

National Survey of Central Venous Catheter Flushing in the Intensive Care Unit

Carrie Sona, RN, MSN, CCNS
 Donna Prentice, RN, MSN, ACNS-BC
 Lynn Schallom, RN, MSN, CCNS

BACKGROUND Evidence is needed on the best solution for flushing central venous catheters.

OBJECTIVE To understand current flushing practices for short-term central venous catheters among critical care nurses before implementation of a randomized, controlled trial comparing physiological saline with heparin solution for flushing to maintain catheter patency.

METHODS A 6-item survey including demographic data was mailed to 2000 practicing critical care nurses in the United States. An additional 316 surveys were completed at the annual conference of the American Association of Critical-Care Nurses.

RESULTS Most (71.5%) of the 632 respondents who completed the survey were staff nurses. Most respondents (64.6%; 95% CI, 60.86%-68.34%) reported using physiological saline exclusively to flush central venous catheters and maintain patency. For heparin-containing solutions, the concentration and volume used varied. The most commonly reported volumes for flushing were 10 mL for saline (63%; 95% CI, 59.18%-66.82%) and 3 mL for heparin (50.2%; 95% CI, 43.5%-56.9%).

CONCLUSION Flushing practices for central venous catheters vary widely. A randomized controlled trial is needed to determine the optimal flushing solution to maintain short-term patency. (*Critical Care Nurse*. 2011;32[1]:e12-e19)

Many patients require short-term (dwell time, <3-4 weeks) central venous catheters (CVCs) to provide necessary fluids, blood, nutritional feedings, and medications. These catheters are also useful for obtaining blood samples from patients without using venipuncture. A CVC is typically

placed in the subclavian, internal jugular, external jugular, or femoral vein. CVCs can increase patients' risk for complications such as bloodstream infection, pneumothorax, and venous air embolism, which can lead to delays in care and increases in the cost of care.¹ Catheter patency is important to maintain catheter function and allow continued use of the device to provide essential care. Fibrin thrombus within, around, or at the tip of the catheter, formed in response to the presence

of the foreign body (ie, the catheter) within the vessel, can cause occlusion of short-term CVCs.² Many factors affect the development of catheter occlusion, such as flushing solution, flushing frequency, and type of catheter and needleless access device in use.^{3,4} The practice of flushing CVCs to maintain catheter patency is the daily work of nurses.

The flushing solutions used most often to maintain catheter patency are 0.9% sodium chloride solution (physiological saline) and solutions containing heparin sodium. In studies⁵⁻⁷ of peripheral and arterial catheters, rates of thrombus formation were equivalent whether saline or a heparin solution was used for flushing. The practice of flushing short-term peripheral and arterial catheters with saline only has been widely adopted and incorporated into practice standards.^{4,7} Perhaps because of this finding with peripheral and arterial catheters, we observed a shift in practice from using the "saline, administer, saline, heparin" flush method to saline-only flushing for CVCs at Barnes Jewish Hospital in St Louis, Missouri. The 2006 Infusion Nursing Standards

of Practice⁴ state that heparin-containing solution in combination with physiological saline should be used for flushing catheters. The questions of the optimal flushing solution to use (heparin alone, saline alone, or a combination of heparin and saline), the volume of solution to use, the concentration of heparin that should be used if necessary, and which needleless cap should be used to prevent catheter occlusion in patients with short-term CVCs remain largely unanswered.⁸

The practice of using needleless connectors to allow easier connections and prevent the use of needles is commonplace, and many commercial needleless access devices are available.⁹ These devices are most commonly named according to the displacement of fluid that occurs when they are used. The devices are generally known as negative-, positive-, or neutral-displacement connectors. Blood can reflux into the CVC lumen when these devices are used if the flushing technique is not performed properly.⁹ The devices are also known by other names, such as Luer-activated devices or split-septum devices; however, these terms are less descriptive of the type of displacement provided by the devices. The impact of the type of needleless device on catheter occlusion rates is currently unknown.

