

CONTINUING MEDICAL EDUCATION

Central Venous Port Systems as an Integral Part of Chemotherapy

by Ulf K. Teichgräber, Robert Pfitzmann, and Herbert A.F. Hofmann

SUMMARY

Background: Port systems are easy to implant on an in- or outpatient basis and provide reliable, long-lasting central venous access. They are used mainly for cancer patients.

Methods: This article is based on a selective literature review, the guidelines of the German Society for Nutrition Medicine and of the European Society for Clinical Nutrition and Metabolism, and the recommendations of the German Society for Pediatric Oncology and Hematology.

Results: In modern oncology, central venous port systems are increasingly replacing short-term and permanently tunneled central venous catheters. They are indicated for patients who need long-term intravenous treatment involving, e.g., the repeated administration of chemotherapeutic drugs, parenteral nutrition, transfusions, infusions, injections, and/or blood sample collection. Port systems can markedly alleviate the burden of intravenous therapy and thereby improve these patients' quality of life. The planning, preparation, and performance of port system implantation require meticulous attention to detail. The rate of implantation-associated complications is less than 2% in experienced hands; overall complication rates have been reported from 4.3% to as high as 46%. The proper postoperative use and care of the port system are of decisive importance to the outcome. Reported infection rates during port system use range from 0.8% to 7.5% in current clinical studies.

Conclusion: The treatment, follow-up care, and rehabilitation of cancer patients are interdisciplinary tasks. Optimal treatment and complication avoidance require a collaborative effort of all of the involved specialists—not just the physician implanting the port system, but also the oncologists, nutritionists, visiting nurses, and other home health care providers. Continuing medical education, too, plays a role in improving outcomes.

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The recent advent of more intensive methods of chemotherapy and parenteral treatment has heightened the need for implantable devices that afford reliable central venous access over the long term. Central venous ports that are wholly implanted beneath the skin play a key role. In oncology, the patient's quality of life is the prime consideration, yet economic aspects of the often expensive treatments for cancer must also be taken into account; this is mandated in Germany by the Law on Cost-Efficient Medical Treatment (*Arzneimittelversorgungs-Wirtschaftlichkeitsgesetz, AVWG*) (1). Central venous port systems, which cost well under 500 euros each and can be used for years, eminently satisfy the economic requirements of modern oncology and add no more than a marginal amount to the cost of chemotherapy.

Learning objectives

The learning objectives for readers of this article are

- to become acquainted with the various uses of port systems,
- to gain an overview of the indications and the inclusion and exclusion criteria for port implantation,
- to know the special considerations in the medical and nursing care of patients with port systems.

In this review article, we discuss the function of, and indications for, port-catheter systems in the light of a selective review of the literature, including the main studies (mostly from the last 10 years) on complications and their management.

Underlying principles and function

Chemotherapeutic drugs can damage the wall of peripheral veins and thereby rapidly put an end to peripheral access. According to the current recommendations of the European Society for Parenteral and Enteral Nutrition (ESPEN), infusions of low osmolarity (<850 mOsm/L) may be given through indwelling peripheral venous

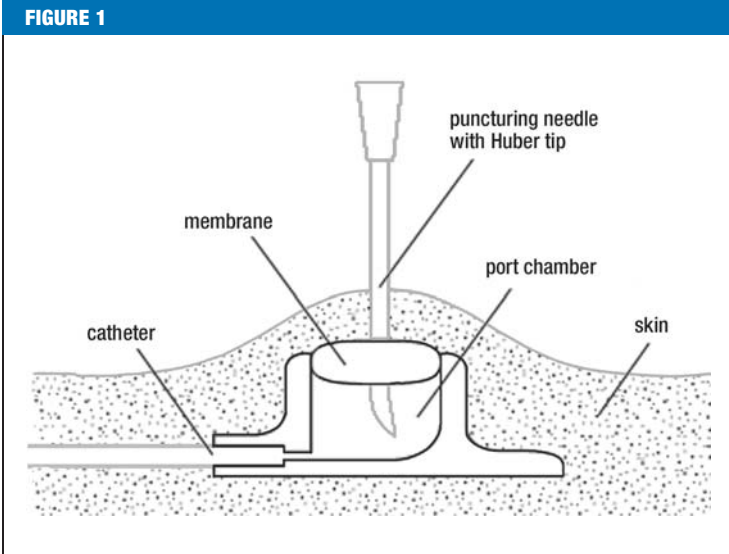
Definition

A central venous port is a venous access system that is implanted entirely under the skin.

