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Methods of central vascular access for haemodialysis

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Abstract

The basic form of renal replacement therapy is haemodialysis. Duration and efficacy of this treatment depend on well-functioning vascular access. Short-term or long-term catheters are used if arterial-venous fistula placement is not possible or not indicated. According to the NKF DOQI (*National Kidney Foundation Disease Outcomes Quality Initiative*) recommendations, the first choice of access is the right internal jugular vein, followed by the left internal jugular, femoral and subclavian veins. In this article, we present approaches to haemodialysis catheter insertion in the above-mentioned veins as well as catheter tip positioning in the venous system to prevent serious complications.

Key words: anaesthetic techniques, central venous access, haemodialysis catheters

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The basic form of renal replacement therapy for end-stage chronic kidney disease is haemodialysis. Its duration and efficacy largely depend on the way in which vascular access (VA) is obtained and maintained. According to the National Kidney Foundation Kidney Disease Outcomes Quality Initiative (NKF K/DOQI), the "gold standard" for VA is an arteriovenous (AV) fistula [1]. In cases where AV fistulae cannot be created, central venous access using temporary or long-term catheters is an alternative. Central venous access via vascular catheters is associated with higher complication rates and shorter catheter survival times when compared with AV fistulae. According to the Dialysis Outcomes Practice Patterns Study (DOPPS) II (2002–2004), 18% of chronically dialysed patients in Europe, 25% in the United States and 33% in Canada had vascular catheters inserted into central veins for haemodialysis. Furthermore, vascular catheters were used in even more patients who were newly initiated to haemodialysis therapy, i.e. 46–70% of the study populations [2]. The DOPPS III (2005–2007) demonstrated that the problem was still relevant, as the percentage of patients who were chronically haemodialysed with central venous catheters between 2005–2007 was 28% in Great Britain, 25% in the United States and 39% in Canada [3]. In Poland, no current data are available regarding the number of patients with irreversible renal failure who are receiving chronic haemodialysis treatment using vascular catheters. In 2001, vascular catheters, mainly of the temporary kind, were used in 53% of patients who were starting haemodialysis in the south-eastern region of Poland [4].

TYPES AND CHARACTERISTICS OF HAEMODIALYSIS CATHETERS

Catheters are characterised by the following criteria:

- duration of use:
  - temporary (short-term) — percutaneous noncuffed catheters (NCCs) designated only for patients who are hospitalised up to 7 days;
  - long-term — percutaneous tunnelled cuffed catheters (TCCs) used when VA must be maintained for longer than 7 days;
- coating with bactericidal, bacteriostatic or anticoagulant agents:
  - non-impregnated;
  - impregnated (minocycline, rifampicin, heparin, silver, chlorhexidine, 5-fluorouracyl);
- material used:
  - silicone;
  - polyurethane;
  - thermoplastic polyurethane;
- vascular tip design (staggered, split, spiral, etc.);

— number of lumens, shape of their cross-section and shape of external cross-section.

Long-term catheters usually have 1 or 2 lumens, whereas temporary catheters have 2 or 3 lumens.