Literature Review

Many safety concerns and dosing errors are associated with the use of heparin. Both Kishimoto et al¹⁰ and Kuehn¹¹ have written about adverse effects associated with the use of contaminated heparin. The development of antibodies to heparin that lead to heparin-induced thrombocytopenia (HIT) and to the heparin-induced thrombocytopenia and thrombosis syndrome (HITTS) has also been reported.^{12,13} If a patient has antibodies to heparin, any exposure to the drug can lead to HIT, and all use of heparin should be discontinued.¹²

Potentially, institutions might achieve a cost savings if heparin-containing solutions are not required for flushing. In a meta-analysis published in 1991, Goode et al¹⁴ found that eliminating heparin flushes in patients with peripheral intravenous catheters could yield a potential yearly savings of \$109 million to \$218 million. At Barnes Jewish Hospital, the cost of a premade 10-mL solution with 10 units of heparin per milliliter is 45 cents each; in contrast, the cost of a premade 10-mL solution of physiological saline is 26 cents. Depending on the flushing practices at individual institutions, eliminating the heparin flush could lead to marked cost savings.

In their guidelines on central venous access, Bishop et al³ discussed

the controversy of intermittent flushing of CVCs with a heparin solution vs similar flushing with saline. Bishop et al noted that the efficacy of heparin flushing in preventing thrombus is unproved. They also discussed the risk of heparin exposure and the development of HIT.

In a recent review, Mitchell et al⁸ provided an eloquent and detailed analysis of all available published guidelines on practices to maintain the patency of central venous access. These authors⁸ reviewed 6 guidelines, 2 systematic reviews, and 22 primary research publications for quality of evidence and research methods regarding the care of short-term CVCs. The 6 guidelines reviewed included (1) guidelines on the insertion and management of central venous access devices in adults,³ (2) the Infusion Nursing Standards of Practice,⁴ (3) national evidence-based guidelines for preventing health care–associated infections in National Health System hospitals in England (epic2),¹⁵ (4) a clinical practice guideline for managing central venous access devices in cancer patients,¹⁶ (5) evidence-based guidelines for preventing health care–associated infections in primary and community care in England,¹⁷ and (6) guidelines for the prevention of intravascular catheter–related infections.¹⁸ The content in the 6 guidelines is conflicting and is based largely on manufacturers' recommendations rather than on the results of randomized trials. The recommendations for the frequency of flushing CVCs are inconsistent and vary from no recommendation, to regular intervals, to after each use, to weekly when

Authors

Carrie Sona is a critical care clinical nurse specialist at Barnes Jewish Hospital, St Louis, Missouri.

Donna Prentice is a critical care clinical nurse specialist at Barnes Jewish Hospital.

Lynn Schallom is an evidence-based practice implementation specialist at Barnes Jewish Hospital.

Corresponding author: Carrie Sona, 5918 Cedar Pointe Ct, St. Louis, MO 63129 (e-mail: css1719@bjc.org).

To purchase electronic or print reprints, contact The InnoVision Group, 101 Columbia, Aliso Viejo, CA 92656. Phone, (800) 899-1712 or (949) 362-2050 (ext 532); fax, (949) 362-2049; e-mail, reprints@aacn.org.

not in use. The decision of whether to use a heparin solution to maintain patency is also inconsistent, and generally manufacturers' recommendations are followed.

The guidelines⁴ of the Infusion Nurses Society state that the minimum flushing volume should be at least 2 times the catheter volume and that the concentration of heparin, if used, should be the lowest concentration needed to maintain patency. The guidelines¹⁸ of the Healthcare Infection Control Practices Advisory Committee for the prevention of intravascular catheter-related infections do not include any recommendations on the type of flushing solution to use or the best practice to follow for flushing CVCs. The volume of flushing solution to use, when listed, is 10 mL for saline and from 3 to 5 mL for a heparin solution. The guidelines⁴ of the Infusion Nurses Society recommend that when saline is used as a flushing solution, the total volume of solution should not exceed 30 mL/d.

