

A single-center study of vascular access sites for intravenous ports

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Abstract

Purpose This study evaluated the use of intravenous ports and provides a guide related to clinical decision making.

Methods This study retrospectively reviewed 1505 patients who had received intravenous ports at Chang Gung Memorial Hospital in 2006. The relationships between the complications and entry routes were assessed. The intervention-free periods were also determined and compared. The patients were followed up until June 2010.

Results Of the 1543 procedures performed, 412 were reinterventions to treat complications, most of which corresponded to fewer than 0.1 episodes per 1000 catheter-days; these were not associated with any particular entry route. There was a higher catheter fracture rate when the right subclavian vein was chosen as the entry vessel ($p < 0.05$). The intervention-free period ranged from 207 to 533 days.

Conclusion The subclavian vein is not recommended for the use of intravenous ports. There is not only a higher risk of iatrogenic pneumothorax or hemothorax using this entry route but also a higher fracture rate, which may be caused by pinch-off syndrome. The greater saphenous vein should only be considered when the patient has superior vena cava syndrome. However, a higher incidence of infection and a lower device survival rate should be expected with this location.

Introduction

Many cancer patients require long-term central venous access for the administration of intravenous medication and parenteral nutrition, as well as the withdrawal of blood [1]. Venotoxic antineoplastic agents may compromise the venous integrity, making it progressively more difficult to achieve and maintain reliable peripheral venous access during chemotherapy [2]. For these reasons, reliable venous access is critical for oncology patients, and to avoid repeated venous puncturing, intravenous ports have been introduced.

Percutaneous central venous catheterization was first described by Aubaniac in 1952 [1]. However, when using this technique, the entry sites still needed to be changed to avoid entry-site infection. Early long-term venous access devices were first described by Broviac et al. and Hickman et al. [3, 4]. However, these devices still contained a subcutaneous cuff and permanent tube, and thus, had cosmetic disadvantages. Finally, Niederhuber et al. [5] introduced a completely implanted venous port system for cancer patients in 1982. Prior to setting up an intravenous port, the most suitable entry point for a vascular route is decided based on the patient's condition. This study analyzed our clinical experience with regard to this issue and provides suggestions for the decision-making process to choose an appropriate vascular access position for intravenous port set-up.

Materials and methods

Patient selection

This study retrospectively reviewed 1505 patients who received intravenous port implantations or reinterventions

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from January 1 to December 31, 2006, at Chang Gung Memorial Hospital; the patients were followed up until June 30, 2010. For living patients, the last outpatient follow-up date was considered as the endpoint of follow-up. In others, the date of death or discharge against advice was considered as the endpoint.

The devices and their use

Single lumen access intravenous ports were used in all cases; these were of the following four types: Arrow Fr. 8 (Arrow International Inc., PA, USA), Bard Fr. 8 (Bard Access System Inc., Utah, USA), Bard Fr. 6.6 (Bard Access System Inc., UT, USA) and Tyco Fr. 6 (Tyco Healthcare Group, CT, USA). The majority of patients (99.53 %) were oncology patients who required chemotherapy for curative or palliative treatment.

The superior vena cava (SVC) route via the right-sided approach was preferred because of the shorter length of catheter required for implantation; this is because left-sided vessels cross the midline via the brachiocephalic vein to form a junction between the SVC and the right atrium (RA). Vessels on the left side were used only under specific clinical scenarios, including situations where patients previously had a right-sided intravenous port removed or had undergone a right modified radical mastectomy. The inferior vena cava (IVC) route was preferred in patients with a high risk of SVC syndrome.

Implantation method

Four different entry vessels can be chosen for the intravenous port: the cephalic vein, the concomitant vein of the deltoid branch of the thoracoacromial artery, the subclavian vein or the internal jugular vein. One small skin incision was created 1 cm below the clavicle for all cases. The cephalic vein lies between the pectoralis major and deltoid muscles at this level. If the cephalic vein was absent, we explored deeper along the deltopectoral groove for the concomitant vein of the deltoid branch of the thoracoacromial artery. If neither the cephalic vein nor the concomitant vein of the deltoid branch of the thoracoacromial artery could be identified, the subclavian and internal jugular veins could be utilized for catheter implantation based on the surgeon's preference. We selected the IVC route only for patients with, or at a high risk of, SVC syndrome. When the catheter was implanted via the IVC route, the greater saphenous vein was preferred. For patients with an intravenous port implanted via the IVC route, the injection chamber was implanted at the position of the anterior–inferior iliac spine or the lower costal ridge. In these two locations, the underlying bony structure provided rigid support for the injection chamber,

which allowed the port system to be easily palpated and punctured.