LONG-TERM CATHETERS

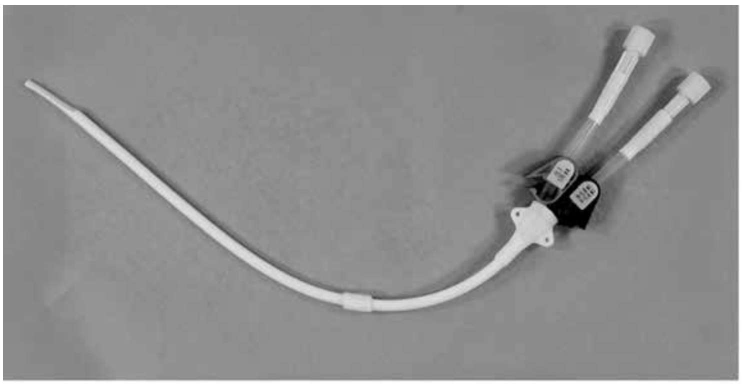
The materials used for long-term catheters are intended to minimise internal vessel damage. The majority of catheters in current use are made of polyurethane or thermoplastic polyurethane (polyurethane and polycarbonate copolymer). Silicon and polyurethane are biocompatible. Thermoplastic polyurethane (e.g. carbothane) is characterised by a mechanical strength comparable to that of polyurethane; it becomes more plastic once warmed inside the body, yet is resistant to the damaging effects of alcohol, iodine and hydrogen peroxide [5]. Due to the higher durability of polyurethane as compared to silicone, polyurethane catheters have thinner walls. Catheters with larger internal diameters and the same external diameters have improved blood flow. Animal studies have demonstrated reduced thrombogenicity and lower infection risks with the use of polyurethane catheters in comparison with silicone catheters. However, *in vivo* and *in vitro* studies have not confirmed the advantage of one material over another [6].

The Dacron cuff used in long-term catheters enables fixing of the device in the subcutaneous tissue and prevents the migration of microorganisms along the catheter tunnel (Fig. 1) [7]. No explicit data exist proving superiority of the use of antibacterial and/or anticoagulant substances in cases of long-term catheter use, as their efficacy is time--limited [8].

Despite the changes introduced into catheter distal tip design (split, staggered, spiral), there are insufficient data indicating improvement in catheter survival rate with these new technologies. Recirculation in all types of tips is 6–8% of total blood flow through an extracorporeal circuit [9]. However, animal studies have revealed that in cases of dialyses with reversed lines, catheters with spiral tips have lower blood recirculation rates (by up to 3%) when compared with staggered tip (18–30%) or split tip catheters (7–18%) [10]. Furthermore, the presence of lateral holes on the distal tip has been demonstrated to increase the risk of catheter-associated bacteraemia due to possible thrombus formation [11]. The available studies comparing double- and single-lumen long-term catheters have failed to show any difference in survival rates, incidence of catheter-associated bacteraemia episodes or disturbances in blood flow through an extracorporeal circuit. However, some evidence suggests that a significantly shorter time is needed to insert a double-lumen catheter as compared with two single-lumen catheters [12, 13].

Several reports have indicated an advantage of using one long-term catheter over another with respect to the parameters evaluated (i.e., survival rates, catheter flow, recirculation, catheter-associated infection). However, large controlled randomised trials demonstrating explicit superiority of one catheter type are still lacking [1, 6].

A



B

Figure 1. Double-lumen, long-term catheter for haemodialysis with a characteristic Dacron cuff allowing subcutaneous tissue ingrowth (A). Double-lumen, short-term catheter without a cuff (B)

CENTRAL VENOUS ACCESS

According to the guidelines of the NKF K/DOQI of 2006, the preferable locations for insertion of both temporary and long-term catheters should be:

— the right internal jugular vein,
— the left internal jugular vein,
— femoral veins.

The following should be considered as emergency access sites:

— subclavian veins,
— the inferior vena cava via translumbar or transhepatic access,
— renal, intercostal, or mediastinal veins.

The catheter distal tip should be placed in the vessels transporting large volumes of blood, which can only be achieved by placing it in the vein of the largest possible diameter, i.e. the inferior or superior vena cava or, in some cases, the right atrium.

Ultrasound-guided catheterisation of veins is recommended to reduce the incidence of early complications [14]. To ensure the optimal location of the catheter distal tip, long-term catheters should be placed under fluoroscopy [14]. When temporary catheters are inserted through the internal jugular or subclavian veins without fluoroscopic control, haemodialysis should be preceded by the chest X-ray to check the catheter position and to exclude early complications [15].

Each central access should be performed in the operating room or in a treatment room that has been specifically designated for this purpose. Aseptic principles must be followed and applied to both the operative field and the uniform of the physician performing the procedure.

