to choose between these two options. Thus, for many situations, reliable risk/benefit ratio comparisons are not available. Before defining a management strategy regarding venous access in ICU patients, we must first take steps toward filling this knowledge gap.

**Table 1. Use of central venous catheters in intensive care units  
(ICUs)**

<b>Source</b>	<b>Nb ICU</b>	<b>Nb patients</b>	<b>% patients with CVC</b>
<b>EPIC Study 1995 (Prevalence)</b>	<b>1417 (17 countries)</b>	<b>10 038</b>	<b>64%</b>
<b>Survey in Finland 1991 (Incidence)</b>	<b>25</b>	<b>14 951</b>	<b>49.3%</b>
<b>CUB Rea 2000-2001 (Incidence)</b>	<b>35</b>	<b>40 413</b>	<b>29.7%</b>

Figure 1. Proportion of patients with CVCs by disease severity (SAPS II) in 35 intensive care units in the Ile-de-France region (2000-2001 CUB REA database; courtesy of Dr Ph Aergenter)



**Table 2. Recommendations for preventing peripheral venous catheter thrombophlebitis (Centers for Disease Control[30])**

- Select the catheter model according to the predicted duration of catheterization; prefer polyurethane catheters.
- Use aseptic technique.
- Cleanse insertion site with alcohol, povidone-iodine, or chlorhexidine.
- Keep the catheter properly positioned by securing it with a semi-permeable transparent adhesive bandage or a sterile gauze bandage.
- Prefer upper-limb veins over lower-limb veins.
- At least once a day, palpate the insertion site and ask the patient about local pain.
- Change peripheral venous catheters every 72 h.
- Remove catheters inserted in the emergency room within 24 h and insert another catheter at another site.
- Change the tubing at each catheter change. Change tubing used for blood products and lipid compounds within 24 h.
- Bandages should be changed when soiled, non-occlusive, or detached.

### **Table 3. Main measures for catheter-related infection prophylaxis**

**(from[31])**

- Maximum “surgical” aseptic precautions during insertion.
- Use chlorhexidine rather than non-alcoholic povidone iodine for insertion site cleansing.
- Use the subclavian route whenever possible.
- Tunnel all jugular and femoral catheters.
- Protection sheath for pulmonary artery catheters.
- Protected aseptic manipulation of tubing and connection pieces.
- Do not routinely change CVCs.
- Surveillance and training program for catheter insertion and care.
- Use catheters impregnated with antiseptics or antibiotics when there is a persistent high infection rate in the ICU despite compliance with prophylactic recommendations.

## References

1. Vincent JL, Bihari DJ, Suter PM, Bruining HA, White J, Nicolas-Chanoin MH, Wolff M, Spencer RC, Hemmer M (1995) The prevalence of nosocomial infection in intensive care units in Europe. Results of the European Prevalence of Infection in Intensive Care (EPIC) Study. EPIC International Advisory Committee. *Jama* 274: 639-644.
2. Saarela E, Kari A, Nikki P, Rauhala V, Iisalo E, Kaukinen L (1991) Current practice regarding invasive monitoring in intensive care units in Finland. A nationwide study of the uses of arterial, pulmonary artery and central venous catheters and their effect on outcome. The Finnish Intensive Care Study Group. *Intensive Care Med* 17: 264-271.
3. McGee DC, Gould MK (2003) Preventing complications of central venous catheterization. *N Engl J Med* 348: 1123-1133.
4. 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 (2001) Complications of femoral and subclavian venous catheterization in critically ill patients: a randomized controlled trial. *Jama* 286: 700-707.
5. Tager IB, Ginsberg MB, Ellis SE, Walsh NE, Dupont I, Simchen E, Faich GA (1983) An epidemiologic study of the risks associated with peripheral intravenous catheters. *Am J Epidemiol* 118: 839-851.
6. Soifer NE, Borzak S, Edlin BR, Weinstein RA (1998) Prevention of peripheral venous catheter complications with an intravenous therapy team: a randomized controlled trial. *Arch Intern Med* 158: 473-477.
7. Maki DG, Ringer M (1991) Risk factors for infusion-related phlebitis with small peripheral venous catheters. A randomized controlled trial. *Ann Intern Med* 114: 845-854.
8. Monreal M, Quilez F, Rey-Joly C, Rodriguez S, Sopena N, Neira C, Roca J (1999) Infusion phlebitis in patients with acute pneumonia: a prospective study. *Chest* 115: 1576-1580.
9. Giuffrida DJ, Bryan-Brown CW, Lumb PD, Kwun KB, Rhoades HM (1986) Central vs peripheral venous catheters in critically ill patients. *Chest* 90: 806-809.
10. Tagalakis V, Kahn SR, Libman M, Blostein M (2002) The epidemiology of peripheral vein infusion thrombophlebitis: a critical review. *Am J Med* 113: 146-151.
11. Coello R, Charlett A, Ward V, Wilson J, Pearson A, Sedgwick J, Borriello P (2003) Device-related sources of bacteraemia in English hospitals--opportunities for the prevention of hospital-acquired bacteraemia. *J Hosp Infect* 53: 46-57.
12. Chemaly RF, de Parres JB, Rehm SJ, Adal KA, Lisgaris MV, Katz-Scott DS, Curtas S, Gordon SM, Steiger E, Olin J, Longworth DL (2002) Venous thrombosis associated with peripherally inserted central catheters: a retrospective analysis of the Cleveland Clinic experience. *Clin Infect Dis* 34: 1179-1183.
13. Lefrant JY, Muller L, Ripart J, de La Coussaye JE (2004) Peripheral venous cannulation in patients with "no more veins". *Can J Anaesth* 51: 90.
14. (2000) Guidelines 2000 for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. Part 6: advanced cardiovascular life support: section 5: pharmacology I: agents for arrhythmias. The American Heart Association in