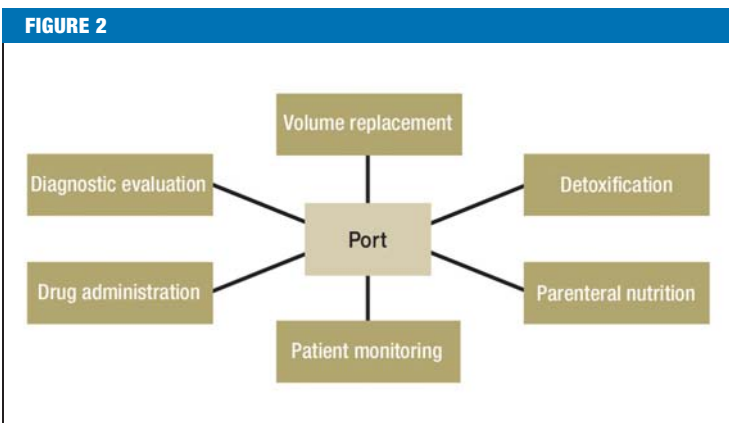
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A subcutaneously implanted central venous port system



While chemotherapy is the most common indication, central venous ports also have other uses

catheters (2). Many chemotherapeutic drugs, however, are administered in solutions of substantially higher osmolarity. Complications such as infection, narrowing of the venous caliber, and thrombotic occlusion can make peripheral venous infusion difficult or impossible. If a catheter is to get past the narrow peripheral vasculature, its tip must be advanced all the way to the vena cava near the heart. When the catheter tip is in this position, a large

volume of blood flows past it, so that medications given through the catheter are immediately diluted and can no longer damage the vessel wall. The first catheters of this type to be developed were percutaneous, non-tunneled catheters, which came into use in the 1950's (3).

Niederhuber et al. introduced the currently used type of port system into clinical use in 1982 (4). Unlike other implants, these devices are used repeatedly by many physicians and nurses and require transcutaneous puncture whenever an infusion is given. Improper use can lead to complications such as infection, extravasation, necrosis, or material failure (5). All persons treating cancer patients with port systems must assume responsibility for the meticulous care of the system. Catheter systems without ports have a connecting device at their distal (extracorporeal) end; in contrast, access to a port system requires puncture with a needle through the skin and the silicone membrane of the port chamber (Figure 1). Ports are always punctured under sterile conditions, with skin prep and sterile gloves, to prevent infection (6, 7).

Port puncture is easier when the port chamber is immobilized between the tips of two or three fingers of the puncturer's nondominant hand (8). Special needles with a non-punching Huber tip are used to puncture the silicone membrane of the port system (9, 10).

Indications

The determination that a port system should be implanted is usually made by oncologists of various subdisciplines, radiotherapists, or dieticians (Figure 2). The physician who is to implant the device reviews the indication and assesses the anatomical situation, which may be far from normal in patients who have previously undergone chemotherapy, radiotherapy, and/or surgery (11). There may be major changes of the skin, soft tissues, veins, or bones of the shoulder girdle. Ultrasonography of the central veins at the thoracic outlet is recommended to rule out anatomical variants and venous thromboses (12–16).

Implantation

A port can be implanted in an inpatient or outpatient setting or in a day surgery unit. The implanting physician should perform a physical examination and, where indicated, venous ultrasonography at the intended implantation site, during the same preoperative visit in which the patient is informed about the procedure and asked to give consent (17). The findings of these examinations determine the approach for central venous access and the appropriate type of port system (Figure 3). Thin or cachectic

Determining the indication

The indication for a port system is usually determined by oncologists, radiotherapists, and dieticians.

Pre-implantation examination

Ultrasonography of the central veins at the upper thoracic aperture is recommended to rule out anatomic variants and vascular thromboses.

patients are best served with a so-called low-profile port system with a flat chamber (18), while a higher-profile port is suitable for obese patients. By choosing appropriately, one can avoid skin necrosis due to large ports in thin patients, as well as difficulties in localizing and puncturing small ports within the abundant subcutaneous fat of obese patients. Double-chamber port systems are available for patients who need simultaneous treatment with chemotherapeutic drugs and parenteral nutrition (19, 20). Computed tomography with the intravenous administration of contrast medium is now used for staging in patients with many different types of cancer; to this end, port systems have recently become available through which contrast medium can be injected (21).