Mitchell et al⁸ concluded that existing guidelines provide conflicting recommendations on the frequency of flushing, the use and dosage of heparin, the use of a saline flush, the volume of flushing solution, and whether or not the use of pressure caps is necessary. Mitchell et al also noted that results of well-designed and appropriately powered randomized controlled trials are not available to help determine the best evidence-based practice to maintain catheter patency, minimize patients' safety risks, and extend the life of CVCs.

Two previous surveys^{19,20} addressed nurses' practices in flushing CVCs. A survey by Williams et al¹⁹ of 25 hospitals in northeastern New

York revealed marked variability in flushing practices. Nurses in many hospitals used intermittent heparin flushes to maintain patency of CVCs.¹⁹ The concentration of heparin used ranged from 10 to 1000 U/mL, and volumes used for flushing ranged from 3 to 5 mL, with variable flushing frequency. The volume of saline used for flushing ranged from 5 to 20 mL for CVCs. In another survey, Clemence et al²⁰ found that 97% of nurses in 24 states used a heparin flush to maintain CVC patency.

In a study in adults, Fuentes i Pumarola et al²¹ compared saline with heparin in triple-lumen catheters with the same catheter design. The study was a 2-phase double-blind randomized controlled trial in intensive care unit (ICU) patients that excluded patients receiving total parenteral nutrition or anticoagulants. In phase 1, the investigators compared 5 mL of heparin solution of 100 U/mL with 5 mL of heparin solution of 20 U/mL. In phase 2, they compared 5 mL of a solution of heparin of 20 U/mL with 5 mL of saline. Occlusion rates did not differ significantly regardless of the flushing solution used, but the study was limited by high attrition in all groups of patients.

Despite the lack of evidence to help nurses make the best decision for their patients, CVCs must be flushed to maintain catheter function.^{3,4} To explore this problem and clearly describe the current state of nursing practice for CVC maintenance, we conducted a nationwide survey on CVC flushing practices of ICU nurses in the United States. A randomized controlled trial comparing saline with heparin-containing solution for flushing short-term

CVCs was starting at the time of the survey. We thought that the results of the survey would provide information on flushing practices that would help us quantify and understand the impact of the trial results.

Methods

A pilot survey was developed by 3 critical care clinical nurse specialists at Barnes Jewish Hospital, a large midwestern university-affiliated hospital. The pilot survey was developed to test for face validity and clarity of questions. Items and content of the survey were based on interventions found in a literature search of CINAHL and PubMed with the search terms (1) *central venous catheters* and (2) *central venous catheters and maintenance, patency, flushing, heparin, and saline*. The survey addressed the care of multilumen centrally placed catheters only, including double-, triple-, and quad-lumen catheters. Care of peripherally placed central catheters, introducer sheaths, and dialysis catheters was excluded because practice patterns and guidelines vary with different types of catheters.³⁻⁸ In addition, one of the authors (D.P.) is a member of a 13-hospital system intravenous products committee and therefore had extensive knowledge of the various needleless devices available on the market, knowledge that contributed to the face validity of the survey.

In the pilot study, the survey was distributed to 3 hospitals and included 8 adult ICUs within the hospital system. In order to clarify unclear points and enhance validity, minor changes to the instructions and types of needleless devices were made after the pilot study.

The modified survey was sent to 3 practicing vascular access nurses for review for face validity by experts in intravascular nursing. No further changes were recommended. The survey results in the pilot study (Table 1) validated inconsistent flushing practices within units and between hospitals. Table 2 is the final survey tool.

