

Firm-Based Trial to Improve Central Venous Catheter Insertion Practices

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BACKGROUND: Central venous catheters placed in femoral veins increase the risk of complications. At our institution, residents place most catheters in the femoral vein.

OBJECTIVE: Determine whether a hands-on educational session reduced femoral venous catheterization and improved residents' confidence and adherence to recommendations for infection control.

DESIGN: Firm-based clinical trial between November 2004 and March 2005.

SETTING: General medical wards of Cook County (Stroger) Hospital (Chicago, IL), a public teaching hospital.

PARTICIPANTS: Internal medicine residents (n = 150).

INTERVENTION: Before their 4-week rotation, intervention-firm residents received a lecture and practiced placing catheters in mannequins; control-firm residents received the usual training.

MEASUREMENTS: Venous insertion site, adherence to recommendations for infection control, knowledge and confidence about catheter insertion, and catheter-associated complications

RESULTS: Residents inserted 54 catheters, or 0.24 insertions per resident per 4-week rotation. There was a nonsignificant decrease in femoral insertions for nondialysis catheters in the intervention group compared to the control group (44% vs. 58%), difference: -14% (95% CI, -52% to 24%). The intervention significantly increased residents' knowledge of complications related to femoral vein catheterization and temporarily increased their confidence about placing internal jugular or subclavian venous catheters. Intervention-group residents were more likely to use masks during catheterization (risk ratio, 2.2; 95% CI, 1.3-2.7), but other practices were similar.

CONCLUSIONS: Our intervention improved residents' knowledge of complications and use of masks during catheter insertion; however, it did not significantly change venous insertion sites. Catheter insertions on our general medicine wards are infrequent, and the skills acquired during the skills-building session may have deteriorated given the few clinical opportunities for reinforcement. *Journal of Hospital Medicine* 2007;2:135-142. © 2007 Society of Hospital Medicine.

KEYWORDS: central venous catheterization, medical education, internship and residency, infection control, patient simulation.

At times central venous catheters are essential to the delivery of appropriate medical care. Because catheter-related complications are associated with limited operator experience,¹ insertion technique,² and venous site of insertion (eg, femoral, internal jugular, or subclavian vein),³ house staff training programs strive to provide their residents with appropriate training and oversight for this skill. Most quality improvement initiatives directed at reducing complications associated with central venous catheters

have focused on patients in the intensive care unit (ICU).^{4,5} However, in some hospitals more central venous catheters are inserted in patients not in the ICU,⁶ and practices that increase the risk of complications may be more common on wards.⁷

In our hospital, most catheters are placed in the femoral vein. Because femoral venous placement likely increases a patient's risk of thrombosis, hematoma, and bloodstream infection,⁸ we developed a program to change residents' choice of venous insertion site and improve their infection-control practices during their general medicine ward rotation. The program provided simulated hands-on experience in a simulation laboratory. We evaluated our intervention through a firm-based clinical trial that compared the usual practice to our intervention. We compared infection-control practices and resident choice of venous insertion site between the intervention and control groups; we also assessed residents' knowledge about catheter-related complications, and we monitored patients for catheter-related complications.

METHODS

Setting and Study Design

We conducted a prospective, firm-based clinical trial approved by the institutional review board at Cook County Hospital, a 464-bed public teaching hospital. We evaluated all central venous catheters inserted by residents on the general medicine service from November 15, 2004, to March 31, 2005. The internal medicine residency program assigns residents to 1 of 3 firms for their entire 3 years of training. We designated 1 firm as the intervention group; the other 2 firms constituted the control group.

Educational Intervention

At the beginning of each 4-week general medicine ward rotation, intervention-firm residents attended an educational and simulation laboratory session. Control-firm residents received the usual ward orientation. We conducted 6 sessions, with total attendance of 40 intervention-firm residents, or approximately 7 residents per session. A chief medical resident experienced in catheter placement and an attending internist led and supervised each 2½-hour training session. The sessions were conducted at the Simulation Laboratory of Rush University and included a presentation about indications for central venous catheter insertion, insertion tech-

niques, common complications, and practice placing catheters in mannequins. During the hands-on session, each participant observed the expert insert a triple-lumen catheter in the mannequin's internal jugular and subclavian veins. Then, with supervision, each participant practiced catheter insertion using recommended infection-control practices (eg, use of gloves, mask, and large drape, and chlorhexidine skin preparation).