CATHETERISATION OF THE UPPER-BODY VEINS

Catheterisation is most commonly performed in the Trendelenburg position to prevent air embolus and to increase the diameters of the subclavian and jugular veins. For the best benefit-complication ratio when obtaining vascular access through the right internal jugular and right subclavian veins, optimal blood flow through the temporary catheter is obtained by placing its distal tip in the superior vena cava above the bifurcation of the trachea. When the left internal jugular vein and left subclavian vein are used, the tip should lie below the bifurcation of the trachea or the upper right atrium (Fig. 2).

The catheter tip inserted from the left side is placed deeper, as it should be parallel to the vascular lumen [16]. As the left brachiocephalic vein enters the superior vena cava at approximately a right angle, if catheter placement is too shallow, the distal tip can rest on the lateral wall of this vein [17]. Changing from a decubitus to an upright position, respiratory movements and movements of the upper limbs can alter the position of the distal tip even by 2–3 cm; therefore, its insertion is particularly important in

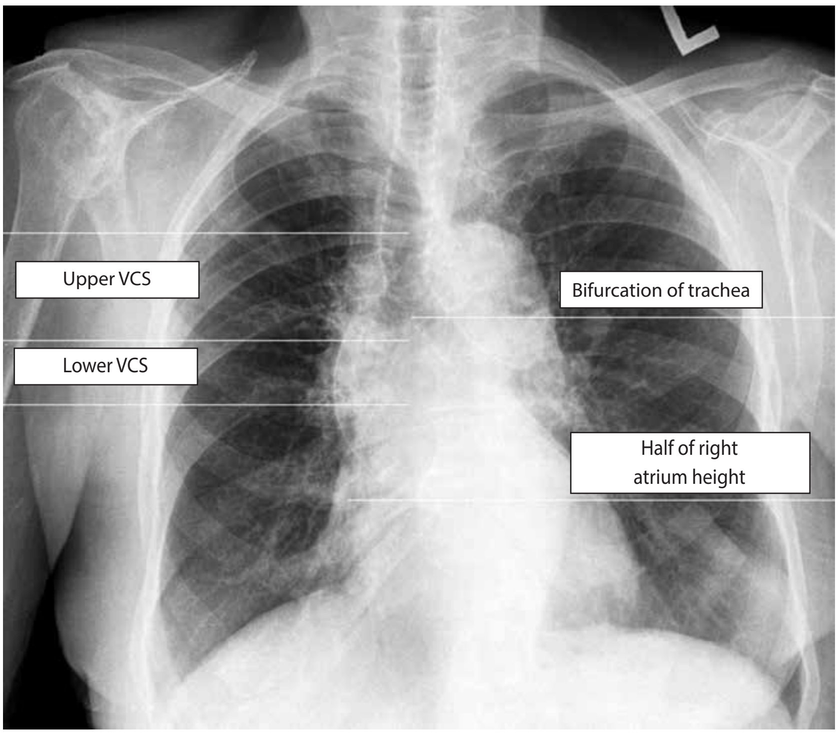


Figure 2. Chest X-ray showing zones of appropriate positioning of the catheter tip (description in the text)

Table 1. Approaches to the internal jugular vein, according to [24]

Method	Needle insertion point	Direction of needle insertion (body planes)	
		In sagittal and transverse plane	**In relation to frontal plane**
Boulanger (high medial approach)	Intersection of lines running along the upper edge of cricoid cartilage (at the level of 4th cervical vertebrae) and medial edge of the sternocleidomastoid (SCM) muscle	Laterally at the angle of 45° in relation to the lateral edge of SCM muscle (towards the ipsilateral mammilla)	Dorsally at the angle of 10°
Vaughan and Weygandt (high medial approach)	Apex of the minor supraclavicular fossa	Cephalad	Dorsally at the angle of 30°
Brinkman and Costley (high Lateran approach)	Along the lateral edge of SCM muscle, cephalad from the point in which the external jugular vein crosses the muscle	Medially towards the suprasternal notch (jugular notch)	As in Boulanger method
Daily (low central approach)	Middle of minor supraclavicular fossa	Cephalad in sagittal plane (if the vein is not found, the direction should be changed by 5–10° laterally in relation to the sagittal plane)	As in Vaughan and Weygandt method
Rao (low central approach)	Notch just above the upper clavicular surface, 0.25–1 cm from the medial clavicular end	As in Daily method	Dorsally at the angle of 30–40°
Jernigan (low lateral approach)	Two fingers above the clavicle on the lateral edge of the lateral head (clavicular) of SCM muscle	Cephalad and medially towards the minor supraclavicular fossa	Dorsally at the angle of 15°