Either the cut-down or the percutaneous puncture method could be used for catheter implantation; the cut-down method could also be utilized for superficial vessels. The cut-down process could be visualized, and the risk of iatrogenic injuries, such as hemopneumothorax or vessel injuries, could thus be minimized. If difficulties were encountered during blunt catheter implantation, a metallic guidewire was used to establish a suitable route prior to catheter implantation. The catheter was slid over the guidewire into the proper position under fluoroscopy, and the metallic wire was removed after catheter implantation. If the vessel diameter was too small for catheter insertion, a modified puncture using the Seldinger technique, as described by Coit and Turnbull [9], increased the success rate of the cut-down approach. The percutaneous puncture method was used in the absence of vessels that prohibited catheter cannulation. After the catheter was implanted, it was connected to the port, which was fixed over the fascia of the pectoralis major. The type of implanted port was chosen based on the surgeon's preference.

Follow-up and surveillance

The pocket appearance was inspected, the upper extremity of the implanted site was physically examined and a functional withdrawal test was performed in the outpatient department on a monthly basis for all patients. We used a 10 ml syringe with heparin solution (50 IU/ml) for the withdrawal test and intravenous port irrigation. An additional 10 ml of heparin solution were used as a heparin lock. The patients were routinely examined by plain chest radiography for regular tumor surveillance; in the absence of any problems, the start of chemotherapy was scheduled. When patients had swelling of the extremities, deep vein thrombosis was strongly suspected. Echo images of peripheral vessels were then obtained, and the port was removed if deep vein thrombosis was confirmed. Anatomical confirmation of the catheter tip was performed by chest radiography (posteroanterior view). The ideal catheter location was at the junction of the SVC and RA.

Statistical analysis

Different vascular sites were compared using the Chi-squared test or Fisher's exact test for categorical variables, *t* tests for continuous variables with a normal distribution, and the Mann–Whitney test for continuous variables that were not normally distributed. A Kaplan–Meier analysis was used to demonstrate the functional period of an intravenous port. A value of $p < 0.05$ was considered to be statistically significant. All analyses were performed using

the Statistical Package for the Social Sciences (SPSS) software program, version 13.0 (Chicago, IL, USA).

Results

Of the 1505 patients reviewed, 853 males and 652 females underwent 1543 procedures, including implantations and reinterventions (Table 1). There were 32 patients (20 males and 12 females) who underwent repeat procedures because of catheter-related problems. Of all the procedures, 11 (0.71 %) gave rise to procedure-related early complications (Table 2). Ten of them underwent further management, including catheter adjustment, hematoma evacuation or change a new intravenous port, in order to resume the port function. Only one patient with pneumothorax underwent conservative treatment instead of chest indwelling tube insertion, but with a 17-day hospitalization. There were 412 reintervention procedures because of mechanical failure or other etiologies (Table 3). Four different types of intravenous ports were utilized for implantation, and a total of 1542 intravenous ports were implanted (Table 4). One

Table 1 Patient characteristics

Number of patients	1505
Number of patients (M/F)	853/652
Mean age (M/F)	59.18/55.76
Median age (M/F)	58/56
Range	0.5–94
Number of patients requiring reintervention (M/F)	20/11
Number of interventions (M/F)	877/666
Underlying disease (M/F)	
Lung malignancy	287/127
Breast malignancy	0/186
Hematological malignancy	79/82
Head and neck malignancy	135/17
Esophageal malignancy	125/5
Colorectal malignancy	62/59
Gynecological malignancy	0/99
Hepatobiliary malignancy	70/14
Gastrointestinal tract malignancy	42/24
Genitourinary tract malignancy	29/13
Bone/Soft tissue/Skin malignancy	11/19
Pancreatic malignancy	13/10
Mediastinal malignancy	8/3
Poor vascular access	6/2
CNS malignancy	3/4
Unknown primary	4/1
Double malignancy	2/2
Thyroid malignancy	1/0

