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ORIGINAL ARTICLE

Patterns of use of vascular access devices in patients undergoing hematopoietic stem cell transplantation: results of an international survey

Juan J. Toro · Manuel Morales · Fausto Loberiza · Jose L. Ochoa-Bayona · Cesar O. Freytes

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Abstract
Introduction There is limited information regarding of use of vascular access devices (VAD) in patients undergoing hematopoietic stem cell transplantation (HSCT). The frequent use of VAD in HSCT and its potential to cause morbidity requires understanding of the general use of VAD in HSCT.
Materials and methods A World Wide Web-based 19-item questionnaire was designed to determine the patterns of use of VAD in patients undergoing HSCT. The questionnaire was sent via electronic mail to the directors of HSCT programs throughout the world.
Results Of the 445 centers surveyed, 163 centers replied for a response rate of 37%. The most commonly used catheter for autologous peripheral blood stem cell (PBSC) harvest is the dual-lumen plasmapheresis/hemodialysis (62%). Of the institutions, 58% utilize the same catheter used for PBSC harvest to provide vascular access support during the transplant. Catheter-related blood stream infection (36%) and withdrawal occlusion (31%) were the most frequently encountered complications of VAD. Of the centers, 65% have established criteria for VAD removal when infection is suspected and 48% when occlusion is suspected.
Discussion Our study demonstrated that there are similarities in the utilization of VAD but also wide differences in the standard procedures for the insertion and care of VAD in the transplant setting. More comprehensive studies are needed to assess the use of central venous catheters in transplant recipients. Important areas for future research include the impact of VAD utilization on the quality of life of transplant recipients and the final consequences of VAD complications.

Keywords Central venous catheter · Catheter-related thrombosis · Catheter-related infection · Hematopoietic stem cell transplantation · Health care surveys

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J. J. Toro · J. L. Ochoa-Bayona · C. O. Freytes
Division of Hematology, Department of Medicine, Bone Marrow Transplant Unit, Audie L. Murphy Memorial Veterans Hospital, 7400 Merton Minter Boulevard, San Antonio, TX 78229-3900, USA

J. J. Toro (✉) · J. L. Ochoa-Bayona · C. O. Freytes
Division of Hematology, Department of Medicine, The University of Texas Health Science Center at San Antonio, 7703 Floyd Curl Drive, San Antonio, TX 78229-3900, USA
e-mail: toro@uthscsa.edu

M. Morales
Service of Medical Oncology, Department of Medicine, Hospital Universitario N S de Candelaria, 38010 Santa Cruz de Tenerife, Canary Islands, Spain

F. Loberiza
Section of Hematology/Oncology, Department of Internal Medicine, University of Nebraska Medical Center, 987680 Nebraska Medical Center, Omaha, NE 68198-7680, USA

Introduction

Vascular access is a critical aspect of the supportive care of patients undergoing hematopoietic stem cell transplantation (HSCT). Vascular access devices (VAD) are necessary to deliver high volumes of fluid and administer chemotherapeutic agents to transplant recipients. In addition, VAD facilitate frequent blood sampling and the administration of blood products and antibiotics necessary for the support of patients undergoing HSCT. Despite their utility, the use of VAD has serious complications including infection and thrombosis [4, 6]. These complications not only cause

patient discomfort but also have major clinical and economic implications.

There are multiple types of catheters utilized for vascular access in patients undergoing transplantation including tunneled and nontunneled catheters and totally implanted catheter systems [11]. Which specific factors influence the use of VAD at particular transplant centers is unclear but these factors might include cost, ease of use, the perceived complication rates of different types of catheters, and the expertise and facilities available for insertion and maintenance of these catheters at each institution.

In the absence of standard criteria for the utilization of VAD in patients undergoing HSCT, there is limited information regarding the use of VAD in patients undergoing HSCT. To determine the pattern of use of VAD in transplant recipients and their donors, a questionnaire was sent to transplant center directors throughout the world addressing basic aspects pertinent to the use of VAD in HSCT. This article summarizes the pattern of use of VAD in transplant recipients and their donors based on the answers to the questionnaire.

Materials and methods

An Internet-based 19-item questionnaire was designed to determine the patterns of use of VAD in patients undergoing HSCT (Table 1). The directors of 445 transplant programs throughout the world were contacted via electronic mail from December 2003 to April 2004. The electronic message had a link to the questionnaire, which could be accessed at any time. Most of the questions had to be answered using a multiple choice format or checking all the answers that applied to facilitate response and analysis of the questionnaire. In addition to questions to determine the type and size of the transplant centers included in the study, the survey included questions to assess the patterns of use of VAD for hematopoietic stem cell harvest and transplantation support. All answers were analyzed independently, and responders were not required to answer all questions.

