Supporting technologies — central venous catheter

© RWD Nickalls,
Department of Anaesthesia,
Nottingham University Hospitals,
City Hospital Campus,
Nottingham, UK.

dick@nickalls.org
www.nickalls.org

FROM: Nickalls RWD. *Notes on thoracic anaesthesia*
revision: 2009α

Chapter 9

Supporting technologies

9.6 Central venous catheter[1]

9.6.1 History

The development of intravascular catheters and the techniques for inserting them has resulted in important advances both diagnostically (angiography) and therapeutically (CVP & Hickman lines; angioplasty).

Werner Forssmann

In the 1920s Werner Forssmann (1904–1979), then a surgical resident, was looking for safer ways of delivering cardio-active drugs to the heart (i.e., other than via direct needle injection), and eventually he hit upon the idea of using a long IV catheter. In 1929, when he was only 26, Forssmann tested this idea in a Berlin hospital, by inserting a long urinary catheter via the antecubital fossa into his own right atrium and confirmed its intra-cardiac position radiologically. He went on to use this method for injecting intra-cardiac contrast in animals, paving the way for diagnostic cardiac angiography, for which he was awarded the Nobel Prize in 1956, together with Cournand (1895–1988) & Richards (1895–1973). The following translation of part of Fossmann's original article (Forssmann, 1929) is by Luft (1994).

> In cases of shock, such as those engendered by sudden cardiac standstill, or during anesthetic emergencies and poisonings, it may be desirable to deliver medications directly to the heart itself. . . . Nevertheless intracardiac puncture is a dangerous procedure for several reasons, including injury to the coronary arteries and its branches, pericardial tamponade, injury to the diaphragm, and pneumothorax. . . . For these reasons I considered a new method to approach the heart in a less dangerous fashion, namely the catheterisation of the right heart from the venous system.
>
> Experiments on a cadaver were productive. I was able to catheterize any vein in the antecubital fossa and was able to regularly reach the right ventricle. . . . I next undertook experiments on a living subject, namely on myself. I first convinced a colleague to puncture a vein in my right antecubital fossa with a large needle. I next advanced a well-oiled ureteral catheter size 4 Charriere in diameter through the needle into the vein. The catheter allowed itself to be advanced with trivial ease to 35 cm. Because my friend objected to our proceeding with these experiments further, we broke them off even though I felt perfectly well. One week later I tried

[1] http://www.nickalls.org/dick/papers/thoracic/hand-cvp.pdf

> again alone. I anesthetized my own left antecubital fossa and because I was not able to manipulate the needle by myself I constructed a "cut-down" and advanced the catheter along its full 65 cm length. From surface estimates, I reasoned that the catheter tip would be at the level of the heart.
>
> I documented the position of the catheter with roentgenograms that I obtained by standing in front of the fluoroscope while observing the catheter in a mirror held by a nurse. In conclusion, I would like to point out the utility of this technique in providing new opportunities to research the metabolic activities and actions of the heart.
>
> Forssemann (1929) [*From*: Luft (1994)]

André Cournand and Dickinson Richards

Cournand and Richards extended Forssmann's intravascular catheter concept and developed long single and double-lumen catheters which allowed them to sample blood and pressures from the right heart and pulmonary artery (c. 1940s). They also determined approximate left atrial pressures by wedging the catheters by pushing them as far as they would go (i.e., not balloon-occlusion wedge pressures as determined by Swan and Ganz in 1967). They studied cardio-pulmonary physiology and patho-physiology, and showed that hypoxia, sufficient to make the arterial oxygen saturation less than 80 %, resulted in significant pulmonary vasoconstriction and a rise in pulmonary artery pressure (Cournand 1956; Richards 1956). Interestingly, they also showed that an infusion of acetylcholine (0·5 mg/min) into the pulmonary artery reversed the pulmonary vasoconstriction while not affecting the systemic blood pressure (Harris *et al.* 1956; Cournand 1956).

Sven-Ivar Seldinger

Radiologists often need to insert long large-diameter catheters into arteries in order to inject contrast into distant vessels. In the early 1950s, however, the two existing techniques had significant shortcomings. For example, the catheter-through-needle technique was associated with a significant leak at the vessel entry point (catheter smaller than needle), and the long narrow catheters made it difficult to inject contrast fast enough to be effective. The catheter-over-needle technique was only feasible with quite short catheters (since the needle did not bend, and long needles were difficult to manipulate safely).