Surgical complications arise in less than 2% of cases in experienced hands (17). Potential approaches for insertion of the central venous catheter are by way of the cephalic and subclavian veins in the area of the shoulder girdle, the basilic vein on the medial side of the arm (22) or forearm (23), or the internal jugular vein on the anterolateral aspect of the neck (5, 24, 25). Alternatively, the external jugular vein can be used for surgical vascular access, particularly in children (e1, e2). In very rare cases, the great saphenous vein can be used for access, either directly in the thigh (e3) or by way of collateral vessels (e4, e5), if all of the approaches mentioned above are unavailable because of prior treatments, operations, and/or venous thromboses. Catheter placement by direct puncture of the subclavian or internal jugular vein has many advantages (e6–e8). In particular, it ordinarily does not require general anesthesia. The mode of local or regional anesthesia should be chosen so that pain does not arise after the procedure (e9). The use of small quantities of tumescence anesthesia has been found to be helpful. The side of central access is often determined by unilateral breast carcinoma (e10), ulcerations on the chest, previously implanted pacemakers, pre-existing unilateral venous thromboses, or other circumstances. Port implantation takes 15 to 30 minutes and can be performed by one physician. The appropriate catheter length is a function of the size of the patient and of the site of implantation of the port chamber. When the catheter is to be implanted by way of the right jugular or subclavian vein, the average intravascular catheter length from the site of vessel entry to the cavo-atrial junction is 12 cm; when access is from the left side, the average length is 18 cm (14). An ECG registered throughout the procedure reveals elevation of the heart rate as soon as the guide wire is introduced into the heart, indicating that central venous access has been successfully achieved. An intraoperative



Figure 3: The choice of port system depends on the indication. From left to right: titanium, synthetic, low-profile, and double-chamber port systems

TABLE

Complications associated with port implantation

Complications	Intervention ^{x1}	Early	Late
Interventional/surgical complications			
Inadvertent arterial puncture (e48)	+	–	–
Air embolism (e49)	+	+	+
Pneumothorax (e50)	++	+	–
Hematoma (e51)	++	+	–
Perforation (heart, major vessels) (e52–e55)	+	+	+
Cardiac arrhythmia (e56)	+	+	+
Plexus irritation (e57)	+	+	–
Catheter-related complications			
Catheter dislocation (e58–e61)	+	+	+
Catheter entrapment (“pinch-off syndrome”) (e62–e65)	–	+	++
Catheter leakage and embolism (e66)	+	++	++
Fibrinous sheath (e67, e68)	–	+	++
Catheter thrombosis/occlusion (e60)	–	+	+
Migration or torsion of the port reservoir (e69)	+	+	+
Infection	–	++	++
Cutaneous necrosis (e70)	–	+	++
Vascular			
Thrombosis	–	++	+++
Arteriovenous fistula (e71)	+	+	+

^{x1}complications arising during impalntation; frequency: – rare; + occasional; ++ common +++ very common

Complications

Interventional complications occur in less than 2% of cases in experienced hands.

Duration of the intervention

Port implantation takes 15 to 30 minutes and can be performed by one physician.

Figures 4 and 5 from: Reichgraber U, Gebauer B, Bentler T, Wagner H. Langfristige zentralvenöse Zugänge und deren Komplikationsmanagement. Fortschr Röntgenstr 2004; 176(7):944-952. With kind permission from Thieme-Verlag