The list of the transplant centers was supplied by the Center for International Blood and Marrow Transplant Research (CIBMTR) (Medical College of Wisconsin, 8701 Watertown Plank Road, Milwaukee, WI 53226, USA). Three attempts were made to contact the transplant director at each center.

Results

Profile of transplant centers included in the study

Of the 445 questionnaires sent, 163 centers replied for a response rate of 37%. Of the respondents, 57% were from North America, 21% from Europe, 7% from Asia, 6% from South America, 5% from Australia, and 4% from other geographic areas such as Africa, Central America, and Oceania.

Of the respondents, 62% were affiliated with a university or teaching institution and 18% were self-described as primarily cancer centers (Table 2). Of the respondents, 24% had an average number of transplants performed per year greater than 100 and 27% had between 1 and 25 transplants per year (Table 2).

Catheter utilization

When asked what type of catheter was utilized for autologous peripheral blood stem cell (PBSC) harvest at their institution when peripheral vein access was not possible, 62% of the respondents answered that dual-lumen plasmapheresis/hemodialysis catheters, such as the Hickmann® and Quinton®, were utilized and 20% of the respondents answered that a three-lumen pheresis/hemodialysis/infusion catheter was utilized, such as the Pheres-Flow® or Neostar© (Table 3).

In 58% of centers performing autologous transplants, the same catheter was used for harvest and transplant support; the remaining 42% utilized different catheters for harvest and transplant support.

The VAD most frequently utilized in patients undergoing allogeneic HSCT were the multilumen long-term cuffed tunneled catheters such as the Broviac®, Hickmann® or Raaf® (68%), followed by the multilumen short-term catheters (9%) (Table 3).

The type of catheters utilized for peripheral blood stem cell (PBSC) harvest from normal donors who do not have adequate peripheral veins for leukopheresis were short-term, noncuffed dialysis catheters (68% of the centers), multilumen cuffed catheters (5% of the centers) or other type of catheters (20% of the centers) (Table 3).

In 39% of the institutions, the VAD were inserted by more than one type of health care provider. In 26% of the centers, interventional radiologists were responsible for VAD insertion; general surgeons in 18% of the centers; and vascular surgeons in 4% of the centers (Table 4). VAD insertion takes place in the operating room (36%) and radiology suite (26%), while in 32% of the institutions, VAD insertion can take place in more than one of these locations (Table 4).

Imaging studies and supportive care related to VAD

Preferred VAD insertion sites were the subclavian vein (62%) and internal jugular vein (31%), while other sites, such as brachial, cephalic, and external jugular veins, were used in 3% of the institutions (Table 4). The methods

Table 1 Questions and choices of answers sent to the surveyed transplant programs

1. How would you **best** describe your institution?

___ cancer center
___ university or teaching institution
___ private institution
___ public or governmental institution

2. Which type of catheter is used at your institution for autologous peripheral blood stem cell (PBSC) harvest, when peripheral vein access is not possible?

___ multilumen (3 lumens) pheresis/hemodialysis/infusion (Pheres-Flow, Neostar)
___ multilumen (2 lumens) plasmapheresis/hemodialysis (Hickmann and Quinton)
___ other (please specify) _____

3. At your institution, do patients receiving autologous transplant utilize the same catheter used for harvest or is a new catheter inserted for transplant support?

___ We utilize the same catheter used for harvest for transplant support
___ We use another catheter for transplant support

4. What kind of VAD is used for patients undergoing allogeneic stem cell transplantation at your institution?

___ multilumen short-term catheters (Arrow)
___ multilumen long-term cuffed tunneled catheters (Broviac, Hickmann, Raaf)
___ multilumen pheresis/hemodialysis/infusion (Pheres-Flow, Neostar, Quinton)
___ peripherally inserted central catheters (PICC)
___ subcutaneous venous access ports (Port-A-Cath, MediPort)
___ multilumen, closed tip with valve (Groshong)
___ other (please specify) _____

5. What type of catheter is used for PBSC normal donors who do not have adequate peripheral veins for leukopheresis (PBSC harvest) at your institution?