In order to obtain a large pool of practicing critical care nurses, the American Association of Critical-Care Nurses (AACN) was contacted to purchase a list of its members. A random list of 2000 nurses from all 50 states was obtained in March 2009. Surveys were distributed via US mail in April 2009 to 2000 critical care nurses. The survey could be completed and submitted by returned fax of a hand-written response or by online submission via SurveyMonkey.com. In order to increase the response rate, the mailed survey included a cover letter explaining the importance of the survey. An additional 316 surveys were distributed to a convenience sample at the annual AACN conference in May 2009 in New Orleans, Louisiana, at the booth sponsored by Barnes Jewish Hospital. Faxed or written surveys were entered into the SurveyMonkey data base by a volunteer nursing student trained by the lead author (C.S.).

Results

A total of 632 surveys were completed and analyzed. Of the 2000 mailed surveys, 153 were returned via fax and 163 were completed online. A total of 316 usable surveys were returned, for a response rate of 15.8%. A total of 15 surveys were returned to the sender, and the

information in 10 could not be used because of incomplete data fields. An additional 316 surveys were submitted at the conference. The majority of surveyed respondents (n=602; 95.3%) stated that their hospitals had a policy on the practice of flushing CVCs; 2% said their hospitals did not have a policy, and less than 2% did not know if their hospital had a policy.

Demographic information included the state in which the respondent practiced, current job role, and years of experience. Nurses from all 50 states responded to the survey. Various ICU specialty units were represented; most of the nurses worked in a combined medical-surgical ICU (see Figure). The roles of the 632 respondents varied, but the majority (n=452; 71.5%) were staff nurses. The other respondents worked as nurse managers or lead charge nurses (n=39; 6.2%), educators (n=30; 4.7%), clinical nurse specialists (n=25; 4%), nurse practitioners (n=9; 1.4%), or in other capacities (n=10; 1.6%); in 67 surveys (10.6%), the item was not answered. Most respondents had more than 10 years of critical care experience; 47% had 11 to 15 years of experience, and 14.2% had 15 years or more. A total of 13.9% had 2 to 5

Table 1 Results of pilot survey

Characteristic	No. of respondents (N = 78)
Hospital site	
1	38
2	15
3	25
Type of flushing solution	
Saline only	62
Heparin only	1
Heparin and saline	15
Volume of flushing solution, mL	
3	6
5	5
10	67
Frequency of flushing	
Every 8 hours and after each use	58
Every 12 hours and after each use	17
Every 24 hours and after each use	3
Type of needleless connector	
Positive displacement	7
Luer activated	57
Neutral displacement	6
Unknown	8

years of experience in critical care, and 14.9% had 6 to 10 years. No respondents had 2 years of experience or less, and the question was left blank in 10% of the surveys.

A majority of respondents (64.6%; 95% CI, 60.86%-68.34%) used physiological saline rather than a heparin solution to flush CVCs. Other solutions used were a combination of heparin and saline (31% of respondents; 95% CI, 27.39%-34.61%), heparin only (4.4%; 95% CI, 2.8%-6.0%), and alteplase (0.5%; 95% CI, 0.0%-1.0%). Alteplase is an enzyme that binds to fibrin in a thrombus, converts plasminogen to plasmin, and initiates the lysis of fibrin to dissolve the clot; the enzyme is generally reserved for catheter failure when a clot has formed.

Among the 632 respondents, 235 reported heparin concentrations. The concentrations most frequently reported were 100 U/mL (37.5%; 95% CI, 33.74%-41.26%) and 10 U/mL

Table 2 Survey tool

Please answer all questions as they pertain **ONLY to multilumen centrally placed catheters** with your standard adult practice in mind. A multilumen catheter includes double, triple, and quad lumen catheters, **not PICCs, introducer sheaths, or dialysis catheters.**

Does your facility have a policy on the type of flush solution to use on central venous catheters to maintain patency?

Yes No I don't know

What flush solution do you use for lumens without continuous infusion or a pressure flush system?

NS only Heparin flush only Combination of NS and heparin Alteplase

If heparin is used, what concentration of heparin do you use?