CNS central nervous system, M male, F female

Table 2 Early procedure-related complications

Early procedure-related complications	Number of patients
Catheter kinking	4
Catheter migration	1
Subcutaneous hematoma	2
Infection	2
Pneumothorax	2

Table 3 Reasons for reintervention

	Vessel			
	Cephalic vein	Subclavian vein	Internal jugular vein	Other ^a
Number of patients	1216	234	63	29
Number of reinterventions	323	68	12	9
Reason for reintervention				
Fracture	29	29	1	0
Migration	28	5	0	1
Infection	110	15	5	4
Malfunction	39	7	0	2
Pocket erosion	14	0	0	1
Hematoma	5	0	0	0
DVT	14	3	1	0
Port rotation	3	0	0	0
Catheter kinking	7	1	0	0
Pain	2	0	0	0
Tx complete	89	13	5	1
Patient request	4	1	0	0
Change to PICC	1	0	0	0

PICC peripherally-inserted central catheter, Tx complete treatment course complete

^a This category includes 13 right greater saphenous veins, 5 left greater saphenous veins, 7 concomitant veins of the thoracoacromial artery, 1 right axillary vein, 1 left axillary vein, 1 right external jugular vein and 1 left external jugular vein

patient was unable to tolerate the procedure, and no further implantation was performed.

Although the SVC route via the right-sided approach was preferred, the IVC was preferred if there were clinical symptoms or signs of SVC syndrome. In all, 1216 and 234 patients received intravenous port implantation via the cephalic (Table 5) and subclavian veins, respectively, using the puncture method. Two patients suffered from pneumothorax (0.85 %, 2/234). In addition, the dominant cephalic vein, including associated tiny vessels and venous plexus formation, was absent in 63 patients who underwent failed subclavian vein puncture; the internal jugular vein

Table 4 Intravenous port types and entry sites

	Vessel							
	Cephalic vein		Subclavian vein		Internal jugular vein		Other	
	Right	Left	Right	Left	Right	Left	Right	Left
Number of patients	1071	145	193	41	48	15	22	7
Average age (years)	57.5	53.524	57.394	52.829	59.375	57.6	52.841	55.86
Gender								
Male	656	54	102	13	29	3	15	5
Female	415	91	91	28	19	12	7	2
Port type								
Arrow Fr. 8	237	38	111	17	19	4	9	5
Bard Fr. 8	513	65	58	15	16	8	5	0
Bard Fr. 6.6	319	36	21	8	17	3	8	2
Tyco Fr. 6	2	6	3	0	8	0	0	0
Average length of operation (min)	36	40	40	45	50	69	59	59
Mean intervention-free period (days)	397.85	511.86	326.73	533.53	409.96	348.47	210	207.14
Range (days)	1–1831	0–1996	0–1495	8–1531	6–1415	9–1022	5–1455	1–961

was used as an entry vessel for these patients. Echo-guided puncturing was performed for internal jugular vein access. In addition, the concomitant vein of the thoracoacromial artery was successfully used as the entry route in seven patients. Two patients received implantation via the axillary vein with purse-string suturing, carried out prior to catheter implantation. Two patients without accessible cephalic and thoracoacromial vessels underwent catheter cannulation via the external jugular vein, which was easily palpable.

After the catheter was cannulated to the proper tip location using fluoroscopy, the intravenous port was connected to the catheter and implanted just above the fascia of the pectoralis major. However, 18 patients received port implantation via the greater saphenous vein because of SVC syndrome or a small SVC caliber caused by external compression. In patients with IVC ports, we created a subcutaneous tunnel and fixed the port over the anterior–inferior iliac spine or costal region; this was done because the underlying bony structure provides better support for the device.

The lengths of the operations were shorter when the cephalic or subclavian vein was used as the entry vessel (Table 5); longer surgery times were encountered when the internal jugular vein or other vessels were used. This might be related to the number of exploration sites and the more sophisticated procedures used. The mean intervention-free periods ranged from 207 (range 1–961) to 534 (range 8–1531) days, thus indicating that the intravenous port provides reliable venous access for at least 6 months.