___ short-term, non-cuffed dialysis catheters (Shalton type)
___ multilumen cuffed catheters (Neostar)
___ other (please specify) _____

6. Who is responsible for inserting VADs at your institution? (Check all that apply)

___ general surgeon
___ interventional radiologist
___ thoracic surgeon
___ nurse
___ other
___ vascular surgeon
___ medical oncologist or hematologist
___ physician assistant
___ medical or surgical resident

7. Where does the VAD insertion take place at your institution? (Check all that apply)

___ operating room or suite
___ patient bedside
___ radiology suite
___ outpatient clinic

8. What is the preferred VAD insertion site at your institution?

___ internal jugular vein
___ subclavian vein
___ femoral vein
___ other (please specify) _____

9. At your institution, which method is utilized to determine the catheter's tip position after insertion?

___ chest X-ray ___ fluoroscopy
___ ultrasound ___ none

10. At your institution, are prophylactic antibiotics given for insertion of VAD?

___ Yes ___ No ___ physician dependent

11. At your institution, are imaging studies routinely performed when thrombosis is suspected?

___ Yes ___ No ___ physician dependent

If yes, which imaging studies do you perform? ___ venography ___ sonography
___ other (please specify) _____

12. At your institution, is low-dose warfarin routinely used for prophylaxis of VAD-related thrombosis?

___ Yes ___ No ___ physician dependent

13. What antithrombotic medication is the initial therapy used at your institution to treat catheter occlusion?

___ heparin ___ urokinase
___ streptokinase ___ recombinant tissue plasminogen activator (rtPA)
___ other (please specify) _____

14. At your institution, are there established criteria for removal of VAD when infection is suspected or documented?

___ Yes ___ No

15. At your institution, are there established criteria for removal of VAD when catheter occlusion is suspected?

___ Yes ___ No

16. At your institution, are there established criteria for removal of VAD after completion of transplant?

___ Yes ___ No

17. In your estimation, what is the most common complication of VADs at your institution?

___ entry site infection ___ tunnel infection
___ catheter-related blood stream infection ___ catheter migration or malposition
___ central venous thrombosis
___ withdrawal occlusion (inability to withdraw blood from catheter)
___ catheter occlusion (inability to infuse and withdraw)
___ other (please specify) _____

18. What kind of instructions or teaching devices does your institution provide to the patient after a VAD insertion? (Check all that apply)

___ booklet given to patient or family

___ instruction sheet given to patient or family
___ formal teaching session given to patient or family
___ audiovisual materials given to patient or family
___ none
___ other (please specify) _____

19. Estimate the average number of transplants performed per year by your institution during the last 3 years:

___ 1-25 ___ 26-50 ___ 51-75 ___ 76-100 ___ greater than 100

utilized to determine the catheter's tip position after insertion were chest X-ray (62%) and fluoroscopy (36%), while no test was done to check the catheter's tip position after insertion in 1% of the institutions (Table 4).

Only 11.5% of centers routinely utilized prophylactic antibiotics before VAD insertion. Of the centers, 82% never utilized prophylactic antibiotics and 6.5% responded that prophylactic antibiotics before catheter insertion were used by some physicians (Table 4). When asked if low-dose warfarin was routinely used for prophylaxis of VAD-related thrombosis, 73% of the respondents answered no, 19% yes, and 8% responded that this decision was left to particular physicians (Table 5).

When asked if imaging studies were routinely performed at their institution when thrombosis was suspected, 82% responded yes, 5% no, and 13% responded that each physician decided if these tests should be ordered (Table 5). The types of imaging studies performed were sonography (63%) and venography (25%), while 5% of the respondents replied that other studies such as Doppler, CAT scan, and MRI were performed (Table 5). When we asked what antithrombotic medication was utilized at their institution as the initial therapy to treat catheter occlusion, 48% responded rtPA, 23% urokinase, and 18% heparin (Table 5).

Table 2 Affiliations and number of transplants performed per year by centers responding to the survey

	Percentage
Affiliations	
University or teaching institution	62
Cancer center	18
Private institution	10
Public or governmental institution	10
Number of transplants performed per year	
1–25	27
26–50	18
51–75	15
76–100	16
Greater than 100	24

Criteria for VAD removal

We asked questions regarding established institutional criteria for VAD removal in specific circumstances. When asked if the institution had established criteria for VAD removal when infection was suspected, 65% responded yes and 35% responded no (Table 6). When asked if there were established criteria for VAD removal when catheter occlusion was suspected, 48% answered yes and 52% answered no (Table 6). Finally, when asked if there were any established criteria for VAD removal after completion of transplant, 69% responded yes and 31% responded no (Table 6).