- collaboration with the International Liaison Committee on Resuscitation. *Circulation* 102: I112-128.
15. Saulnier F (2004) Recommendations d'experts de la Société de Réanimation de Langue Française: Indicateurs du remplissage vasculaire au cours de l'insuffisance circulatoire. *Réanimation* 13: 299-305.
  16. Connors AF, Jr., Speroff T, Dawson NV, Thomas C, Harrell FE, Jr., Wagner D, Desbiens N, Goldman L, Wu AW, Califf RM, Fulkerson WJ, Jr., Vidaillet H, Broste S, Bellamy P, Lynn J, Knaus WA (1996) The effectiveness of right heart catheterization in the initial care of critically ill patients. SUPPORT Investigators. *Jama* 276: 889-897.
  17. Richard C, Warszawski J, Anguel N, Deye N, Combes A, Barnoud D, Boulain T, Lefort Y, Fartoukh M, Baud F, Boyer A, Brochard L, Teboul JL (2003) Early use of the pulmonary artery catheter and outcomes in patients with shock and acute respiratory distress syndrome: a randomized controlled trial. *Jama* 290: 2713-2720.
  18. Baron JF. *Monitoring de la volémie au cours de l'anesthésie*. in *Conférences d'actualisation. 38<sup>ème</sup> Congrès national d'anesthésie*. 1996. Paris: Elsevier.
  19. Heyland DK, MacDonald S, Keefe L, Drover JW (1998) Total parenteral nutrition in the critically ill patient: a meta-analysis. *Jama* 280: 2013-2019.
  20. (1991) Perioperative total parenteral nutrition in surgical patients. The Veterans Affairs Total Parenteral Nutrition Cooperative Study Group. *N Engl J Med* 325: 525-532.
  21. Souba WW (1997) Nutritional support. *N Engl J Med* 336: 41-48.
  22. Marik PE, Zaloga GP (2001) Early enteral nutrition in acutely ill patients: a systematic review. *Crit Care Med* 29: 2264-2270.
  23. Marik PE, Zaloga GP (2004) Meta-analysis of parenteral nutrition versus enteral nutrition in patients with acute pancreatitis. *Bmj* 328: 1407.
  24. Anonymous (1995) Perioperative artificial nutrition in planned surgery in adults. Consensus development conference. Saint-Mande, France, 16 December 1994. *Ann Fr Anesth Reanim* 14 Suppl 2: 1-136.
  25. Koretz RL (1995) Nutritional supplementation in the ICU. How critical is nutrition for the critically ill? *Am J Respir Crit Care Med* 151: 570-573.
  26. Thuong M, Leteurtre S (2003) Recommendations des experts de la Société de Réanimation de Langue Française: Nutrition entérale en réanimation. *Réanimation* 12: 350-354.
  27. Anonymous (1998) Nutrition in the critically ill. Consensus conference. Long text. *Ann Fr Anesth Reanim* 17: 1274-1284.
  28. Randolph AG, Cook DJ, Gonzales CA, Andrew M (1998) Benefit of heparin in peripheral venous and arterial catheters: systematic review and meta-analysis of randomised controlled trials. *Bmj* 316: 969-975.
  29. Kahn JM, Kress JP, Hall JB (2002) Skin necrosis after extravasation of low-dose vasopressin administered for septic shock. *Crit Care Med* 30: 1899-1901.
  30. O'Grady NP, Alexander M, Dellinger EP, Gerberding JL, Heard SO, Maki DG, Masur H, McCormick RD, Mermel LA, Pearson ML, Raad, II, Randolph A, Weinstein RA (2002) Guidelines for the prevention of intravascular catheter-related infections. *Infect Control Hosp Epidemiol* 23: 759-769.
  31. Timsit JF (2003) Réactualisation de la XII<sup>e</sup> conférence de consensus de la Société de Réanimation de Langue Française. Infections liées aux cathéters veineux centraux en réanimation. *Réanimation* 12: 258-265.