In 1952 Sven-Ivar Seldinger (1921–1998) a Swedish radiologist at the Karolinska Hospital, Stockholm overcame these difficulties by developing his catheter-over-guidewire technique (Seldinger 1953; Seldinger 1987; Higgs *et al.* 2005; Greitz 1999). He actually used a guidewire with a straight flexible tip. Seldinger described the process of development as follows.

> However, rightly or not, some people considered the procedure [translumbar aortography] hazardous and searched for a technique where a catheter could be inserted via a peripheral artery. Surgical cut down methods had been reported ... and Bierman *et al.* (1951) ... suggested a percutaneous technique in which a catheter was inserted through a puncture instrument into the femoral artery and advanced to the aorta. The catheter had to be wide enough to permit a very rapid injection. If not, the contrast medium would be so diluted by the voluminous aortic bloodflow that diagnostic angiographs would not be obtained. In turn a very wide-bore puncture instrument, with consequent risk of trauma, was required.
>
> Thus there was obviously a need for an improved percutaneous method for aortography, and one of the requirements to the solution was an increased bore of the catheter. ... There existed a "puncture equipment" named after Cournand, consisting of an inner sharp needle in an outer blunt cannula, the edge exceeding the cannula by one or two mm. One alternative was to use a flexible catheter instead

> of the cannula, but it would certainly be tricky to handle an inner needle, half a meter or more long. I avoided this trouble by cutting a side hole on a polythene catheter at such a level that a cutting needle of convenient length, when inserted through it, exceeded the tip of the catheter by one or two mm. After some moulding of the catheter and a minute incision in the skin, this instrument could be inserted into the artery by percutaneous puncture.
>
> Some obvious disadvantages were inherent in this technique. For instance, the thin-walled catheters were so flexible that, sometimes it was impossible to advance them further into the vessel. This difficulty could often be overcome. When intravascular position was obtained, the needle could be withdrawn from the side hole and replaced by a semi-flexible metal wire which was introduced through the entire length of the catheter to support it.
>
> Now! After an unsuccessful attempt to use this technique I found myself, disappointed and sad, with three objects in my hand—a needle, a wire and a catheter—and, in a split second, I realised in what sequence I should use them: *needle in—wire in—needle off—catheter on wire—catheter in—catheter advance—wire off.*
>
> I have been asked how this idea turned up and I can quote Phokion,[2] the Greek: "I had a severe attack of common sense."
>
> The tools could not be less complicated; they could be found among the instruments of any hospital and, if necessary, could be completed at the nearest ironmonger's. Any handy person could use them.
>
> With the 'beginner's luck' the first angiography performed with this technique was a success: a subclavian arteriography, with one single exposure, the catheter introduced through the brachial artery after puncture at the cubital level, which revealed a parathyroid adenoma, unsuccessfully searched for by the surgeon in the mediastinum,
>
> With my permission, the Head of the Department, Knut Lindblom, reported on the technique at the Radiological Congress of Northern Europe which took place in Helsinki one week later, in June 1952.
>
> Seldinger (1987)

The January 1984 issue of the *American Journal of Roentgenology* (volume 142) celebrated the 30th anniversary of the Seldinger Technique with a series of articles on Seldinger.[3] The article by Doby (1984) gives an excellent historical overview, and includes some detailed sketches by Seldinger himself relating to his development of the technique.

Stanley Baum and Herbert Abrams

A not uncommon problem associated with the straight guidewire, particularly when cannulating the femoral artery, was failure to advance easily. This problem was largely overcome in 1964 by Baum and Abrams' development of the J-tipped catheter which is threaded over the guidewire (Baum and Abrams 1964). Once the catheter has been positioned above the obstruction then the catheter is changed (by reinserting the guidewire) for a special angiography catheter.

Charles Dotter

At approximately the same time the American radiologist Charles Dotter (1920–1985), widely regarded as the father of interventional radiology, was beginning to lay the foundations of this new speciality at the Oregon Health State University,[4] in conjunction with his student Melvin Judkins.

In 1963 Dotter inadvertently unblocked an occluded right iliac artery while passing a catheter through it in order to reach the aorta for an abdominal aortogram, and realised that intravascular

[2] Phocion (402–317 B.C.): Athenian statesman, general, and pupil of Plato.