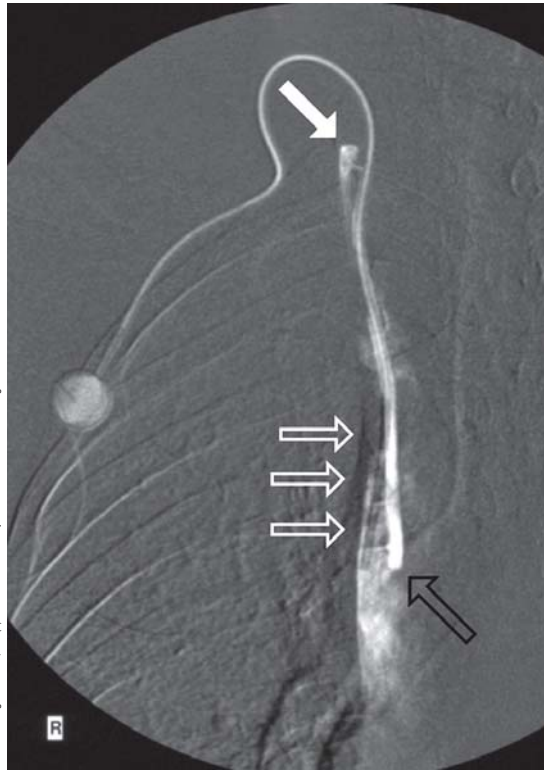


Figure 4: The cause of progressively severe dysfunction of a port catheter system: a fibrinous sheath (transparent white arrows) forms around the proximal portion of the catheter near its tip in the superior vena cava. The tip lies in correct position (transparent black arrow) at the cavo-atrial junction. Contrast medium injected into the port is seen to run along the catheter beneath the fibrinous sheath and to enter the vascular lumen at an undesired position (white arrow)

X-ray with a so-called C-arm is thus not always needed, but should nonetheless be available for potential use in every case. When the procedure is performed under fluoroscopic control, the catheter length can be adjusted as needed during port implantation. Whether or not this is done, a chest X-ray is obligatory after the procedure, both to document the catheter position and to rule out pneumothorax. This post-procedural X-ray must also be checked by the physician responsible for the patient's further treatment (e11, e12).

In Germany, ports are implanted by surgeons and interventional radiologists (25, e13). The techniques used for

implantation include the classic surgical cut-down method with exposure of the vessel to be punctured, direct puncture with the aid of anatomic landmarks, and ultrasound-guided puncture (e14, e15). Biffi et al., in a randomized, controlled trial published in 2009, found that the choice of implantation technique, approach, and side of implantation made no significant difference with respect to early or late complications (16). They did find, however, that punctures could generally be performed more successfully under ultrasound guidance, as was also found by other authors (15, e16–e18). In the *eTable*, we provide an overview of prospective and retrospective studies of port implantation at the chest wall that included more than 100 patients and that yielded information about complication rates and port survival times as a function of the approach used (16; e19–e34).

Infection rates in recent studies range from 0.8% (16) to 7.5% (e19); infection remains both the most common port complication and the most common cause for explanation. Pre- or post-procedural antimicrobial prophylaxis is generally unnecessary. Gebauer et al. found, however, that a single periprocedural intravenous short infusion of a broad-spectrum antibiotic lowered the rate of port infections from 6.7% to 1.3 % (e35). Controversy surrounds both post-procedural thrombosis prophylaxis and regular flushing of the port catheter with heparin solution (e36–e40). The manufacturers of port systems recommend flushing the system after each use with heparin in normal saline in concentrations ranging from 10 to 100 IU/mL (5), yet there are no scientific data to justify doing this routinely. Bisseling et al., in a trial carried out on a small number of patients, found that flushing the catheter with taurididine, rather than heparin, significantly lowered the rate of catheter infection (e41). A possible reduction of the infection rate by flushing with ethanol has also been published (e42–e47). Safdar et al. concluded in a meta-analysis that catheter flushing with vancomycin may reduce the frequency of catheter-related bacteremia in high-risk patients (e43).

Complication management

Once a port system has been implanted, it should be used in such a way as to minimize functional disturbances and complications. It is essential that the treating physicians and nurses be trained in the proper use of port systems. The implanting physician clearly plays a central role in user training. He or she should remain the first resort of all treating personnel for any questions or problems that might arise.

Implantation techniques

- Classic surgical cut-down
- Direct puncture based on anatomic landmarks
- Ultrasound-guided puncture

Infection rates

The reported infection rates in recent studies range from 0.8% to 7.5%. Infection remains the most common complication and the most common reason for port explantation.

Port complications can be subdivided into procedural complications that arise during implantation, catheter-related complications, and vascular complications. Early complications are, by definition, those arising between 24 hours and 4 weeks after implantation, while late complications are those arising more than 4 weeks after implantation. Late complications are unlikely to be due to the port implantation procedure itself.