10 units/mL 100 units/mL 1000 units/mL Other _____

What volume of flush do you use?

NS flush: 3 mL 5 mL 10 mL Other _____

Heparin flush: 3 mL 5 mL 10 mL Other _____

Alteplase flush: 2 mL Other _____

How frequently do you flush a lumen without continuous infusions or a pressure flush system?

Q 8 hours and after each use Q 12 hours
 Q 12 hours and after each use Q 24 hours
 Q 24 hours and after each use Only after each use
 Q 8 hours Other _____

What type of needleless cap for access do you use on the end of each lumen?

Positive displacement (Ultrasite, Clave CLC 2000, PosiSite, MaxPlusm, Smartsite Plus, PosiFlow)
 Luer activated valve (Clave, Safesite, Smartsite, Clearlink, FloStar)
 Split septum (Baxter Interlink, blunt cannula, LifeShield, Safeline, Q-Syte)
 Neutral displacement (InVision Plus, Micro Clave)
 LifeShield TKO
 Unknown

Demographics: Please Circle

Work area: SICU MICU CCU Med-Surg ICU CTICU ED Other _____
 Current Position: Staff RN Nurse manager CNS Educator
 Years in critical care < 2 year 2-5 6-10 >10 years
 Years as RN < 2 year 2-5 6-10 >10 years
 What state do you practice in? _____

Abbreviations: CCU, coronary care unit; CNS, clinical nurse specialist; CTICU, cardiothoracic intensive care unit; ED, emergency department; med-surg ICU, medical-surgical intensive care unit; MICU, medical intensive care unit; NS, normal (physiological) saline; PICC, peripherally inserted central catheter; Q, every; RN, registered nurse; SICU, surgical intensive care unit.

(29.7%; 95% CI, 26.13%-33.27%). Only 6% (95% CI, 4.15%-7.85%) of the respondents used 1000 U/mL, and 0.9% (95% CI, 0.16%-1.64%) used some other solution.

The volume of flushing solution used varied depending on whether heparin or saline was used. Among

the respondents, 213 reported volumes of heparin solution, and 612 reported volumes of saline (Table 3). Volumes reported by the majority were 3 mL for heparin solution (50.2%) and 10 mL for saline (63%). Other volumes reported were 2.5 mL for heparin solution and 20 mL

for saline. The most frequent interval for flushing was every 8 hours and after each use (Table 4). The most common needleless connectors used were positive displacement and Luer activated (Table 5), also known as negative-pressure devices. The different responses for

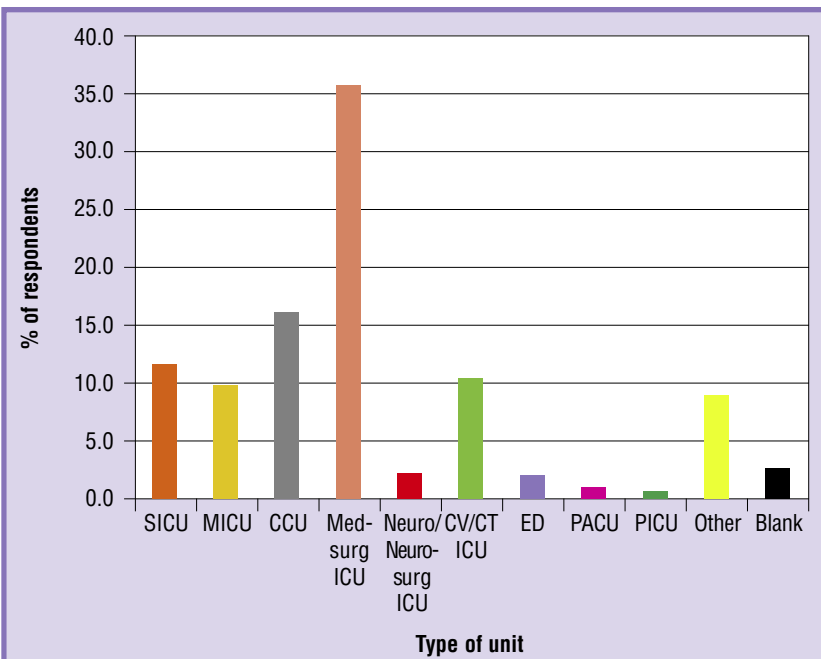


Figure Percentage of respondents working in various intensive care units.