[3] See their web site at `http://www.ajronline.org/` Most are are on the thoracic anaesthesia CD.

[4] see `http://www.ptca.org/nv/history.html`, and also `http://www.ohsu.edu/dotter/`

catheterisation can be used therapeutically as well as diagnostically. On 16 January 1964, Dotter, together with Judkins, performed the first deliberate dilation of an arterial obstruction, and thereafter developed the tools and techniques for what is now known as transluminal angioplasty (Payne 2001). Dotter also developed the first safety J-tipped guidewire (Judkins *et al.* 1967), flow-guided catheter, an intravascular biopsy catheter, and intravascular coils which were the forerunner of expandable stents (http://www.ohsu.edu/dotter/ctdotter.htm).

PICC catheters—Broviac JW and Hickman

With the advent of intensive care, intravenous nutrition and chemotherapy central catheters were increasingly used for long periods of time, leading to significant catheter-related infections. This prompted engineers to address design and materials issues, leading to new long-term so-called PICC catheters,[5] first by Broviac *et al.* (1973) and later by Hickman *et al.* (1979). Special valved catheters (Croshong catheter) were developed by Bard Access Systems.

- Baum S and Abrams HL (1964). A J-shaped catheter for retrograde catheterization of tortuous vessels. *Radiology*; 83, 436–437. [first description/use of the J-catheter]
- Broviac JW, Cole JJ and Scribner BH (1973). A silicone rubber atrial catheter for prolonged parenteral alimentation. *Surg. Gynaecol. Obstet.*; 136, 602–606.
- Cournand AF (1956). Control of the pulmonary circulation in man with some remarks on methodology. (Nobel Lecture)
- Doby T (1984). A tribute to Sven-Ivar Seldinger. *American Journal of Roentgenology*; 142 (Jan), 1–3. [http://www.ajronline.org/cgi/reprint/142/1/1.pdf]
- Forssmann W (1929). Catheterization of the right heart. *Klinische Wochenschrift*; 8 (No. 45), 2085–2087. [from Luft 1994]
- Greitz T (1999). Sven-Ivar Seldinger. *Am. J. Neuroradiol.*; 20 (June/July), 1180–1181. [http://www.ajnr.org/cgi/content/full/20/6/1180]
- Harris P, Fritts HW, Clauss RH, Odell JE and Cournand A (1956). Influence of acetylcholine on human pulmonary circulation under normal and hypoxic conditions. *Proc. Soc. Exptl. Biol. Med.*; 93, 77.
- Higgs ZCJ, Macafee DAL, Braithwaite BD and Maxwell-Armstrong CA (2005). The Seldinger technique: 50 years on. *Lancet*, 366, 1407–1409.
- Judkins M, Kidd HJ *et al.* (1967). Lumen-following J-guide for catheterization of tortuous vessels. *Radiology*; 88, 1127.
- Luft FC (1994). The birth of a common procedure. *Annals of Internal Medicine*; 120, 974.
- Payne MM (2001). Charles Theodore Dotter, the father of intervention. *Texas Heart Institute Journal*; 28, 28–38. http://www.tmc.edu/thi/thiaward.html
- Richards DW (1956). The contribution of right heart catheterization to physiology and medicine, with some observations on the pathophysiology of pulmonary heart disease. (Nobel Lecture)
- Seldinger SI (1953). Catheter replacement of the needle in percutaneous arteriography: a new technique. *Acta Radiologica Scandinavica*; 39, 368–376.
- Seldinger SI (1987). *A leaf out of the history of angiography.* In: Silvestre ME, Abecasis F and Veiga-Pires JA (1987); *Radiology: Faculty Proceedings of the 6th European Congress of Radiology, Lisbon, Portugal, 31 May–6 June 1987.* (Excerpta Medica, International Congress Series No. 749; Elsevier Science Publishers BV [Biomedical Division], Amsterdam, The Netherlands.) ISBN: 0-444-80947-3. p. 3–6. [from Greitz (1999)]

[5] PICC — Peripherally Inserted Central Catheter.