cases of catheters placed through the veins of the left side of the body [18].

The distal tip of all long-term catheters inserted through the upper-body veins should be situated midway the height of the right atrium [19].

The required catheter length can be calculated using the formula: height in cm/10 [20]. It should be noted, however, that this formula was designed for a catheter inserted through the right internal jugular vein, through the puncture site located halfway up the neck and assuming that the distal tip is placed at the superior vena cava-right atrium junction. Utilising measurements of the distance between surface landmarks along the selected venous vessel appears to be a more accurate method [21]. The required catheter length is calculated by placing the catheter over the sterilely draped skin and measuring from the point of skin puncture, through the clavicular notch on the puncture side to the attachment of the second rib on the right side to the sternum angle, corresponding to the bifurcation of the trachea in the horizontal plane. During the measurement, the patient's head should be in a neutral position.

APPROACHES TO THE INTERNAL JUGULAR VEINS

The preferred location for catheter insertion is the right internal jugular vein, as it is the simplest access point to the superior vena cava and right atrium and is the relatively safest option. Catheter insertion through the left internal jugular vein increases the potential risk of future fistulae or vascular grafts on the same side. Moreover, catheterisation of the left internal jugular vein favours an increased incidence of constrictions, thrombosis and vessel damage.

During catheterisation of the internal jugular veins, it is recommended to slightly rotate the head in the direction opposite to the punctured vessel. Excessive rotation and bending of the head can decrease the vessel lumen. Therefore, nothing should be placed under the patient's shoulders [22].

The techniques for internal jugular vein access are divided into low and high approaches:

- low approaches — between the apex pulmonis and the vertex of a triangle formed by the two heads of the sternocleidomastoid muscle (minor supraclavicular fossa);
- high approaches — above the triangle formed by the two heads of the sternocleidomastoid muscle (at the level or above the cricoid cartilage) [23].

The most common methods of catheterisation of the internal jugular veins are presented in Table 1. The authors typically use the method described by Jernigan and co-workers [24] and modified according to the ultrasound scan.

A study by Metz and colleagues [25] demonstrated that the mean skin-internal jugular vein distance is 2.6 cm. According to Both et al., the distance in the triangle formed by the heads of the sternocleidomastoid muscle ranges from 1 to 1.5 cm. The lack of aspiration at deeper needle insertion is often caused by an unrecognised perforation of the anterior

Table 2. Approaches to the subclavian vein, according to [24, 27]

Method	Needle insertion point	Direction of needle insertion (body planes)	
		In the sagittal and transverse plane	In relation to frontal plane
Aubaniac (subclavicular)	1 cm below the centre of lower clavicular edge	Medially towards the minor supraclavicular fossa	In frontal plane under the clavicle
Morgan and Harkins (subclavicular)	Just below the lower clavicular edge	Medially towards the suprasternal (jugular) notch	In frontal plane under the clavicle
Tofield (subclavicular)	1 cm below and laterally to the centre of lower clavicular edge	Medially towards the suprasternal (jugular) notch	In frontal plane under the clavicle
Goedecke (subclavicular)	1.5 cm below the medial edge of tuberositas deltoidea of clavicule	Medially towards the suprasternal notch (if the vein is not found, the direction should be changed by 10° cephalad)	In frontal plane under the clavicle

and posterior vascular wall; in such cases, the vein can be correctly identified during needle withdrawal.