The incidence of catheter-related complications per 1000 catheter-days is shown in Table 5. The majority of

patients had less than 0.1 episodes per 1000 catheter-days. The incidence of catheter infection was 0.2219 episodes per 1000 catheter-days. When other vessels (i.e., vessels other than the cephalic, subclavian, and internal jugular veins) were used for entry, the infection incidence increased to more than 0.6 episodes per 1000 catheter-days. The majority of these patients received intravenous port implantation via the greater saphenous vein and had shorter intervention-free periods and higher infection rates.

The relationship between the entry vessel and complications was analyzed. The occurrence of complications was as high as 13.47 % in the patients who underwent 193 right subclavian punctures, and the incidence was 0.3758 episodes per 1000 catheter-days (Table 5). There was a greater catheter fracture rate when the catheter was implanted via the right subclavian vein ($p < 0.05$). Thus, only catheter fracture was related to the entry vessel chosen (Table 5). There was no clear relationship between the catheter entry route and complications, aside from catheter fracture.

The follow-up status for patients who received port implantation is summarized in Table 6. Patients who died and those with a critical discharge were considered to have completed the follow-up program in our hospital. For surviving patients, the last date that they visited our outpatient department was considered as the endpoint for the follow-up program. In this study, only 62.35 % of patients completed the follow-up program in our hospital. The mean follow-up period was 646 days (range 2–3302 days). In this study, the patients who underwent port implantation or reintervention in 2006 were included. Therefore, patients who had undergone port implantation prior to

Table 5 Rates and incidence of complications

Complication	Vessel								Total 1542 patients	
	Cephalic vein 1216 patients		Subclavian vein 234 patients		Internal jugular vein 63 patients		Other 29 patients			
	Right	Left	Right	Left	Right	Left	Right	Left		
Pneumothorax	0	0	1.04 % ^a	0	0	0	0	0	0	0.13 %
Fracture	2.05 %	4.83 %	13.47 % ^{*#}	7.32 %	2.08 %	0	0	0	0	3.83 %
Migration	2.33 %	2.07 %	2.59 %	0	0	0	0	0	14.29 %	2.2 %
Infection	8.87 %	10.34 %	6.22 %	7.32 %	10.42 %	0	13.64	14.29 %	14.29 %	8.69 %
Malfunction	3.17 %	3.44 %	2.59 %	4.88 %	0	0	%	14.29 %	14.29 %	2.98 %
Pocket erosion	1.31 %	0	0	0	0	0	4.55 %	0	0	0.97 %
Hematoma	0.37 %	0.69 %	0	0	0	0	4.55 %	0	0	0.32 %
DVT	1.12 %	1.38 %	1.04 %	2.44 %	2.08 %	0	0	0	0	1.17 %
Port rotation	0.19 %	0.69 %	0	0	0	0	0	0	0	0.19 %
Catheter kinking	0.56 %	0.69 %	0	2.44 %	0	0	0	0	0	0.45 %
Pain	0.19 %	0	0	0	0	0	0	0	0	0.13 %
Incidence ^b	Vessel									
	Cephalic vein		Subclavian vein		Internal jugular vein		Other			
	Right	Left	Right	Left	Right	Left	Right	Left		
Fracture	0.0516	0.0943	0.3758	0.1406	0.0508	0	0	0	0.0948	
Migration	0.0587	0.0404	0.0723	0	0	0	0	0.6897	0.0546	
Infection	0.2229	0.2021	0.1734	0.1406	0.2541	0	0.6493	0.6897	0.2219	
Malfunction	0.0798	0.0674	0.0723	0.0469	0	0	0.2165	0.6897	0.0772	
Pocket erosion	0.0329	0	0	0	0	0	0.2165	0	0.0241	
Hematoma	0.0094	0.0135	0	0	0	0	0	0	0.0096	
DVT	0.0281	0.0269	0.0289	0.0469	0.0508	0	0	0	0.0289	
Port rotation	0.0047	0.0135	0	0	0	0	0	0	0.0048	
Catheter kinking	0.0141	0.0135	0	0.0469	0	0	0	0	0.0127	
Pain	0.0047	0	0	0	0	0	0	0	0.003	

DVT deep vein thrombosis

^a No cephalic vein was present, and the patient underwent repeated failed punctures for the right subclavian vein. We finally opted for a right internal jugular vein puncture for port implantation. The patient presented with pneumothorax after the operation and received chest tube drainage for 5 days

^b Number of episodes per 1000 catheter-days

* $p < 0.05$, right subclavian vein vs. right cephalic vein

$p < 0.05$, right subclavian vein vs. left cephalic vein

! $p < 0.05$, right subclavian vein vs. right internal jugular vein

2006, but who received reintervention in 2006, were also included. This led to a maximum follow-up period of up to 3302 days.