- (1984). Sven-Ivar Seldinger: a biography and bibliography. *American Journal of Roentgenology*; 142 (Jan), 4.
- (1984). The Seldinger technique. *American Journal of Roentgenology*; 142 (Jan), 5–7. [a reproduction of Seldinger's original article]
- (1984). Testimonials to Seldinger. *American Journal of Roentgenology*; 142 (Jan), 8–11. [reflections by Dotter CT, Grainger RG, Nordenström B, Abrams HL, and Athanasoulis CA]

9.6.2 Optimum position

The current view regarding the optimum location of the tip of a CVP-catheter is driven by the need to avoid the possibility of the catheter migrating into the pericardium. Consequently the tip should be *above* the pericardial reflection on to the SVC (Chalkiadis and Goucke 1998), which is generally held to be at the level of the carina (T4–T5; sternal angle)—i.e., above the left and right atria. Ryu *et al.* (2007) give a simple landmark-based method for safely positioning the tip of the CVP line in relation to the carina. Several articles have appeared recently describing the use of ultrasound to facilitate CVP-line placement, including a good editorial by Scott (2004).

Techniques for correcting/relocating subclavian and internal-jugular catheters which have taken an aberrant course are addressed by Pattnaik and Bodra (1999); they highlight an article by Kayal *et al.* (1989) who used ultrasound while flushing with saline to detect when the tip of the catheter is in the correct vessel. Pattnaik and Bodra (1999) suggest listening with a stethoscope is useful. An alternative approach to the 'aberrant catheter' problem, might be to consider placing a new J-wire into the same vein via the proximal lumen[6] (hopefully in the internal jugular vein), removing the misplaced CVP line and then railroading a new one—with luck the new wire will be in a better location (one could check the new wire position with an x-ray first perhaps).

Occasionally a CVP line inserted via the left IJ vein will go down the left internal mammary vein; quite how this happens is not clear since the curved tip of the J-wire should prevent the wire from going down a small vessel. The distal lumen in such cases is typically associated with difficult aspiration and poor CVP waveform. Since redirecting a misplaced CVP line can be difficult, consider monitoring the CVP via one of the more proximal lumens—withdrawing the line slightly if necessary—until you see a good CVP waveform. Consequently, always X-ray a left IJ line *before* considering railroading a Swan-sheath over it. For information and video clips relating to CVP insertion technique see the Clinical Cases web-site (http://clinicalcases.blogspot.com).

9.6.3 Anatomy

- Albrecht K *et al.* (2004). Applied anatomy of the superior vena cava—the carina as a landmark to guide central venous catheter placement. *Br. J. Anaesth.*; 92, 75–77.
- Davidson A, Blumgard C, Paes ML and Enever G (1993). Posture and internal jugular vein size studied with the 'Siterite' ultrasound device. *Br. J. Anaesth.*; 71, 771P. [November issue]
  [gives a useful table of depth and diameter of the vein for various amounts of head tilt. My own working of their data gives the mean depth of the middle of the vein as 1·64 cm, which is equivalent to a distance of 2·3 cm at 45 degrees to the skin]
- Daseler EH and Anson BJ (1959). Surgical anatomy of the subclavian artery and its branches.*Surg. Gynecol. Obstet.*; 108, 149–174.
- Galloway S and Bodenham A (2003). Ultrasound imaging of the axillary vein—anatomical basis for central venous access. *Br. J. Anaesth.*, 90, 589–595.
- Mathers LH, Smith DW and Frankel L (1992). Anatomic considerations in placement of central venous catheters. *Clinical Anatomy*; 5, 89–106.

[6] I have not tried this as yet, but it seems as though it ought to work.

- Pahwa R and Kumar A (2003). Persistent left superior vena cava: an intensivist's experience and review of the literature. *Southern Medical Journal*; 96, 528–529. [see example CXR on the http://www.learningradiology.com/ website (search for 'persistent left superior vena cava')]
- Rosen M, Latto IP and Ng WS [Eds.] (1992). *Handbook of percutaneous central venous catheterisation*; 2nd ed, (W. B. Saunders Company Ltd., London, UK).
- Schummer W, Schummer C and Fröber R (2003). Internal jugular vein and anatomic relationship at the root of the neck. *Anesthesia and Analgesia*; 96, 1540.
- Schummer W, Schummer C and Geold M (2002). Persistent left superior vena cava: clinical implications for central venous cannulation. *American Society for Parenteral and Enteral Nutrition*; 17, 304–308.
- Sulek CA, Gravenstein N, Blackshear RH and Weis L (1996). Head rotation during internal jugular vein cannulation and the risk of carotid artery puncture. *Anesthesia and Analgesia*; 82, 125–128. [keeping the head in the midline position reduces the incidence of carotid artery puncture]