Grouping complications by the time at which they arise facilitates their classification as well as the determination of causes (*Table*) (18).

Infection at the port site shows the typical clinical features of local infection. Bacterial colonization of the catheter or port chamber arises after the system is used and manifests itself as fever, shaking chills, and malaise (e72–e75). Extravasation is generally treated conservatively; extensive extravasation may necessitate the implantation of a subcutaneous drain or the explantation of the port (e76).

Pneumothorax manifests itself with coughing fits, shortness of breath, and anxiety (e50). Patients with pneumothorax must be hospitalized immediately and often need drainage through a chest tube. If hemorrhage is found to have occurred in connection with the implantation procedure, the site should be shown at once to the implanting physician (rather than to third parties). Post-procedural hemorrhage is often a complication of the underlying illness (e51). The port should be left in place if possible; a subcutaneous drain can be inserted if necessary. The port system can be used again in a few days (5).

If the port system cannot be flushed and no blood can be aspirated from it after a properly performed chamber puncture, an obstruction is likely to be present somewhere in the system. The common causes of obstruction are blood clot, remnants of parenteral nutrition, and encrusted medications (e60). To determine the type of obstruction that is present, one should inquire specifically about the manner in which the system was last used. The following procedure can be followed to eliminate the obstruction (e77, e78): First, 100 IU of heparin in 5 mL of 0.9% saline are injected and aspirated without pressure through a 5 mL syringe. If the system is still blocked, the port needle should be removed, the skin-reprepped, and another attempt made to unblock the system with a fresh port needle. If the blockage persists, one should dissolve 10 000 IU of urokinase in 2 mL of 0.9% saline and inject 1 mL of this solution. 20 minutes later, this solution is aspirated out of the port and the port is flushed with 20 mL of 0.9% saline. The procedure can be repeated up to three

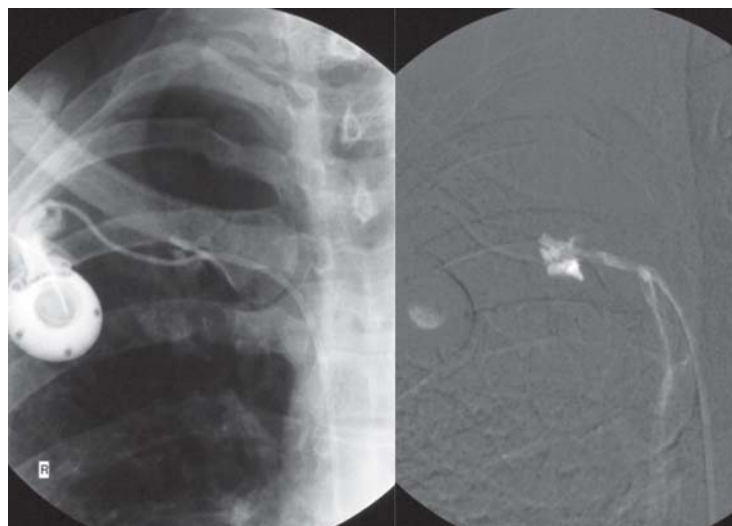


Figure 5: Catheter fractures due to entrapment of the catheter between the first rib and the clavicle (“pinch-off syndrome”) are especially dangerous, because chemotherapeutic drugs can leak out through the fracture into the surrounding tissue and cause extensive necrosis

times. According to the literature, unblocking with alteplase is comparably effective (e79–e81); here, an attempt is made to flush the system with 1 to 4 mg of alteplase (e82).

If the port system cannot be unblocked by flushing, it should be investigated with a radiographic contrast study. Contrast medium is injected through a port needle, and fluoroscopy is performed. Movement of the catheter, leading to kinking or to displacement of the catheter tip, is a possible cause of sudden loss of patency of the system (e61). Such catheter dislocations can usually be repositioned in an interventional radiological procedure performed by way of the femoral vein, obviating the need for explantation of the port and implantation of a new port. If a port functions well at first but then gradually becomes more difficult to use, this is often due to the formation of a fibrinous sheath around the catheter near its tip (*Figure 4*) (e67, e68). Catheter fractures and leaks can be caused by entrapment of the catheter between the first rib and the clavicle (“pinch-off syndrome”), if the catheter has been inserted through the subclavian vein; leakage is dangerous, as chemotherapeutic drugs leaking out into the surrounding tissue can cause extensive necrosis (e70, e83). A catheter leak can be demonstrated with a fluoroscopic contrast study of the port system (*Figure 5*). Catheter-tip dislocation can occur months after implantation of the

Port complications

Port complications are classified as procedural (arising during implantation), catheter-related, and vascular.