32. Renaud B, Brun-Buisson C (2001) Outcomes of primary and catheter-related bacteremia. A cohort and case-control study in critically ill patients. *Am J Respir Crit Care Med* 163: 1584-1590.
33. Giraud T, Dhainaut JF, Vaxelaire JF, Joseph T, Journois D, Bleichner G, Sollet JP, Chevret S, Monsallier JF (1993) Iatrogenic complications in adult intensive care units: a prospective two-center study. *Crit Care Med* 21: 40-51.
34. Salah A, Chevrel G, Timsit JF, Mourvillier B, Soufir L, Vincent F, Garrouste-Orgeas M, Cheval C, Cohen Y, Thuong M, Moreau D, de Lassece A (2003) Iatrogenic pneumothorax in intensive care unit patients. *Intensive Care Med* 29: S21.
35. Mansfield PF, Hohn DC, Fornage BD, Gregurich MA, Ota DM (1994) Complications and failures of subclavian-vein catheterization. *N Engl J Med* 331: 1735-1738.
36. Lefrant JY, Muller L, De La Coussaye JE, Prudhomme M, Ripart J, Gouzes C, Peray P, Saissi G, Eledjam JJ (2002) Risk factors of failure and immediate complication of subclavian vein catheterization in critically ill patients. *Intensive Care Med* 28: 1036-1041.
37. Randolph AG, Cook DJ, Gonzales CA, Pribble CG (1996) Ultrasound guidance for placement of central venous catheters: a meta-analysis of the literature. *Crit Care Med* 24: 2053-2058.
38. Lefrant JY, Cuvillon P, Benezet JF, Dauzat M, Peray P, Saissi G, de La Coussaye JE, Eledjam JJ (1998) Pulsed Doppler ultrasonography guidance for catheterization of the subclavian vein: a randomized study. *Anesthesiology* 88: 1195-1201.
39. Bold RJ, Winchester DJ, Madary AR, Gregurich MA, Mansfield PF (1998) Prospective, randomized trial of Doppler-assisted subclavian vein catheterization. *Arch Surg* 133: 1089-1093.
40. Gualtieri E, Deppe SA, Sipperly ME, Thompson DR (1995) Subclavian venous catheterization: greater success rate for less experienced operators using ultrasound guidance. *Crit Care Med* 23: 692-697.
41. Hind D, Calvert N, McWilliams R, Davidson A, Paisley S, Beverley C, Thomas S (2003) Ultrasonic locating devices for central venous cannulation: meta-analysis. *Bmj* 327: 361.
42. Trick WE, Vernon MO, Welbel SF, Wisniewski MF, Jernigan JA, Weinstein RA (2004) Unnecessary use of central venous catheters: the need to look outside the intensive care unit. *Infect Control Hosp Epidemiol* 25: 266-268.
43. Timsit JF (2002) Central venous access in intensive care unit patients: is the subclavian vein the royal route? *Intensive Care Med* 28: 1006-1008.