9.6.4 Position of CVP tip

- Albrecht K *et al.* (2004). Applied anatomy of the superior vena cava—the carina as a landmark to guide central venous catheter placement. *Br. J. Anaesth.*; 92, 75–77.
- Chalkiadis GA and Goucke CR (1998). Depth of central venous catheter insertion in adults: an audit and assessment of a technique to improve tip position. *Anaesthesia and Intensive Care*; 26, 61–66. [they used the subclavian method—their tailored technique (8 cm distal from the tip of needle) gave a mean distance from the skin of 13·2 cm (range: 11·5–15 cms; n=73)]
- Ryu H-G, Bahk J-H, Kim J-T and Lee J-H (2007). Bedside prediction of the central venous-catheter insertion depth. *Br. J. Anaesth.*, 98, 225–227.

9.6.5 General

- Chalkiadis GA and Goucke CR (1998). Depth of central venous catheter insertion in adults: an audit and assessment of a technique to improve tip position. *Anaesthesia and Intensive Care*; 26, 61–66. [they used the subclavian method—their tailored technique (8 cm distal from the tip of needle) gave a mean distance from the skin of 13·2 cm (range: 11·5–15 cms; n=73)]
- Kayal RD, Salloum LJ, Snyder AB and Barone JE (1989). A simple method of repositioning the wayward central catheter. *Journal of Parenteral and Enteral Nutrition*; 13, 438–439.
- Kitagawa N *et al.* (2004). Proper shoulder position for subclavian venepuncture. *Anesthesiology*; 101, 1306–1312. [evidence from CT studies suggests that best position is with the shoulder pushed inferiorly]
- Messahel FM and Al-Mazroa AA (1992). Cannulation of the internal jugular vein; the very high approach. *Anaesthesia*; 47, 842–844.
- Nandwani N, Fairfield MC, Krarup K and Thompson J (1997). The effect of laryngeal mask airway insertion on the position of the internal jugular vein. *Anesthesia*; 52, 77–83. [no lateral movement, but perhaps some slight anterior movement 0·6–1·1 cm, mean 0·8 cm]
- Ng PK, Ault MJ and Maldonaldo LS (1996). Peripherally inserted central catheters in the intensive care unit [review]. *J. Intensive Care Medicine*; 11, 49–54.

- Oropello JM, Leibowitz AB, Manasia A, Guidice RD and Benjamin E (1996). Dilator associated complications of central vein catheter insertion: possible mechanisms of injury and suggestions for prevention. *Journal of Cardiothoracic and Vascular Anesthesia*; 10, 634–637.
- Pattnaik SK and Bodra R (1999). Another 'whoosh' test. *Anaesthesia*; 54, 1224–1225. [they describe gradually withdrawing the the malpositioned central line while listening for the disappearance of the distal 'whoosh' sound (caused by flushing it with saline) with a stethoscope over the vein. Also list other useful references on this theme (6 refs)].
- Rosen M, Latto IP and Ng WS [Eds.] (1992). *Handbook of percutaneous central venous catheterisation*; 2nd ed, (W. B. Saunders Company Ltd., London, UK).
- Sha K *et al.* (1998). Use of transoesophageal echocardiography probe imaging to guide internal jugular vein cannulation. *Anesthesia & Analgesia*, 87, 1032–1033.
- Stickle BR and McFarlane H (1997). Prediction of a small internal jugular vein by external jugular vein diameter. *Anaesthesia*, 52, 220–222.
  [if the external jugular vein is greater than 7 mm diam, then the internal jugular vein is likely to have a diameter less than 7 mm, and so may be difficult to find]
- Tripathi M, Dubey PK and Ambesh SP (2005). Direction of the J-tip of the guidewire in Seldinger technique is a significant factor in misplacement of subclavian vein catheter: a randomised controlled study. *Anesthesia and Analgesia*; 100, 21-24.
- Tripathi M and Tripathi M (1996). Subclavian vein cannulation: an approach with definite landmarks. *Ann. Thoracic Surgery*; 61, 238–240.
- Willeford KL and Reitan JA (1994). Neutral head position for placement of internal jugular vein catheters. *Anaesthesia*; 49, 202–204.
- Williamson RM and Werstler E (2006). Central line in patients with AV fistula. *Anaesthesia*; 61 (August), 819-820. [describes confusion with the sampled blood gases in a renal patient with a left-arm dialysis fistula]