Resident Survey

Before each session, we administered a survey that assessed residents' knowledge of insertion techniques and their confidence in placing catheters at each venous insertion site. To measure change in the confidence level of residents, we distributed an abbreviated survey 2 additional times, immediately after the session and at the end of the study period. We measured confidence with answers to survey questions, which were rated on a 5-point Likert scale, from strongly disagree to strongly agree. In addition to measuring the change in residents' confidence, the final survey repeated knowledge assessment questions, evaluated residents' attitudes regarding venous insertion sites, and asked about potential strategies to improve insertion practices.

Central Venous Catheter Detection and Monitoring

At the end of each day, residents reported catheter insertions to chief residents during routine sign-out rounds. If a catheter had been inserted, the chief resident interviewed the resident about type of catheter, venous insertion site, duration of attempt, patient location, immediate complications, number of inserters, inserter attendance at an educational session, inserter specialty, and professional designation (eg, resident, fellow, attending), indication for insertion, and adherence to infection-control practices. For all insertion attempts, the research team reviewed the medical record and recorded patient characteristics that might influence venous insertion site (eg, thrombocytopenia, coagulopathy, and body mass index) and evaluated patients for insertion-related complications.

We prospectively monitored patients for mechanical (ie, pneumothorax or hematoma), thromboembolic, or infectious complications. To evaluate for pneumothorax, postinsertion chest radiographs were reviewed by a physician-investigator, and radiologists' interpretations and progress notes were reviewed. To evaluate for infectious or other me-

chanical complications, progress notes also were reviewed. We required radiographic confirmation of venous thromboembolism. To categorize potential bloodstream infections, we used Centers for Disease Control and Prevention definitions.⁹ All medical record and radiograph reviews were performed by investigators who were masked to patient firm assignment. We monitored patients until catheter removal or hospital discharge. After patient discharge, we reviewed the electronic record, including emergency room visits and repeat hospitalizations, for 30 days after the earlier of hospital discharge or catheter removal.

Statistics

Because we were aware that temporary dialysis catheters are sometimes placed in femoral veins to preserve the subclavian or internal jugular venous sites for more permanent tunneled intravascular catheters, our prespecified plans were to compare venous insertion sites between intervention and control groups after excluding temporary dialysis catheters. To more completely describe catheter use, we also collected data on temporary dialysis catheters, and we present the results both with and without inclusion of data on temporary dialysis catheters. If multiple residents attempted to insert a catheter, we would have used the group that the final inserter was in to determine intervention versus control group assignment; however, this never occurred.

To determine resident confidence in inserting catheters, we collapsed the responses of “agree” and “strongly agree” and of “disagree” and “strongly disagree” into single categories; thus, frequency of agreement was evaluated as a dichotomous outcome. To test whether residents’ confidence changed between the 3 surveys, we analyzed responses using the matched-pair signed rank test, with the initial survey used as the referent.

We dichotomized certain continuous variables using the following cut points: body mass index ≥ 30 kg/m²; coagulopathy, international normalized ratio (INR) > 1.5 ; thrombocytopenia, platelets $< 100 \times 10^9$ /L. Data were entered into a relational database (Microsoft Access, Microsoft Inc., Redmond, WA) and merged analyzed using Stata software, version 8.2 (Stata Corporation, College Station, TX).

TABLE 1
Comparison of Central Venous Catheter and Characteristics of Patients Treated by Residents in Educational Intervention Group Versus Those in Control Group

Characteristic	Central venous catheters inserted		P
	Intervention (n = 16), n (%)	Control (n = 38), n (%)	
<i>Patient</i>			
Body mass index ≥ 30 kg/m ²	5 (31)	11 (29)	1.0
INR > 1.5	3 (19)	3 (7.9)	0.37
Platelet count $< 100k$	0 (0)	9 (24)	0.05
Charlson index, mean (interquartile range)	2 (2-4)	2 (1-4)	0.58
<i>Physician inserting catheter</i>			
Resident on general medicine service ^a	15 (100)	34/37 (92)	1.0
Subspecialty fellow	0 (0)	2/37 (5.3)	1.0
Radiology fellow or attending	0 (0)	1/37 (2.6)	1.0
<i>Reason for insertion</i>			
No intravenous access	7 (44)	19 (50)	0.67
Temporary dialysis catheter ^b	7 (44)	14 (37)	0.63
Total parenteral nutrition	1 (6.2)	3 (7.9)	1.0
Other ^c	1 (6.2)	2 (5.3)	1.0
<i>Time of day of insertion</i>			
Between 7 AM and 5 PM	12/14 (86)	25/37 (68)	0.30

^aOne intervention group catheter was inserted by the attending after an unsuccessful resident attempt; inserter unspecified for 1 catheter inserted by control group.