Abbreviations: CCU, coronary care unit; CV/CTICU: cardiovascular/cardiothoracic intensive care unit; ED, emergency department; MICU, medical intensive care unit; PACU, postanesthesia care unit; PICU, progressive intensive care unit; SICU, surgical intensive care unit.

Table 3 Volume of solution used for flushing

Volume, mL	Percentage of respondents (95% CI)	
	Heparin solution	Saline
3	50.2 (43.5-56.9)	13.2 (10.51-15.89)
5	25.8 (19.92-31.68)	18.7 (15.61-21.79)
10	10.0 (5.9-14.1)	63.0 (59.18-66.82)
Other	13.6 (8.99-18.21)	4.9 (3.19-6.61)

Table 4 Frequency of standardized flushing

Frequency	No. (%)	95% CI
Every 8 hours	19 (8.0)	6.14%-9.86%
Every 8 hours and after each use	102 (43.0)	39.09%-46.91%
Every 12 hours	19 (8.0)	6.16%-9.84%
Every 12 hours and after each use	70 (29.5)	25.95%-33.05%
Every 24 hours	2 (0.8)	0.01%-1.50%
Every 24 hours and after each use	12 (5.1)	1.44%-6.36%
Only after each use	4 (1.7)	0.05%-3.35%
Other	9 (3.8)	1.37%-6.23%
Total respondents	237 (100.0)	

each survey question highlight current variations in flushing practices for CVC maintenance.

Discussion

Our results indicate that a large shift in practice has occurred since the mid-1990s. In earlier surveys, heparin solution was the most common flushing solution used by nurses. Today, the predominant

flushing solution is physiological saline. The volume of solution used for flushing appears to have remained similar. The increased awareness of HIT and HITTS associated with the use of heparin that can lead to life- and limb-threatening complications may explain this change.¹² Another possible explanation is the evidence that heparin and physiological saline are associated with similar rates of thrombosis for shorter length peripheral venous and arterial catheters with shorter dwell times.⁶ Last, the recommended use of a heparin solution rather than saline for flushing is considered inconclusive in guidelines for maintenance of short-term CVCs.³

The percentage of respondents who used heparin-containing flush solutions was higher for the 64 advanced practice nurses (clinical nurse specialists, nurse practitioners, or educators) than for the other groups. The most commonly used solution reported by the advanced practice group was a combination of heparin solution and saline (58.6%; 95% CI, 52.32%-64.88%). Only 35.4% (95% CI, 29.33%-41.47%) of the advanced practice group reported using saline only. Although 95.3% of respondents reported having a policy on CVC flushing practices, the advanced practice nurses appeared to adhere to the 2006 guidelines⁴ of the Infusion Nurses Society, which include the continued use of heparin-containing flush solution. The largest proportion of both advanced practice nurses and staff nurses used 3 mL of a heparin-containing solution for flushing and 10 mL of saline. The most commonly reported frequency of flushing for both groups was every 8 hours and after each use.