Catheter-related complications

We asked for an estimate of the most common complication of VAD per institution. Of the respondents, 36% felt that catheter-related blood stream infection was the most common complication at their center. Thirty-one percent felt the most common complication at their center was withdrawal occlusion (inability to withdraw blood from catheter), 19% entry site infection, and only 2% of the respondents felt the most common complication was central venous thrombosis (Table 7).

Patient education

We asked a question regarding instructions or teaching devices that the institutions might provide to the patient after VAD insertion. Of the centers, 23% had formal teaching sessions given to the patient or family, 16% provided instruction sheets to the patient or family, 8% gave booklets to the patient or family, 7% gave no instructions to the patient or family, 3% gave informal or verbal instructions to the patients, and 43% used a combination of 2 or more of the above.

Table 3 Types of catheters used in different transplant settings

Types of catheters	Percentage
For autologous PBSC harvest when peripheral vein access is not possible	
Dual-lumen plasmapheresis/hemodialysis catheter (Hickmann®, Quinton®)	62
Three-lumen pheresis/hemodialysis/infusion catheter (Pheres-Flow®, Neostar®)	20
Other (two-lumen Vascath®, Arrow®, Schilley, Neostar, Permcath, and single lumen)	17
Did not answer	1
For allogeneic stem cell transplantation	
Multilumen long-term cuffed tunneled catheters (Broviac, Hickmann, Raaf)	68
Multilumen short-term catheters (Arrow)	9
Multilumen pheresis/hemodialysis/infusion (Pheres-Flow, Neostar, Quinton)	5.5
Multilumen, closed tip with valve (Groshong)	4
Subcutaneous venous access ports (Port-A-Cath, MediPort)	3
Peripherally inserted central catheters (PICC)	2.5
Institutions with no allogeneic transplantation program	2
Other (single lumen Hickmann, Hong catheter bard)	3
Did not answer	3
For PBSC in normal donors who do not have adequate peripheral vein access	
Short-term, noncuffed dialysis catheters (Shalton type)	68
Multilumen cuffed catheters (Neostar)	5
Other (Quinton, Marhurkar, Arrow, VasCath)	20
Did not answer	7

Table 4 VAD insertion procedures

	Percentage
Health care professionals responsible for inserting the VAD	
Interventional radiologist	26
General surgeon	18
Vascular surgeon	4
Thoracic surgeon	2
Medical oncologist or hematologist	1
Physician assistant	1
Others	9
More than one per institution	39
Hospital facility where VAD insertion takes place	
Operating room or suite	36
Radiology suite	26
Patient bedside	4
Outpatient clinic	2
Insertion can take place in more than one location	32
Puncture site for VAD insertion	
Subclavian vein	62
Internal jugular vein	31
Femoral vein	4
Other: brachial, cephalic, and external jugular veins	3
Methods utilized to determine the catheter's tip position after insertion	
Chest X-ray	62
Fluoroscopy	36
Ultrasound	1
None	1
Prophylactic antibiotics	
Yes	11.5
No	82
Physician-dependent	6.5

Table 5 Thrombosis diagnosis, treatment and prophylaxis

	Percentage
Are imaging studies routinely performed when thrombosis is suspected?	
Yes	82
No	5
Physician-dependent	13
Imaging studies utilized when catheter thrombosis is suspected	
Sonography	63
Venography	25
Others like Doppler, CAT scan and MRI	5
Did not respond	7
Antithrombotic therapy	
Recombinant tissue plasminogen activator (rtPA)	48
Urokinase	23
Heparin	18
Streptokinase	10
Alteplase	1
Is low-dose warfarin routinely used for prophylaxis of VAD-related thrombosis?	
Yes	19
No	73
Physician-dependent	8

Discussion

The purpose of our study was to determine the approach to key aspects of VAD management including the types of catheters utilized and the approach to catheter infection and thromboprophylaxis. We also wanted to ascertain the proportion of centers with standard criteria for the management of frequent complications and catheter removal.