A cumulative functional period curve for the intravenous ports implanted via different entry sites is presented in Fig. 1. Port systems implanted via the greater saphenous vein showed a lower device survival rate. At 6 months after the procedure, only 46.6 % of the port systems remained functional and could be kept in clinical use. However, more than 90 % of the port systems implanted via other routes survived beyond the 6-month interval.

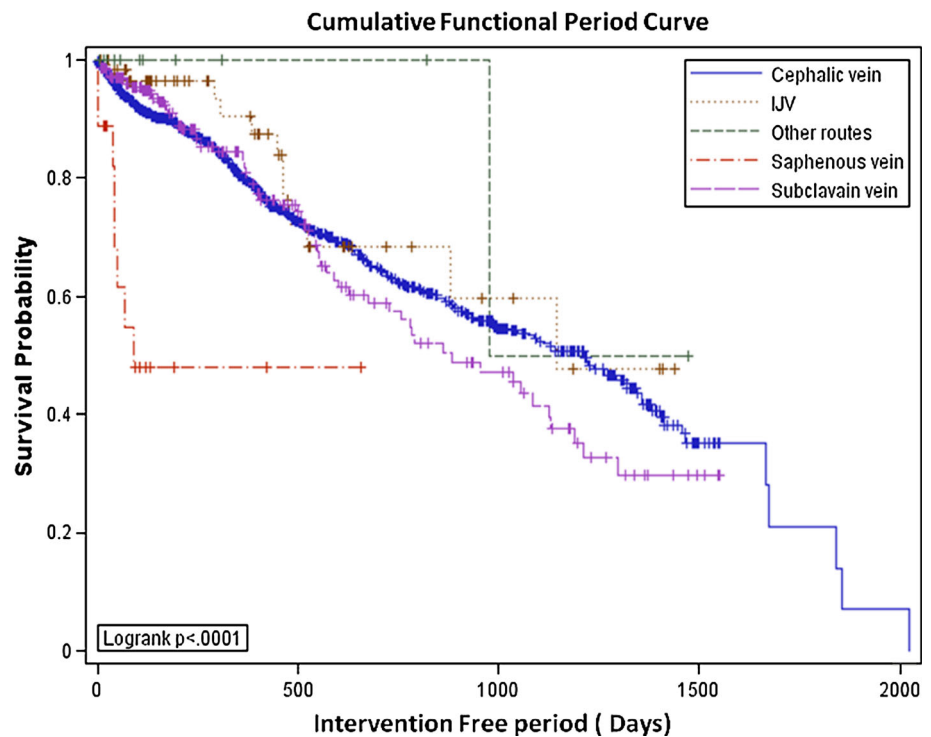
Discussion

The choice of the entry vessel is crucial for predicting the outcome of port implantation. A review of the literature revealed that the preferred route is via the SVC [6]. When the SVC is thrombosed, the IVC can be accessed via the saphenous, femoral, inferior gastric or iliac routes [7]. We summarize our recommendations for the implantation sites as an algorithm in Fig. 2. The cephalic vein is the first choice of entry vessel. If there is no predominant cephalic vein, the concomitant vein of the deltoid branch of the

Table 6 Patient follow-up status

Entry site	Follow-up status				Mean (range)
	Alive	Deceased	Critical discharge ^a	Lost to follow-up	
Internal jugular vein	16	13	7	27 (42.85 %)	726.33 (3–1922)
Cephalic vein	249	258	241	468 (38.48 %)	642.35 (2–3302)
Subclavian vein	54	58	46	76 (32.47 %)	647.58 (8–2444)
Greater saphenous vein	6	0	7	5 (27.78 %)	246 (15–646)
Other routes	5	2	0	5 (41.67 %)	654 (15–2399)
Overall	330	331	301	581 (37.65 %)	645.92 (2–3302)