APPROACH TO SUBCLAVIAN VEINS

Table 2 presents the methods of catheterisation of subclavian veins. We most commonly apply the approach suggested by Goedecke and colleagues [27], in which the deltoid tuberosity of clavicule is used as an anatomic landmark. The use of this point substantially facilitates determination of the skin puncture site. In this method, as opposed to other techniques of subclavian vein catheterisation, the patient remains in the dorsal decubitus position with the head and shoulders in the neutral position. The insertion of the needle in the distal segment of the subclavian vein reduces the risk of accidentally passing through the costoclavicular ligament or the subclavian aponeurosis, thus facilitating the placement of a soft long-term haemodialysis catheter. Compared to proximal approaches, the distal vascular puncture results in lesser catheter bending between the skin puncture site and superior vena cava. This may be extremely relevant when rigid, large-external diameter catheters, such as short-term catheters, are used [28].

The use of a subclavian approach for long-term catheters carries the risk of the "pinch off" phenomenon, in which extravascular catheter compression in the limited area between the first rib and the clavicle can cause fissure or tearing off of the catheter [29].

Basing on the methods of Morgan and Harkins and the method described by Tofield [24], when the vein is not found, we modify needle insertion by directing it medially 2 cm above the centre of the suprasternal notch and changing the position of the needle by 5–10° dorsally in relation to the frontal plane. Due to the above modifications, the costoclavicular ligament is not passed.

CATHETERISATION OF LOWER-BODY VEINS

APPROACH TO FEMORAL VEINS

No explicit opinion has been established regarding the optimal location of the distal tip of catheters inserted through the iliac veins. The majority of standard catheters (20 cm long) reach the iliac veins. The placement of the distal catheter tip in the iliac vein can cause increased blood recirculation. Recirculation can be reduced by placing the catheter tip in the inferior vena cava or the right atrium, which provides the proper catheter length, 24 cm and 30–40 cm, respectively. Longer catheters, however, increase the resistance of blood flow, which should be considered.

The femoral vein can be punctured using the method by Hohn and Lambert [24], in which the point of needle insertion is situated directly medially to the femoral artery below the inguinal ligament (approximately 2 cm). The needle is inserted cephalad at an angle of 10–15° dorsally in relation to the frontal plane and slightly medially in relation to the sagittal plane.

NON-CONVENTIONAL VASCULAR APPROACHES TO CENTRAL VEINS

Once standard approaches have failed, translumbar and transhepatic approaches to the interior vena cava are considered to be rescue methods. Although the literature regarding their usefulness is sparse, the available studies document that functioning of the translumbar approach and the incidence of complications do not differ from those observed in standard approaches [30, 31].

The transhepatic approach should be used only when classic and translumbar approaches have failed, due to the numerous complications and short survival rates associated with the procedure.

SUMMARY

The wide variety of available catheterisation methods proves the lack of ensured and safe access to central veins. To reduce the number of complications, central venous catheterisation should be performed following aseptic principles, under ultrasound guidance and with subsequent radiologic confirmation of the distal catheter tip location.

In accordance with the NKF K/DOQI guidelines published in 2006, catheterisation of the subclavian veins is not recommended due to the high risk of constrictions and/or thrombosis, making later formation of a vascular fistula on the appropriate upper limb impossible. Catheterisation of the femoral veins is associated with an increased risk of thrombosis compared with catheterisation of internal jugular and subclavian veins. Catheter insertion through the femoral veins in patients who are qualified for kidney transplants is not recommended as the renal veins of the donor kidney are transplanted to the femoral veins.

The preferred locations for vascular access are the internal jugular veins (in particular, the right internal jugular vein), followed by the femoral and subclavian veins. Prior to choosing the catheter and the location of catheterisation, the nephrologist and the assisting anaesthesiologist should determine the venous vessels available for catheterisation, the anticipated duration of catheter use and the target access for dialysis therapy in cases of chronic renal replacement treatment.

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