Obstruction within the system

If the port chamber cannot be flushed and blood cannot be aspirated from it after a properly performed puncture, there is likely to be an obstruction somewhere within the system.

system. Patients sometimes complain of pressure in a neck vein during infusion. Port-catheter-associated thromboses can lead to the occlusion of central veins and even to superior vena cava syndrome (e84). Malposition of the catheter tip in the mediastinum is a very serious complication that may lead to the entry of infused solutions into the mediastinum or pleural space (“infusion thorax”) (e53–e85).

If the rules of proper use are observed and the system is flushed with 20 mL of 0.9% saline before each infusion, the patient becomes aware of the problem through a sensation of pressure and burning at the level of the defect. Injections of less than 10 mL should not be given at the port, because the higher pressure under which such injections are delivered may lead to catheter disconnection or tearing. If this happens, the damaged system has to be explanted. Current studies do not support the notion that port systems need regular puncturing, flushing, and heparin flushing in the interval between treatments (e37, e86), even though some port manufacturers recommend that this be done, citing the requirements of the German Law on Medical Products. In any case, the manufacturer’s recommendations with respect to pressures should be followed, and contrast medium should only be administered through high-pressure port systems (21).

Overview

Frequent puncturing of peripheral veins and the local effects of chemotherapeutic drugs cause damage, thrombosis, and sclerosis of the vascular wall. Port systems for permanent central venous access therefore play an essential role in modern oncology. They have the advantage that the puncturing needle can be removed after each infusion and the skin covering the port reservoir serves as a natural protection against infection. Open, tunneled central venous catheter systems, such as Hickman or Borviak catheters, have a higher infection rate, because one end of the catheter remains outside the body (e31); they also produce a cosmetic deformity and markedly restrict the patient’s physical activity.

Port systems can now be implanted in a minimally invasive procedure by a surgeon or interventional radiologist. Venous access is gained by way of central veins at the upper thoracic aperture, or by way of the arm veins. The risk of complications is a function of the patient’s condition, the approach for central venous access, the techniques of implantation and puncture, and the implanting physician’s experience (e87). Patient satisfaction after port implantation ultimately depends not just on what happens

in the hands of specialized oncologists, but on the collegial and patient-oriented collaboration of all physicians and nurses involved in the care of the patient. The proper use and care of port systems is very important to cancer patients. Potential complications must be promptly recognized and adequately treated, and prevented whenever possible, to ensure the continued availability of central venous access for infusion therapy.

Conflict of interest statement

PD Dr. Teichgräber serves as a paid consultant to the Bard company and receives research support from med-Korn. The remaining authors state that they have no conflict of interest as defined by the guidelines of the International Committee of Medical Journal Editors.

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Serious complications

Malposition of the catheter tip in the mediastinum is an especially serious complication because it may lead to the entry of infused solutions into the mediastinum or pleural space.

Patient satisfaction after port implantation

Patient satisfaction depends not just on what happens in specialized oncology practices, but also on the collegial and patient-oriented collaboration of all physicians and nurses participating in the care of the patient.

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The solutions to the following questions will be published in issue 17/2011. The CME unit “The Treatment of Spinal Metastases” (issue 5/2011) can be accessed until 18 March 2011.

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Harms E, Olgemöller B:

Neonatal Screening for Metabolic and Endocrine Disorders.

Solutions: 1c, 2a, 3a, 4b, 5d, 6b, 7e, 8d, 9b, 10a

Please answer the following questions to participate in our certified Continuing Medical Education program. Only one answer is possible per question. Please select the answer that is most appropriate.

Question 1

According to the current recommendations of the European Society for Parenteral and Enteral Nutrition, which of the following types of infusion may be given through an indwelling peripheral venous catheter?

- a) Infusions of low osmolarity
- b) Infusions of high osmolarity
- c) Infusions of high equivalent concentration
- d) Infusions of low equivalent concentration
- e) Hypertonic glucose infusions

Question 2

How do port systems differ from catheter systems without a port?