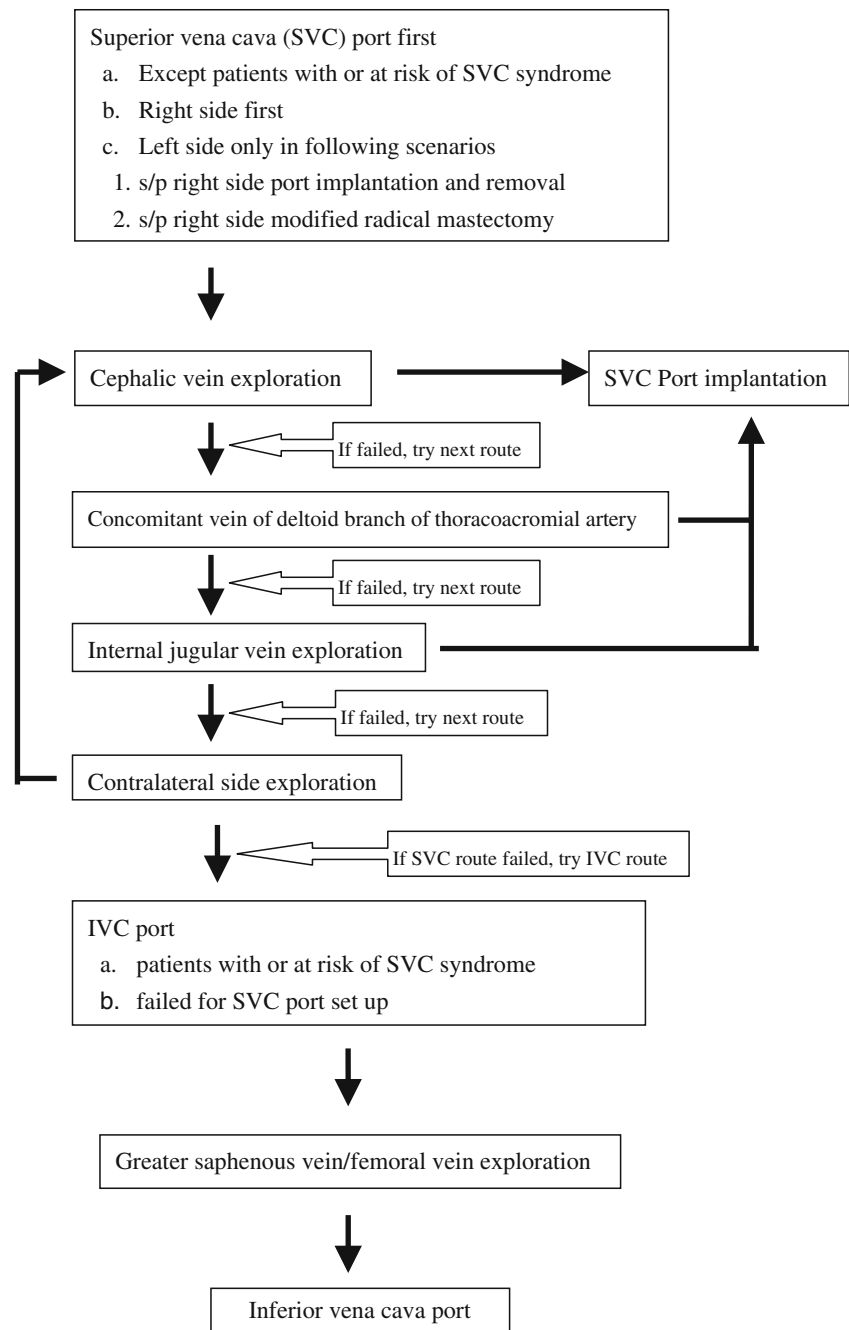
^a For patients with disease progression, unstable hemodynamics and death may occur even after aggressive treatment. We defined those patients with unstable hemodynamics who refused further management and requested discharge from the hospital as having a “critical discharge.”

Fig. 1 Cumulative functional period curve of intravenous ports via different entry sites

thoracoacromial artery may be considered. If neither the cephalic vein nor the concomitant vein of the thoracoacromial artery is found, then the internal jugular vein can be used by means of the echo-guided puncture method. Implantation via the subclavian vein using the puncture method is not recommended owing to the risk of iatrogenic injury. The greater saphenous vein should only be considered in patients who present with SVC syndrome or external compression of the SVC due to large mediastinal lymphadenopathy.