Table 5 Needleless connector used

Needleless conductor	No. (%)	95% CI
Positive displacement	219 (34.6)	30.89%-38.31%
Luer-activated valve (Clave, Safesite, Smartsite, Clearline, FloStar)	231 (36.6)	32.84%-40.36%
Split septum (Baxter Interlink, blunt cannula, Lifeshield, Safeline)	58 (9.2)	6.95%-11.45%
Neutral displacement (InVision Plus, Micro Clave)	24 (3.8)	2.31%-5.29%
Life Shield TKO	6 (0.9)	0.16%-1.64%
Other	78 (12.3)	9.74%-14.86%
Unknown	8 (1.3)	0.42%-2.18%
Blank	8 (1.3)	0.42%-2.18%
Total respondents	632 (100.0)	

A risk with any survey is sampling error and bias, which limit generalizability.²² Our survey included a random sample and a convenience sample of AACN members surveyed via US mail and during attendance at a conference. Although use of a random sample reduces sampling bias,²³ the additional use of the convenience sample increased our overall response rate and was used in an attempt to reduce sampling error and enhance generalization. Because the current state of flushing practice in the United States had not been examined since 1995, we could not estimate variation in the population.²³ Therefore, we did not do a power analysis to determine the response rate needed; the lack of this analysis is a limitation of the study.

Our sample included practicing critical care nurses from across the United States. In addition, the demographics of our respondent are similar to the demographics of the AACN membership in 2010,²⁴ a characteristic that enhances our confidence in the generalizability of our results. The majority of AACN

members (67%) are direct care providers²⁴; 71% of our respondents were direct care providers. Distribution of current position was also similar for both AACN members and our respondents. With one exception, the years of experience reported were also well matched. Approximately 11% of AACN members have less than 2 years of experience, whereas all of our respondents had more than 2 years of experience. This variation may be due to response bias associated with the convenience sample of nurses who attended the conference and stopped at the booths of hospitals in the exhibit hall to determine possible job opportunities. Lack of any respondents with less than 2 years of experience may limit the generalizability of the study results.

We did no follow-up of nonresponders; therefore, we do not know the error introduced by the nonresponse component.²² This lack of knowledge about nonresponders is a limitation. However, because of the purpose of the survey, which was not to affect current practice but to provide a gauge of current practice in flushing, this bias is less significant than in other types of surveys.²² Our results provide information about the impact of any research on solutions used to flush CVCs rather than serve as a call for change.

A limitation of any survey is the inability to correct any misunderstanding in the questions or to probe deeper.²² This limitation is applicable to our survey. We were unable to explore the reasons for current flushing practices. Additionally, obtaining information on catheter occlusion and bloodstream infection rates in the respondents' units would have been beneficial.

The lack of research on and standardized guidelines for the flushing of CVCs is highlighted by our results, which indicate the current variability in flushing practices by critical care nurses. Even though most of the respondents were experienced staff nurses from across the United States, flushing practices are inconsistent in all areas: solution, volume, and frequency.

Conclusion

Our findings highlight the current inconsistency in CVC flushing practices. The survey results indicate that the use of saline only to maintain patency of short-term CVC lumens has been adopted by many ICUs without evidence to support this practice. Our results support the need for a randomized controlled trial comparing saline with a heparin-containing solution to determine the equivalence or superiority of either flush solution in decreasing catheter occlusion rates. **CCN**

eLetters

Now that you've read the article, create or contribute to an online discussion about this topic using eLetters. Just visit www.ccnonline.org and click "Submit a response" in either the full-text or PDF view of the article.

Acknowledgments

Special thanks to Lee Skrupky, PharmD, Scott Micek, PharmD, Maggie Ulione, PhD, Natalie Taylor SN, and Julie Jackson for their assistance with the survey.

Financial Disclosures

None reported.