- a) Port systems have a pumping chamber which can be manually compressed to facilitate infusion.
- b) Access to a port system requires needle puncture through the skin and the silicone membrane of the port chamber.
- c) Port systems have a connector at their external end.
- d) Port systems enable sterile, needle-free vascular access for fluid administration.
- e) The tip of the catheter of a port system is located in the inferior vena cava.

Question 3

A man whose body-mass index is 30 needs a suitable port system. He does not need parenteral nutrition. Which type of port system would be best for him?

- a) A double-chamber port system
- b) A titanium port system
- c) A port system made of synthetic material
- d) A low-profile port system
- e) A high-profile port system

Question 4

What is the intervention-related complication rate of port system implantation, in experienced hands?

- a) Up to 2%
- b) Up to 4%
- c) Up to 6%
- d) Up to 8%
- e) Up to 10%

Question 5

What surgical/interventional complication of port system implantation sometimes arises during the procedure itself?

- a) Hypovolemic shock
- b) Catheter dislocation
- c) Inadvertent arterial puncture
- d) Cutaneous necrosis
- e) Catheter entrapment

Question 6

A 68-year-old woman underwent the implantation of a low-profile port system two weeks ago. Now she complains of coughing fits, shortness of breath, and anxiety. What is your provisional diagnosis?

- a) Myocardial infarction
- b) Clavicular fracture
- c) Bronchitis
- d) Pneumothorax
- e) Pleurisy

Question 7

How can a catheter leak be detected fluoroscopically?

- a) With the aid of a red lamp
- b) With the aid of electrostimulation of the surrounding tissue
- c) With the aid of positron emission tomography
- d) With the aid of manual displacement of the port
- e) With the aid of contrast medium injection into the port

Question 8

Having punctured a port chamber with proper technique, you find that you cannot flush it, nor can you aspirate any blood from it. You suspect obstruction of the port catheter. What should you do next?

- a) Flush the obstruction away with a 2-mL syringe
- b) Unblock the catheter with urokinase
- c) Explant the port system
- d) Attempt systemic lysis therapy with alteplase
- e) Perform loop extraction via an inguinal approach to remove an obstructing fibrinous sheath

Question 9

Where should the catheter tip of a port system lie?

- a) In the brachiocephalic vein
- b) In the internal thoracic vein
- c) In the azygous vein
- d) At the cavo-atrial junction
- e) In the right atrium

Question 10

You have a high suspicion of port catheter infection in a patient currently receiving chemotherapy. What should you do?

- a) Flush the port system with antibiotics daily
- b) Continue chemotherapy and observe the further course
- c) Take blood cultures from the port system, await the result, then initiate specific treatment
- d) Temporarily stop chemotherapy and observe until the port infection has resolved
- e) Explant the port system at once, obtain alternative central venous access contralaterally, and continue chemotherapy if indicated