Our survey suggests that there is agreement on some aspects of the management of vascular access in transplant recipients. One is catheter selection. The most frequently utilized catheters in patients undergoing allogeneic stem cell transplantation are the multilumen long-term cuffed tunneled catheters. Approximately 70% of respondents utilized these types of catheters for allogeneic stem cell transplant support. The same proportion of centers utilized noncuffed dialysis catheters for PBSC harvest from normal donors with poor peripheral vein access. In addition, a high proportion of centers utilized the double-lumen plasmapheresis/hemodialysis long-term catheter, of the Hickmann or Quinton type, for autologous transplantation, and most of the centers utilized different catheters for PBSC harvest and post transplant support. This is of interest because previous studies demonstrate a relatively high complication rate for long-term hemodialysis central venous catheters with only one third of catheters being useful throughout the entire treatment period in contrast to more recent reports utilizing hybrid central venous catheters for PBSC harvest and post transplant support [5, 12]. Also of interest is the fact that our survey demonstrated that the subclavian vein is the preferred VAD insertion site (62%) in contrast to the internal jugular vein (31%) despite the easier access and lower complication rate of the internal jugular vein access [8].

There was also uniformity in the approach to infection and thrombosis prophylaxis. Of the centers, 82% do not administer antibiotic prophylaxis routinely before VAD insertion. This practice is supported by the Guidelines for the Prevention of Intravascular Catheter-related Infections issued

Table 6 Established criteria for removal of VAD

	Percentage
When infection Is suspected?	
Yes	65
No	35
When catheter occlusion is suspected?	
Yes	48
No	52
After completion of transplant?	
Yes	69
No	31

Table 7 Estimation of the most common complications of VAD per institution

Most common complications of VAD	Percentage
Catheter-related blood stream infection	36
Withdrawal occlusion (inability to withdraw blood from catheter)	31
Entry site infection	19
Catheter occlusion (inability to infuse and withdraw)	7
Tunnel infection	3
Catheter migration or malposition	2
Central venous thrombosis	2

by the United States Centers for Disease Control and Prevention because no studies have demonstrated that oral or parenteral antibiotics reduce the incidence of catheter-related bloodstream infections. In addition, the prophylactic use of vancomycin is an independent risk factor for the acquisition of vancomycin-resistant enterococci, which outweighs the benefit of using prophylactic vancomycin [10].

Thromboprophylaxis with low-dose warfarin was not utilized in the majority of centers (73%). At the time of our survey, the role of prophylaxis for vascular access-related thrombosis was not clear [14]. It is likely that the use of thromboprophylaxis will decrease even more because two recent articles have demonstrated that thromboprophylaxis with low-dose warfarin and with low molecular weight heparins did not result in a significant decrease in the incidence of catheter-related thrombosis [1, 2, 15].

Our survey also demonstrated large differences in key aspects of the management of vascular access in transplant recipients including VAD insertion. In approximately 40% percent of the centers, VAD were inserted by multiple services including interventional radiology, general surgery, and thoracic surgery. Some investigators have reported that radiological-guided insertion of tunneled and nontunneled central venous catheters is cheaper and has lower complication rates than the insertion by surgeons utilizing anatomical landmarks mostly due to the benefit of ultrasound guidance for the venous puncture site [13]. Other authors favor VAD insertion in the operating room or suite because complications, such as pneumothorax, can arise in patients undergoing VAD insertion, and these complications are easier to manage in the operating room. Nevertheless, other authors have documented that long-term central venous catheters can be inserted safely at the patient's bedside [9].

There was also a difference in the evaluation of patients suspected of having catheter-related thrombosis. Approximately two thirds of the centers utilized sonography as the initial diagnostic test for the evaluation of catheter-related thrombosis, whereas one fourth of the centers utilized phlebography. These results are somewhat surprising because color duplex Doppler sonography is an accurate and safe method for the diagnosis of catheter-related thrombosis. Most experts consider it the test of choice for the evaluation of catheter-related thrombosis [3].

Despite the fact that the majority of responding centers have established criteria for VAD removal when catheter-related infection is suspected (65%) and after completion of the transplant procedure (69%), only 48% of the institutions had established criteria for VAD removal due to thrombotic complications. The fact that the optimal management of patients with catheter-related thrombosis is controversial is a possible explanation for such a low percentage of centers having standard criteria for the management of this common complication [6].

One surprising finding of our survey is that only 24% of the centers give written information regarding the care of VAD to the patient or to a caregiver. Based on our survey, it appears that patient education is an area that requires more emphasis because inadequate care of VAD by the patient can result in significant infection and thrombotic complications [7].