9.6.6 Ultrasound guided

- Chapman GA, Johnson D and Bodenham AR (2006). Visualisation of needle position using ultrasonography. *Anaesthesia*; 61, 148–158.
- Galloway S and Bodenham A (2003). Ultrasound imaging of the axillary vein—anatomical basis for central venous access. *Br. J. Anaesth.*, 90, 589–595.
- Hall AP and Russell WC (2005). Towards safer central venous access: ultrasound guidance and sound advice. *Anaesthesia*; 60, 1–4. [see also correspondence from Reavley P (2005)]
- Habib FA and McKenney MG (2004). Surgeon-performed ultrasound in the ICU setting. *Surgical Clinics of North America*; 84, 1151–1179. [see section on CVP line placement 1165–1166, with screen images]
- National Institute for Clinical Excellence (NICE) (2002). Guidance on the use of ultrasound locating devices for placing central venous catheters. Technical Appraisal Guidance 2002, **49**. http://www.nice.org.uk/pdf/ultrasound_49_GUIDANCE.pdf [see also: Proposal to move guidance to the static list (NICE, 2005) http://www.nice.org.uk/pdf/ta049reviewproposal.pdf]
- Riopelle JM, Ruiz DP, Hunt JP *et al.* (2005). Circumferential adjustment of ultrasound probe position to determine the optimal approach to the internal jugular vein: a noninvasive geometric study in adults. *Anesth. Analg.*; 100, 512–519.
- Scott DHT (2004). The king of the blind extends his frontiers. *Br. J. Anaesth.*; 93, 175–177. [editorial on ultrasound-guided techniques]

9.6.7 External jugular vein

If the external jugular vein distends on head-down position, then a Venflon in this site adequately reflects CVP providing the chest is not open. Placing a central catheter via this route has a high failure rate.

- Blitt CD, Wright WA, Petty WC and Webster TA (1974). Central venous catheterisation via the external jugular vein. A technique employing the J-wire. *JAMA*; 229, 817.
- Briscoe CE (1973). A comparison of jugular [external] and central venous pressure measurement during anaesthesia. *Br. J. Anaesth.*; 45, 173.
- Dailey RH (1988). External jugular vein cannulation and its use for CVP monitoring. *Journal of Emergency Medicine*; 6, 133.
- Shah MV, Swai EA and Latto IP (1986). Comparison between pressures measured from the proximal external jugular vein and a central vein. *Br. J. Anaesth.*; 58, 1384.

9.6.8 Axillary vein

- Andel H, Rab M, Felfernig M *et al.* (1999). The axillary vein central venous catheter in severely burned patients. *Burns*; 25, 753–756.
- Galloway S and Bodenham A (2003). Ultrasound imaging of the axillary vein—anatomical basis for central venous access. *British Journal of Anesthesia*, 90, 589–595.
- Nickalls RWD (1987). A new percutaneous infra-clavicular approach to the axillary vein. *Anaesthesia*; 42, 151–154.
- Sandhu (2004). Transpectoral ultrasound-guided catheterization of the axillary vein: an alternative to standard catheterization of the subclavian vein. *Anesthesia and Analgesia*; 99, 183–187.
- Sharma A, Bodenham AR and Mallick (2004). Ultrasound-guided infraclavicular axillary vein cannulation for central venous access. *Br. J. Anaesth.*; 93, 188-192.
- Taylor BL and Yellowlees I (1990). Central venous cannulation using the infraclavicular axillary vein. *Anesthesiology*; 72, 55.

9.6.9 Femoral vein

There are many papers in the literature showing that CVP is accurately reflected by inferior vena cava and common iliac venous pressure measurements in supine patients (both adult and paediatric), providing the transducer is zeroed at the usual right-atrial level on the mid-axillary line. Measurements of inferior vena cava pressures seem to be approximately 0·5 mm Hg lower than superior vena cava pressures on average, and rarely more than 3 mm Hg different, even in patients with high PEEP or raised mean airway pressures (Desmond 2003). Femoral CVP results may be less accurate in patients with significantly raised intra-abdominal pressure [the references below are from Desmond (2003)].[7]

- Chait HI, Kuhn MA, Baum VC (1994). Inferior vena caval pressure reliably predicts right atrial pressure in pediatric cardiac surgical patients. *Crit. Care Med.*; 22, 219–24.
- Desmond J (2003). Is the central venous pressure reading equally reliable if the central line is inserted via the femoral vein? http://www.bestbets.org/ [critical care section]
- Ho KM, Joynt GM, Tan P. (1998). A comparison of central venous pressure and common iliac venous pressure in critically ill mechanically ventilated patients. *Crit. Care Med.*; 26, 461–4.