References

1. McGee DC, Gould MK. Preventing complications of central venous catheterization. *N Engl J Med*. 2003;348(12):1123-1133.
2. Yacopetti N. Central venous catheter-related thrombosis: a systematic review. *J Infus Nurs*. 2008;31(4):241-248.
3. Bishop L, Dougherty L, Bodenham A, et al. Guidelines on the insertion and management of central venous access in adults. *Int J Hematol*. 2007;29(4):261-278.
4. Infusion Nurses Society. Infusion Nursing Standards of Practice. *J Infus Nurs*. 2006; 29(1 suppl):S1-S92.
5. American Association of Critical-Care Nurses. Evaluation of the effects of heparinized and nonheparinized flush solutions on the patency of arterial pressure monitoring lines: the AACN Thunder Project. *Am J Crit Care*. 1993;2(1):3-15.
6. Randolph AG, Cook DJ, Gonzales CA, Andrew M. Benefit of heparin in peripheral venous and arterial catheters: systematic review and meta-analysis of randomized controlled trials. *BMJ*. 1998;316(7136):969-975.
7. Del Cotillo M, Grané N, Lloré M, Quintana S. Heparinized solution vs saline solution in the maintenance of arterial catheters: a double blind randomized clinical trial. *Intensive Care Med*. 2008;34(2):339-343.
8. Mitchell MD, Anderson BJ, Williams K, Umscheid CA. Heparin flushing and other interventions to maintain patency of central venous catheters: a systematic review. *J Adv Nurs*. 2009;65(10):2007-2021.
9. Hadaway L, Richardson D. Needleless connectors: a primer on terminology. *J Infus Nurs*. 2010;33(1):21-31.
10. Kishimoto TK, Viswanathan K, Ganguly T, et al. Contaminated heparin associated with adverse clinical events and activation of the contact system. *N Engl J Med* [published correction appears in *N Engl J Med*. 2010; 362(11):1056]. 2008;358(23):2457-2467.
11. Kuehn BM. FDA to boost its presence in China. *JAMA*. 2008;299(15):1762.
12. Selleng K, Warkentin TE, Greinacher A. Heparin-induced thrombocytopenia in intensive care patients. *Crit Care Med*. 2007; 35:1165-1176.
13. Warkentin TE. Heparin-induced thrombocytopenia. *Hematol Oncol Clin North Am*. 2007;21(4):589-607.
14. Goode CJ, Titler M, Rakel B, et al. A meta-analysis of effects of heparin flush and saline flush: quality and cost implications. *Nurs Res*. 1991;40(6):324-330.
15. Pratt RJ, Pellowe CM, Wilson JA, et al. epic2: national evidence-based guidelines for preventing healthcare-associated infections in NHS hospitals in England. *J Hosp Infect*. 2007;65(suppl 1):S1-S64.
16. Central Venous Access Device Guideline Panel. *Managing Central Venous Access Devices in Cancer Patients: A Clinical Practice Guideline*. Toronto, ON: Cancer Care Ontario; 2006. Evidence-based series No. 16-1.
17. Pellowe CM, Pratt RJ, Harper P, et al. Evidence-based guidelines for preventing healthcare-associated infections in primary and community care in England. *J Hosp Infect*. 2003;55(suppl 2):S2-S127.
18. O'Grady NP, Alexander N, Dellinger EP, et al. Guidelines for the prevention of intravascular catheter-related infections. *MMWR Recomm Rep*. 2002;51(RR-10):1-29.
19. Williams EM, Kelman GB, Jacox M. A regional survey of intravenous therapy practices. *J Intraven Nurs*. 1994;17(4):195-199.
20. Clemence MA, Walker D, Farr BM. Central venous catheter practices: results of a survey. *Am J Infect Control*. 1995;23:5-12.
21. Fuentes i Pumarola C, Casademont Mercader R, Colomer Plana M, et al. Comparative study of maintenance of patency of triple lumen central venous catheter [in Spanish]. *Enferm Intensiva*. 2007;18(1):25-35.
22. Curtis EA, Redmond RA. Survey postal questionnaire: optimizing response and dealing with non-response. *Nurse Res*. 2009; 16(2):76-88.
23. Price JH, Dake JA, Murman J, Dimmig J, Akpanudo S. Power analysis in survey research: importance and use for health educators. *Am J Health Educ*. 2005;36(4): 202-207.
24. American Association of Critical-Care Nurses. Membership demographics. <http://www.aacn.org/WD/Memberships/Docs/membdemographics.pdf>. Accessed November 7, 2011.