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Mechanical Complications of Central Venous Catheters

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We analyzed 385 consecutive central venous catheter (CVC) attempts over a 6-month period. All critically ill patients 18 years of age or older requiring a CVC were included. The rate of mechanical complications not including failure to place was 14%. Complications included failure to place the CVC (n = 86), arterial puncture (n = 18), improper position (n = 14), pneumothorax (n = 5 in 258 subclavian and internal jugular attempts), hematoma (n = 3), hemothorax (n = 1), and asystolic cardiac arrest of unknown etiology (n = 1). Male patients had a significantly higher complication rate than female patients (37% vs 27%, $P = .04$). The subclavian approach had a higher complication rate than the internal jugular or the femoral approach (39% vs 33% vs. 24%, $P = .02$). The complication rate increased with the number of percutaneous punctures, with a rate of 54% when more than 2 punctures were required.

Key words: *central venous catheterization, complications, critical care, pneumothorax, education*

Central venous catheters (CVC) are an essential component of modern critical care. They allow delivery of medications, intravenous fluids, parenteral nutrition, and hemodialysis and monitoring of hemodynamic variables. Despite their utility, place-

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ment of central venous catheters is often associated with mechanical, infectious, and thromboembolic complications [1]. Mechanical complications are important, because their effects are usually immediate and contribute to increased length of stay, increased hospital costs, need for subsequent interventions, and mortality rate. These include failure to place the catheter, pneumothorax, arterial puncture, pulmonary embolism, air embolism, dysrhythmia, and death. Prior studies have demonstrated mechanical complication rates in 5% to 29% of catheter attempts [1].

Several studies have identified factors associated with mechanical complications. These factors include low or high patient body mass index (BMI), prior catheterization, prior surgery, prior radiotherapy, number of venipunctures, advanced age, and the time needed for catheter placement [2-4]. Other factors of potential interest, such as the emergent indication for the CVC, the time of day the catheter was placed, the patient's state of consciousness, and the supervisor's training level, have not been fully explored. Furthermore, prior studies differ on whether complication rates are influenced by the training level of the operator [2,3] and whether ultrasonography should be used to locate the vessel cannulated [2,5-8].

We collected data on mechanical complication rates, along with specific patient, operator, supervisor, and procedure characteristics. The aim of the study was to determine risk factors associated with mechanical complications of central venous catheterization.

Materials and Methods

Beth Israel Medical Center, the University Hospital and Manhattan Campus for the Albert Einstein College of Medicine, is a 697-bed urban teaching

hospital. This study was conducted in its 16-bed medical intensive care unit, 12-bed respiratory care unit (respiratory step-down or intermediate respiratory care unit), and 8-bed cardiac care unit. These units serve the nonsurgical population of the hospital. All patients were 18 years of age or older. The study was approved by the Beth Israel Medical Center Institutional Review Board. The requirement for informed consent was waived.

We constructed a database consisting of 385 consecutive CVC placement attempts over a 6-month period beginning October 1, 2003. There were no exclusion criteria: data were recorded on all insertion attempts, including triple-lumen catheters (Multi-Med Central Venous Catheter Kit, Edwards Lifesciences LLC, Irvine, CA), introducer sheaths (Input Introducer Sheath 6 French, ALE Ireland LTD, Galway, Ireland), and hemodialysis catheters (Dual Lumen Catheter Kit, Tyco Health Care Group LP, Mansfield, MA). All catheters were placed by medical house staff, fellows in pulmonary/critical care medicine or cardiology, or pulmonary/critical care attending physicians (attendings). Hospital policy specifies that physicians must be supervised while placing CVCs until they are deemed competent to perform the procedure independently. This requires placing at least 10 subclavian, 10 internal jugular, or 5 femoral venous catheters. The physician may then insert CVCs independently and supervise other physicians not yet credentialed to perform the procedure. Choice of CVC site was at the discretion of the operator based on patient characteristics, patient preference, personal experience, and the medical literature [1-4].