The related literature reports complication rates ranging from 11 to 25 % [8]. The current study found an overall complication rate of 19.32 % (298/1542). The early complications reported included incorrect positioning, improper anchoring of the reservoir, skin infection and vascular

perforation [9]. In this study, only 11 patients (0.71 %) exhibited early complications (Table 2). The majority (10/11) underwent further management, including catheter adjustment, hematoma evacuation or change a new intravenous port, in order to resume the port function. Only one patient with pneumothorax who was treated conservatively. The reported incidence of pneumothorax is 0.2–0.5 % in the internal jugular vein, 0.5–2 % in subclavian vein catheterization [10], and was 0.85 % (2/234) in the present study, which is consistent with the medical literature. For patients with SVC ports, only catheter fracture was related to the entry vessel chosen. The catheter fracture rate was higher when the implantation was made via the right subclavian route than when the bilateral cephalic or right internal jugular vein was used ($p < 0.05$). This may be

Fig. 2 Algorithm of choosing an entry vessel

related to the development of pinch-off syndrome, as described by Aitken and Minton [11]. Pinch-off syndrome is defined as the anatomical mechanical compression of a catheter as it passes between the clavicle and the first costoclavicular space. It can be avoided as long as the catheter is inserted lateral to the midclavicular line when subclavian puncturing is used.

The spontaneous migration of a central catheter is not rare. The reported catheter dislocation rate is 1.3–5.4 % [12]. In this study, the migration rate was 1.89 %. Malpositioned catheter tips (79.4 %; 27/34) located in the

internal jugular and subclavian veins have also been reported [12]. Such malpositioning of the catheter tips may be related to physical movements that cause increased intrathoracic pressure, such as coughing, sneezing, straining or sighing [13]. A review of the pertinent literature suggests that malpositioning results not only in local phlebitis but also in venous thrombosis [14]. Once a malposition occurs, the position of the catheter must then be corrected.

The incidence of infection following venous port placement is reported to be 5–10 % [15]. The reported

catheter-related infection rate was 0.41 episodes per 1000 catheter-days in 82 patients who successfully underwent intravenous port placement via cephalic vein cut-down [16]. In this study, the incidence of infection was 8.3 %, and the overall catheter-related infection rate was 0.21 episodes per 1000 catheter-days. There was a shorter intervention-free period and greater infection incidence when other vessels were used. The “other vessels” included predominantly the greater saphenous vein, which would only be used in cases with a more severe disease status and tumor-related cachexia. This factor may be the main cause of the shorter intervention-free period and greater infection rate.

In this study, the estimated incidence and rate of catheter malfunction were 2.98 % and 0.0772 episodes per 1000 catheter-days, respectively. The mechanism of malfunction is a complex process that is influenced by multiple factors, including the rupture of the endothelium and the interruption of laminar blood flow by local trauma caused by catheter insertion. Morphological correlation studies have indicated that the fibrin sheath is a thrombotic coat containing fibrin, which can progress to form vascularized fibrous connective tissue [15]. A thin layer of clot that initially covers the catheter prevents the aspiration of blood through the central venous catheter, because it acts like a valve at the catheter tip. Fibrin sheath progression, leading to increased pressure, necessitates infusion and eventually causes occlusion. There are four different approaches that are used to resolve fibrin sheath formation: mechanical disruption, over-the-wire exchange, fibrin sheath stripping and thrombolytic therapy [17]. In our clinical practice, a metallic wire is used to cannulate the RA and change the catheter over the wire.

The reported rate of venous thrombosis caused by port catheters is 1.1–16.3 %. A review of the literature revealed that the incidence of symptomatic deep venous thrombosis of the upper extremities in most surgical studies using the subclavian approach is at least 0.4 per 1000 catheter-days [1]. In this study, the incidence of catheter-related deep vein thrombosis was 0.0289 per 1000 catheter-days, and the rate of deep vein thrombosis was 1.17 %. This lower incidence may be because there were fewer subclavian punctures and central vein injuries in our cases. Fewer central vein injuries would result in a lower level of stenosis. Catheters are routinely removed when clinical symptoms and signs of deep vein thrombosis are present in order to alleviate venous hypertension and decrease the possibility of chronic venous-stasis ulcers and SVC syndrome.