Our study has several limitations that need to be taken into consideration when interpreting our findings. First, the number of questions was limited by the nature of the electronic survey. The limited number of questions does not allow assessing in-depth specific management of complications such as infections. Second, the response rate was relatively low despite multiple requests to complete the questionnaire. Finally, the results were based solely on the opinion of the center director, which adds an element of subjectivity to the answers provided.

In summary, our study demonstrated that there are similarities in the utilization of VAD but also wide differences in the standard procedures for the insertion and care of VAD in the transplant setting. More comprehensive studies are needed to assess the use of central venous catheters in transplant recipients. Important areas for future research include the impact of VAD utilization on the quality of life of transplant recipients and the final consequences of VAD complications.

References

1. Couban S, Goodyear M, Burnell B, Dolan S, Wasi P, Barnes D, MacLeod D, Burton E, Andreou P, Anderson DR (2005) Randomized placebo-controlled study of low-dose warfarin for the prevention of central venous catheter-associated thrombosis in patients with cancer. J Clin Oncol 23:4063–4069
2. Cunningham MS, White B, Hollywood D, O'Donell J (2006) Primary thromboprophylaxis for cancer patients with central venous catheters—a reappraisal of the evidence. Br J Cancer 94:189–194
3. Gaitini D, Beck-Razi, Haim N, Brenner B (2006) Prevalence of upper extremity deep venous thrombosis diagnosed by color Doppler duplex sonography in cancer patients with central venous catheters. J Ultrasound Med 25:1297–1303
4. Hachem R, Raad I (2002) Prevention and management of long-term catheter related infections in cancer patients. Cancer Invest 20:1105–1113
5. Johansson E, Sollen Hansson M, Nilson A, Engervall P (1999) Vascular devices used during harvest of peripheral blood stem cells: high complication rate in patients with long-term dialysis central venous catheter. Bone Marrow Transplant 24:793–797
6. Linenberger ML (2006) Catheter-related thrombosis: risks, diagnosis and management. J Natl Compr Cancer Netw 4:889–901
7. McDermott MK (1995) Patient education and compliance issues associated with access devices. Semin Oncol Nurs 11:221–226
8. Mey U, Glasmacher A, Hahn C, Gorschluter M, Ziske C, Mergerlsberg M, Sauerbruch T, Schmidt-Wolf IG (2003) Evaluation of an ultrasound-guided technique for central venous access via the internal jugular vein in 493 patients. Support Care Cancer 11:148–155

9. Morales M, Dorta J (1994) Percutaneous insertion of Hickman catheters while the patient is in bed: a simplification of the technique. Support Care Cancer 2:270–271
10. O'Grady NP, Alexander M, Dellinger EP, Gerberding JL, Heard SO, Maki DG, Masur H, McCormick RD, Mermel LA, Pearson ML, Raad II, Randolph A, Weinstein RA; Healthcare Infection Control Practices Advisory Committee (2002). Guidelines for the prevention of intravascular catheter-related infections. Infect Control Hosp Epidemiol 23:759–769
11. Raaf JH (1994) Administration of chemotherapeutic agents. Techniques and controversies. Support Care Cancer 2:335–346
12. Restrepo A, Devore P, Encarnacion CE, Wholey MH, Schneider D, Callander NS, Ferral H, Postoak D, Anderson JE, Walsh T, Padayao G, Gokmen E, Ehsan A, Ochoa L, Neumon B, West G, Restrepo MI, Przykucki J, Patterson J, Freytes CO (2002) Performance of a hybrid central venous catheter utilized for both peripheral blood stem cell harvest and transplant support of patients undergoing autologous peripheral blood stem cell transplantation. Bone Marrow Transplant 30:389–395
13. Sadler DJ, McCarthy M, Saliken JC, So CB, Klassen J, Selinger S, Grey RR (2000) Image-guided central venous catheter placement for apheresis in allogeneic stem cell donors. J Clin Apher 15:173–175
14. Verso M, Agnelli G (2003) Venous thromboembolism associated with long-term use of central venous catheters in cancer patients. J Clin Oncol 21:3665–3675
15. Verso M, Agnelli G, Bertoglio S, DiSoma FC, Paoletti F, Ageno W, Bazzan M, Parise P, Quintavalla R, Naglieri E, Santoro A, Imberti D, Soraru M, Mosca S (2005) Enoxaparin for the prevention of venous thromboembolism associated with central vein catheter: a double-blind, placebo-controlled, randomized study in cancer patients. J Clin Oncol 23:4057–4062