^bReasons for placement were temporary dialysis (n = 16), plasmapheresis (n = 4), or leukapheresis (n = 1)

^cPlaced for fluid resuscitation (n = 2) or exchange transfusion (n = 1).

RESULTS

Patient and Catheter Characteristics

Fifty-four catheters were inserted in 48 patients during the study period, 16 (30%) in the intervention group and 38 (70%) in the control group. Mean number of catheters inserted per resident for each 4-week rotation was 0.24; therefore, on average, a resident would insert 1 catheter every 4 general-medicine rotations. Most catheters were inserted between 7:00 AM and 5:00 PM; the most common reason for insertion was to administer intravenous medications to a patient without intravenous access, followed by the need for a temporary dialysis catheter. Most catheters were inserted by the medicine team rather than radiology or a subspecialty service (Table 1). Most patient characteristics and reasons for insertion were similar between groups; however, more patients in the control group had thrombocytopenia (Table 1).

TABLE 2
Comparison of Central Venous Catheter (CVC) Insertion Practices of Residents in Control and Intervention Groups

	Intervention (n = 16), n (%)	Control (n = 38), n (%)	Risk ratio (95% CI)	P
Self-reported practices during CVC insertion				
Mask worn	12 (75)	13 (34)	2.2 (1.3-3.7)	0.008
Large drape used	15 (94)	28 (74)	1.3 (1.0-1.6)	0.14
Cap worn	3 (19)	5 (13)	1.4 (0.4-5.3)	0.6
Gown worn	8 (50)	18 (47)	1.1 (0.6-1.9)	0.9
Sterile gloves worn	15 (94)	36 (95)	1.0 (0.8-1.2)	1.0
Venous insertion site ^a			Difference (95% CI)	
Femoral	10 (62)	26 (68)	-6% (-34%-22%)	0.67
Internal jugular	5 (31)	9 (24)	—	—
Subclavian	1 (6.2)	3 (7.9)	—	—
<i>Excluding dialysis catheters^a</i>		n = 9		n = 24
Femoral	4 (44)	14 (58)	-14% (-52%-24%)	0.7
Internal jugular	5 (56)	8 (33)	—	—
Subclavian	0 (0)	2 (8)	—	—

^aWe compared venous insertions at the femoral site versus at the subclavian or internal jugular sites.

TABLE 3
Comparison of Complications for Femoral Versus Subclavian or Internal Jugular (IJ) Central Venous Catheter (CVC) Placement

Complication	Femoral (n = 36), n (%)	Subclavian or IJ (n = 18), n (%)	Difference (95% CI)
Mechanical (arterial puncture, hematoma, or pneumothorax) ^a	4 (11)	0	11% (1%-21%)
Venous thromboembolism ^b	0 (0)	0 (0)	0%
Infection rate (per 1000 central-line days) ^c	4.3	7.0	-2.7 (-19-13)

^aThere were 4 episodes of arterial puncture, one of which resulted in a clinically apparent hematoma. There were no pneumothoraxes. For comparison of insertion sites, $P = .29$ using Fisher's exact test.

^bOne patient who had a subclavian catheter returned to the emergency department with a swollen upper extremity after catheter removal; the patient refused diagnostic tests, and no therapy was initiated.

^cInfection occurred in a patient who had femoral and internal jugular CVCs. There was no clinical evidence of infection at the exit site of either catheter. We attributed one infection to each site.

Insertion Practices

Femoral venous insertion was the most common type of catheter insertion (67%), followed by internal jugular (26%) and subclavian (7%); there were no differences in insertion site between the intervention and control groups (Table 2). When we excluded temporary dialysis catheters, 39% of central venous catheters were inserted in the internal jugular vein. Although a smaller proportion of catheters inserted by the intervention group were placed in a femoral vein, the difference was not significant (Table 2).

For most insertions, residents reported using sterile gloves (94%) and a large drape (80%); however, most did not report use of a sterile gown (48%), mask (46%), or cap (15%). Residents in the intervention group were more likely to report use of a mask, and there was a trend toward increased use

of large drapes (Table 2). No patient characteristics predicted femoral venous insertion (data not shown).