CONTINUING MEDICAL EDUCATION

Port Systems as an Integral Component of Chemotherapy

by Ulf K. Teichgräber, Robert Pfitzmann, and Herbert A.F. Hofmann

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eTABLE

Prospective and retrospective studies on port implantation in the chest wall¹

Authors	No. ports	Discipline ^{*2}	Technique ^{*3}	Approach ^{*4}	Catheter days	Complications	Infections	Venous thromboses	Pneumothorax	Catheter fracture	Explantation ^{*5}
Ignatov et al. 2009 (e19)	561	Surg. (7%) Rad. (3%)	Surg.	EJV (358)	675	104 (19%)	42 (7.5%)	30 (5.3%)	2 (0.36%)	NA	46 (8.2%)
			Seld./Im	IJV (15)							
				ScIV (179)							
				CephV (9)							
Hsieh et al. 2009 (e20)	1348	Surg.	Seld./Im	ScIV (196)	178	102 (7.5%)	40 (2.96%)	47 (3.48%)	NA	NA	102 (7.6%)
			Surg.	CephV (1100)							
			NA	Other (52)							
Biffi et al. 2009 (16)	401	Surg.	Seld./Im	IJV (132)	356.5 (0–1087)	60 (15%)	1 (0.8%)	15 (12.8%)	0	0	1 (0.9%)
			Seld./US	ScIV (136)			3 (2.4%)	8 (6.5%)	0	0	1 (0.8%)
			Surg.	CephV (133)			3 (2.5%)	11 (9.2%)	1 (0.7%)	0	6 (5%)
Rouzrokh et al. 2009 (e21)	524	Surg.	Surg.	IJV	329.5 (8–2028)	120 (22.9%)	29 (5.5%)	7 (1.3%)	NA	0	14 (2.7%)
Vandoni et al. 2009 (e22)	228	Surg.	Seld./Im	ScIV	441 (6–3090)	56 (24.6%)	10 (4.3%)	NA	10 (4.3%)	13 (5.7%)	24 (10.5%)
Samaras et al. 2008 (e24)	201	Surg.	Seld./Im	ScIV (62)	175 (1–831)	46 (22.9%)	14 (7%)	12 (6%)	4 (2%)	0	20 (10%)
			Surg.	CephV (139)							
Araujo et al. 2008 (e23)	1231	Surg.	Seld./Im	ScIV (617)	363 (3–1132)	118 (20.8%)	19 (3.4%)	11 (2%)	6 (1%)	2 (0.4%)	43 (17.3%)
				IJV (614)	244 (3–853)	48 (9.2%)	11 (2%)	3 (0.6%)	2 (0.3%)	0	16 (13.9%)
Chen et al. 2007 (e25)	100	Surg.	Surg.	CephV/ScIV	170 (65–274)	9 (9%)	4 (8%)	1 (2%)	0	0	7 (14%)
		An.	Seld./Im	IJV			1 (2%)	0	0	0	1 (2%)
Marcy et al. 2005 (e26)	100	Surg.	Surg.	CephV	222 (12–680)	16 (16%)	6 (6%)	3 (3%)	0	0	11 (11%)
Stein et al. 2005 (24)	2359	Surg.	Surg.	CephV (2253)	NA	147 (4.3%)	57 (2.4%)	49 (2%)	5 (0.2%)	0	15 (0.6%)
			Seld./Im	ScIV (106)							
Caers et al. 2005 (e27)	448	Surg.	Surg.	CephV	366 (3–1 206)	91 (20.8%)	19 (4.3%)	37 (8.5%)	3 (0.7%)	1 (0.2%)	42 (9.6%)
Vardy et al. 2004 (e28)	111	Rad.	Seld./Im	ScIV	210 (60–570)	23 (20.7%)	6 (5.4%)	2 (2%)	2 (2%)	NA	8 (7.2%)
Biffi et al. 2004 (e29)	377	Surg.	Seld./Im	ScIV	473 (1–1419)	19 (5%)	5 (1.33%)	4 (1.1%)	7 (1.9%)	0	11 (2.9%)
Wolosker et al. 2004 (e30)	519	Surg.	Surg.	EJV (383)	353 (5–1729)	83 (16%)	44 (8.5%)	14 (2.7%)	0	1 (0.2%)	35 (6.7%)
			Seld./Im	Other (40)							
			Seld./Im	IJV (73)							
				Other (23)							
Moureau et al. 2002 (e31)	8210	Surg./Rad.	NA	NA	NA	362 (4.4%)	208 (2.5%)	43 (0.5%)	NA	16 (0.2%)	NA
Yip et al. 2002 (e32)	118	Rad.	Seld./US	IJV	342.8 (21–813)	10 (8.5%)	5 (4.2%)	2 (1.7%)	0	0	8 (6.8%)
Biffi et al. 2001 (e33)	302	Surg./Rad.	Seld./Im	ScIV	237	55 (18.2%)	4 (1.3%)	17 (5.6%)	8 (2.6%)	1 (0.3%)	9 (3%)
Hartkamp et al. 2000 (e34)	126	Surg.	NA	NA	192.5 (2–1091)	58 (46%)	20 (16.3%)	9 (7.3%)	1 (0.8%)	0	16 (13%)

¹This table includes studies involving more than 100 port implantations in the period 2000 to 2010. ²Medical discipline: Surg. = surgery; Rad. = radiology; An. = anesthesia; ³Technique: Surg. = open surgical; Seld./Im = Seldinger/landmark; Seld./US = Seldinger/ultrasound; ⁴Approach: EJV = external jugular vein; IJV = internal jugular vein; ScIV = subclavian vein; CephV = cephalic vein; NA = data not available; ⁵Explantation due to complications