[7] I thank Dr Mofolashade Enebeli-Cliffe for drawing my attention to many of these references.

- Nahum E, Dagan O, Sulkes J, *et al.* (1996). A comparison between continuous central venous pressure measurement from right atrium and abdominal vena cava or common iliac vein. *Intensive Care Med.*; 22, 571–4.
- Joynt GM, Gomersall CD, Buckley TA, *et al.* (1996). Comparison of intrathoracic and intra-abdominal measurements of central venous pressure. *Lancet*; 347, 1155–7.
- Walsh JT, Hildick-Smith DJ, Newell SA, *et al.* (2000). Comparison of central venous and inferior vena caval pressures. *Am. J. Cardiol.*; 85, 518–20.

9.6.10 Complications

These are mostly related to air embolism, vessel damage from needle or dilator or kinked guide-wire, introducing the guide-wire *outside* the vessel, catheter knotting, dysrhythmias, pneumothorax and cardiac tamponade. Unusual anatomy[8] and failure to use ultrasound visualisation appear to be prominent factors in many complications (see Section 9.6.3).

Guide-wire problems

The guide-wire is easily kinked, and once kinked it can not be straightened and can easily damage/tear the vein if introduced into it. A simple test to check for such kinking while trying to advance the dilator (over the wire) is to intermittently check that you can slide the wire back and forth (say, ± 1 cm or so) inside the introducer. Any difficulty in sliding the wire back and forth is a good sign that the wire may have become kinked.

In my my experience, the guide-wire is most easily damaged/kinked when using the femoral approach in fat patients. The kinking of the guide-wire usually occurs while trying to introduce the dilator through the subcutaneous tissue, since in fat patients the path of the guide-wire here becomes quite curved once the Sonosite probe is removed.[9] Consequently, it may be preferable to replace the Sonosite probe (i.e., to straighten the subcutaneous path of the guide-wire) while introducing the dilator.

If a dialysis catheter guide-wire does become kinked it is often possible to exchange it safely by first railroading an ordinary CVP line into the vein (while protecting the kink within the CVP line), replacing the damaged wire with a new guide-wire and then removing the CVP line, and continuing with the dialysis line as before.

- Dhanani J, Senthuran S, Olivotto R, Boots RJ and Lipman J (2007). The entrapped central venous catheter. *Br. J. Anaesth.*; 98, 89–92.
  [a new catheter pierced an existing catheter in the same vein; interventional radiology used for diagnosis and determination of a removal strategy; the literature is reviewed; 11 refs]
- Lobato EB, Gravenstein N and Paige GB. (1997). Dilator-associated complications of central vein catheter placement: possible mechanisms of injury and suggestions for prevention. *Journal of Cardiothoracic and Vascular Anesthesia*; 11, 539.
- Muhn M, Sunder-Plassmann G and Druml W (1996). Malposition of a dialysis catheter in the accessory hemiazygos vein. *Anesthesia and Analgesia*; 83, 883-885.
- Oropello JM, Leibowitz AB, Manasia A, Guidice RD and Benjamin E (1996). Dilator-associated complications of central vein catheter placement: possible mechanisms of injury and suggestions for prevention. *Journal of Cardiothoracic and Vascular Anesthesia*; 10, 634–637.
- Jiha JG, Weinberg GL and Laurito CE (1996). Intraoperative cardiac tamponade after central venous cannulation. *Anesthesia and Analgesia*; 82, 661–665.

[8] Persistence of the left superior vena cava (LSVC)—which is asymptomatic—is thought to be the most common anomaly of the venous circulation and can be a significant hazard with regard to CVP line placement (see paper by Schummer, Schummer and Gerald(2002) listed in Section 9.6.3).

[9] Since the guide-wire is initially introduced via a straight needle *while the Sonosite probe is pressing down over the vein.*

- Scott WL and Collier P (2001). The vessel dilator for central venous catheter placement: forerunner for success or vascular misadventure? *Journal of Intensive Care Medicine*; 16, 263–269.