Complications

The most frequent complication was arterial puncture (n = 4); all four occurred during femoral venous insertion attempts. Compared to subclavian or internal jugular venous placement, there was a trend toward more mechanical complications among femoral catheters (Table 3). One episode of clinical sepsis occurred, in an intervention-group patient who had femoral and internal jugular catheters, and no pneumothoraxes or episodes of venous thromboembolism occurred (Table 3). The overall incidence of bloodstream infection was 2.7 per 1000 central-line days; there was no difference

TABLE 4
Results of Surveys Administered to Resident Attendees of Central Venous Catheter (CVC) Educational Session before (Pre-session), Immediately after (Post-session), and at Study Conclusion (Follow-up)

	Respondents in Agreement, n (%)		
	Pre-session n = 35	Post-session n = 34	Follow-up n = 35
Knowledge			
Complications are most frequent at the femoral site	27 (77%)	30 (86%)	
Arterial puncture risk is lowest at the femoral site ^a	16 (46%)	7 (21%) ^b	
Thrombosis risk is lowest at the femoral site ^a	11 (31%)	6 (18%)	
Infection risk is lowest at the femoral site	1/33 (3%)	0 (0%)	
Attitudes			
<i>I feel confident:^c</i>			
Inserting a femoral CVC	53	59 ^b	89 ^d
Inserting an internal jugular CVC	41	71 ^d	40
Inserting a subclavian CVC	24	65 ^d	34 ^d
<i>Options to increase placement in jugular or subclavian veins</i>			
Availability of ultrasound machine			31 (89)
Expert supervisor available to assist with placement			30 (86)
Insert CVC within 2 weeks of educational session			30 (86)
Rotation through a service that often places CVCs ^a			26 (76)
I do not plan to use this skill after my residency			4 (11)
<i>Barriers to inserting a subclavian or internal jugular CVC</i>			
Preexisting internal jugular or subclavian CVC			11 (31)
For temporary dialysis, desire to preserve site			26 (74)
Practices			
More likely to remove unnecessary catheter			29 (83)
Improved infection-control practices			28 (80)
Increased motivation for internal jugular or subclavian venous insertion			27 (78)
Less likely to place a CVC			9 (26)
Internal jugular or subclavian CVC inserted for the first time after training			7/30 (23)

^aOne participant did not respond to these questions.

^bSignificant at $P < .05$.

^cStatistical test performed using the matched-pair signed rank test. Responses to the pre-session survey were considered the referent. There were 17 matched pairs for the pre- and post-session surveys and 14 for the pre-session and follow-up session surveys.

^dSignificant at $P < .01$.

between the intervention and control groups (9.2 versus 0 per 1000 central-line days; $P = .29$).

Survey Responses

Before the educational session, many residents did not recognize that femoral venous catheter insertions had a higher risk of arterial puncture or venous thrombosis (Table 4); by the final survey, residents were more likely to recognize the higher risk of these complications during femoral venous insertions. Most residents recognized the higher risk of infectious complications at the femoral site (Table 4).

Residents overwhelmingly responded that the lecture was useful (95%), that mannequins provided a valuable skill-building exercise (90%), and that the session should be incorporated into the training program (95%). Immediately after the session, residents

had increased confidence about inserting a central venous catheter at any venous site, especially for internal jugular or subclavian insertions. By the final survey, the confidence of residents about inserting catheters in the internal jugular or subclavian veins had returned to baseline but had increased for femoral-site insertions (Table 4).

Most residents in the intervention group agreed that the educational session motivated them to remove unnecessary catheters, improve insertion-related infection-control practices, and place the catheter in an internal jugular or subclavian vein; some agreed because of the educational session, they were less likely to place a central venous catheter. Some reported successfully inserting a central venous catheter in the subclavian or internal jugular vein for the first time (Table 4).

DISCUSSION

An educational session designed to teach residents appropriate central venous catheter insertion practices that included simulated hands-on training increased knowledge about insertion-related complications and improved certain infection-control practices. Although residents' confidence in inserting subclavian or internal jugular catheters initially improved, our training session did not change the choice of venous insertion site from femoral to subclavian or internal jugular veins, possibly because there were few opportunities for residents to insert a catheter during the 4-week general medical ward rotations. Thus, although an active educational intervention improved the knowledge and confidence of residents, it had a minimal effect on behavior (only improved certain infection-control practices). Catheter-associated complications were infrequent and similar in the intervention and control groups.