A cumulative functional period curve of intravenous ports showed a lower device survival rate for the greater saphenous vein. At 6 months after implantation, only 46.6 % of the port systems remained functional and were

still in clinical use. This was the result of a high incidence of infection (>0.6 episodes per 1000 catheter-days). However, more than 90 % of port systems using other routes remained functional after this point. This indicates that the port system is a safe means of vascular access for individuals needing chemotherapy.

Conclusions

The subclavian vein is not recommended as a location for an intravenous port. There is not only a higher risk of iatrogenic pneumothorax or hemothorax, but also a higher fracture rate when ports are implanted via the right subclavian vein, which may cause pinch-off syndrome. The greater saphenous vein should only be considered when the patient has SVC syndrome. However, a higher incidence of infection and a lower device survival rate are to be expected when this location is used.

References

1. Charvát J, Linke Z, Horáèková M, Prausová J. Implantation of central venous ports with catheter insertion via the right internal jugular vein in oncology patients: single center experience. *Support Care Cancer*. 2006;14(11):1162–5 (Epub 2006 Apr 5).
2. Bow EJ, Klipatrck MG, Clinch JJ. Totally implantable venous access ports systems for patients receiving chemotherapy for solid tissue malignancies: a randomized controlled clinical trial examining the safety, efficacy, costs, and impact on quality of life. *J Clin Oncol*. 1999;17(4):1267.
3. Broviac JW, Cole JJ, Scribner BH. A silicone rubber atrial catheter for prolonged parenteral alimentation. *Surg Gynecol Obstet*. 1973;136:602–6.
4. Hickman RO, Buckner CD, Clift RA, Sanders JE, Stewart P, Thomas ED. A modified right atrial catheter for access to the venous system in marrow transplant recipients. *Surg Gynecol Obstet*. 1979;148:871–5.
5. Niederhuber JE, Ensminger W, Gyves JW, Liepman M, Doan K, Cozzi E. Totally implanted venous and arterial access system to replace external catheters in cancer treatment. *Surgery*. 1982; 92(4):706–12.
6. Shankar KR, Anbu AT, Losty PD. Use of the gonadal vein in children with difficult central venous access: a novel technique. *J Pediatr Surg*. 2001;36(6):E3.
7. Aubaniac R. Subclavian intravenous injection; advantages and technique. *Presse Med*. 1952;60(68):1456.
8. Eastridge BJ, Lefor AT. Complications of indwelling venous access devices in cancer patients. *J Clin Oncol*. 1995;13:233–8.
9. Chang CL, Chen HH, Lin SE. Catheter fracture and cardiac migration—an unusual fracture site of totally implantable venous devices: report of two cases. *Chang Gung Med J*. 2005; 28(6):425–30.
10. Kincaid EH, Davis PW, Chang MC, Fenstermaker JM, Pennell TC. “Blind” placement of long-term central venous access devices: report of 589 consecutive procedures. *Am Surg*. 1999; 65(6):520–3 (discussion 523–4).
11. Aitken DR, Minton JP. The “pinch-off sign”: a warning of impending problems with permanent subclavian catheters. *Am J Surg*. 1984;148:633–6.

12. Rauthe G, Altmann C. Complications in connection with venous port system: prevent and therapy. *Eur J Surg Oncol.* 1998; 24(3):192–9.
13. Collin GR, Ahmadinejad AS, Misse E. Spontaneous migration of subcutaneous central venous catheters. *Am Surg.* 1997;63(4): 322–6.
14. Vasquez RM, Brodski EG. Primary and secondary malposition of silicone central venous catheter. *Acta Anaesthesiol Scand.* 1985;81: 22–5.
15. Chang L, Tsai JS, Huang SJ, Shih CC. Evaluation of infectious complications of the implantable venous access system in a general oncologic population. *Am J Infect Control.* 2003;31(1): 34–9.
16. Povoski SP. A prospective analysis of the cephalic vein cut-down approach for chronic indwelling central venous access in 100 consecutive cancer patients. *Ann Surg Oncol.* 2000;7(7):496–502.
17. Teichgräber UK, Gebauer B, Benter T, Wagner HJ. Central venous access catheters: radiological management of complications. *Cardiovasc Intervent Radiol.* 2003;26(4):321–33.