Central venous catheter insertion is a skill that many general internists do not perform¹⁰; however, until recently the American Board of Internal Medicine considered it a requisite skill for internal medicine residents, and most residents at our hospital reported a desire to learn this skill. Although in our study complications were infrequent, suggesting that a change in venous insertion site is unlikely to dramatically improve patient safety, we believe that residents should become skilled at inserting catheters in internal jugular or subclavian veins, the currently recommended optimal venous insertion.⁸

There is evidence that single educational interventions are unlikely to result in substantial, sustained behavioral change, especially passive educational programs.¹¹ However, a previous study documented a change in provider behavior and possibly a reduction in bloodstream infections after a single hands-on training session.¹² Our hands-on educational format was very popular and likely improved some infection-control practices but did not change provider behavior about choice of venous insertion site. In other institutions, mentoring residents on appropriate catheter insertion technique has been accomplished by establishing a procedure service¹³ or by resident rotation in a high-volume location (eg, cardiac catheterization laboratory).¹⁴ Another option to facilitate behavioral change would be to provide a portable ultrasound machine, as requested by our residents, which may reduce complication rates.^{15,16} At our hospital, we

decided to supplement hands-on training with expert bedside supervision during catheter insertion; the expert is provided through a procedure service that is led by hospitalists. The procedure service has a dedicated portable ultrasound machine to assist with internal jugular vein cannulation.

By the end of our study period, residents' confidence in subclavian or internal jugular catheter insertions had returned to pre-session levels; however, they reported increased confidence in femoral venous catheter insertions. These findings suggest that the session increased residents' confidence with catheter insertions in general, but not specifically for venous sites for which they had no previous experience. For subclavian or internal jugular catheter insertions, their confidence decayed to the pre-session baseline, likely because of few opportunities to insert catheters in patients; on average, each resident inserts 1 central venous catheter on the general medicine wards approximately every 4 months.

Our survey found that our intervention changed residents' attitudes about infection-control practices. In particular, intervention-group residents reported that they were more likely to remove unnecessary catheters and that they had used a mask and large drape during catheter insertion. Use of "full-barrier" precautions (ie, sterile gloves and gown, large sterile drape, cap, and mask) has been shown to reduce the risk of bloodstream infection² and is included in national guidelines.¹⁷ Adherence to these guidelines has been included in successful quality improvement initiatives.^{4,5,18} Compared to internists' adherence to recommendations for infection control reported in another survey,¹⁰ residents who attended our educational session reported more use of large sterile drapes (94% vs. 35%) or masks (75% vs. 66%); however, they were less likely to use a sterile gown (50% vs. 72%). Use of a large sterile drape is common in our hospital, likely because the drape is included in the central venous catheter package. We suspect that at our hospital, poor adherence to certain recommendations (eg, using a sterile gown) was due in part to difficulty accessing supplies. Another possibility is that use of a cap, compared to use of large drapes, is perceived as not giving the patient much additional protection. In fact, there is no evidence that using a cap provides benefit beyond that of other, more intuitively beneficial recommended infection-control practices, such as using sterile gloves and a large sterile drape. The procedure service has

addressed the supply problem by stocking hard-to-find items on a procedure cart.

Only 2 clinically evident complications associated with catheter insertion occurred (one patient with clinical sepsis and one with a hematoma). Although it is possible that we missed minor complications, our rates were similar to those reported by other investigators: clinically diagnosed venous thromboembolism, 0%-2.2%^{3,19,20}; pneumothorax, 1.4%²¹; catheter-associated primary bloodstream infection, 1-6/1000 catheter-days.^{22,23} Comparing complication rates was hindered by variability in definitions, methods of ascertainment, and populations evaluated. For example, the rate of venous thromboembolism was dramatically higher when routine diagnostic imaging was used, and detection of catheter-associated infections likely increased when catheter-tip cultures were routinely performed. We required clinical evidence of complications, and our study differs from others in that we evaluated general medicine ward patients.

This study had several limitations. Placement of central venous catheters on general medicine wards was less frequent than we anticipated based on a brief period of pilot data collection; therefore, our study was not powered to detect relatively small changes in venous insertion sites or differences in complications. Also, because direct observation was not possible, we relied on self-reported adherence to infection-control practices. However, intervention residents' self-reported poor adherence to gown, glove, and cap use suggests that their responses were unbiased.

An educational session focused on central venous catheter insertion practices was well received by residents, increased their knowledge about complications, and improved infection-control practices, but had no effect on increasing use of subclavian or internal jugular veins for catheter insertion. Despite continued frequent use of femoral venous catheters, clinically apparent complications were infrequent. However, we believe it is important to teach residents optimal catheter insertion techniques, including preferential placement of catheters in subclavian or internal jugular veins. Therefore, the section of hospital medicine at our hospital initiated a procedure service that provides expert bedside supervision, including use of a portable ultrasound machine, for catheter insertions.

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