By protocol, all catheters are inserted via a modification of the original Seldinger technique [9]. At our hospital, the subclavian approach is preferred for catheterization expected to last more than 1 day because of the reduced incidence of infection compared with other sites [4]. Depending on the preference of the operator, the internal jugular vein was cannulated by either the anterior or posterior approach. Operators and supervisors perform a sterile hand wash and wear masks, gloves, surgical gowns, and hair covers. After anatomical landmarks are visualized, the skin is prepared with chlorhexidine and draped. Lidocaine (1%) is used for local anesthesia, and the patient is sedated at the discretion of the operator. In spontaneously breathing patients, catheters are introduced during exhalation to minimize the possibility of air embolization. Less than 5% of catheters were placed with ultrasound guidance. These were all placed by pulmonary fellows when the patient was deemed unsuited for the landmark technique.

Once the CVC is inserted, it is sutured into place and covered with a sterile dressing. Catheter position is preliminarily confirmed by return of blood and free flow of fluid through all ports. All patients are observed for mechanical complications. For internal jugular and subclavian catheters, all patients routinely have a chest radiograph that is read by a radiologist blinded to the clinical status of the patient to assess for catheter position, pneumothorax, hydrothorax, and mediastinal hematoma. All complications are managed as clinically indicated.

Only the first attempt at a central line insertion was evaluated in this study to avoid confounding of patient factors. Multiple percutaneous punctures by 1 operator at 1 site were scored as 1 attempt. The number of percutaneous punctures (needle traversing skin) was recorded. If the first puncture was unsuccessful, the operator was permitted to make additional punctures until either the procedure was successful or the supervisor decided that the operator should cease, in which case the attempt was recorded as a failure.

A database was constructed with patient characteristics, operator characteristics, supervisor characteristics, procedure characteristics, and complication type. Patient characteristics recorded were age, gender, level of consciousness, and BMI (weight in kilograms divided by height in square meters). Age was divided into deciles. Body mass indices were analyzed in three groups (10-20, >20-30, >30 kg/m²). A patient was deemed unconscious if he or she had no response to painful stimuli. Procedure characteristics were site of insertion, time of procedure (day defined as 7 AM to 7 PM, night as 7 PM to 7 AM), number of percutaneous punctures, the patient care unit where the procedure took place, and whether the procedure was emergent or elective. A procedure was defined as emergent if the operator judged that a 1-hour delay would be harmful. Operator characteristics were the number of years of postgraduate training of the person placing the CVC. Supervisor characteristics were the number of years of postgraduate training of the supervisor. If the operator was credentialed to place the central venous catheter independently, no supervisor was recorded for the attempt. Mechanical complications were characterized as either none, failure to place, arterial puncture, improper position, pneumothorax, hematoma, hemothorax, or death. Improper position was defined as any catheter that needed repositioning after review of the chest radiograph. Whenever possible, one of the authors was present during the CVC attempt. In addition, mechanical complications were tracked by a combination of interviews of the operators and

supervisors, review of radiologic reports, and chart review.

Quantitative parameters were expressed as mean \pm standard deviation. Potential risk factors for mechanical complications were analyzed in a bivariate analysis by using the chi-square test. Because of the small number of catheter attempts by attendings, catheter attempts by attendings and fellows were combined for the chi-square analysis. Characteristics associated with complication rate with $P < .2$ were entered into a multivariate logistic regression analysis with complications as the dependent variable and various parameters as the independent variables.

All P values are based on two-tailed tests of significance. $P < .05$ was considered statistically significant. All computations were performed by SPSS version 11.5 (SPSS, Chicago, IL) on data imported from a Microsoft Excel 2002 spreadsheet (Microsoft Corporation, Redmond, WA).

Results

During the study period, we studied 385 consecutive CVC attempts. Baseline characteristics are presented in Table 1. There were 218 (57%) subclavian attempts, 127 (33%) femoral attempts, and 40 (10%) internal jugular attempts. More than 80% of all catheters were placed in the medical intensive care unit. Thirty percent of all catheters were considered emergent, and 26% of all catheters were placed between 7 PM and 7 AM. Female patients comprised 39% of the attempts, and 72% of patients were unconscious at the time of catheter placement. Residents and interns placed more than 75% of all catheters, and 31% of all attempts were unsupervised. Attendings attempted or directly supervised 3% of all attempts.

Mechanical complications are described in Table 2. Sixty-seven percent of attempts (256 of 385) were uncomplicated. If failure to place was not counted, 14% of attempts had mechanical complications with variable clinical significance. Among procedure characteristics, only the site of insertion affected complication rate. Subclavian, internal jugular, and femoral catheterization was associated with a mechanical complication in 39%, 33%, and 24% of all attempts, respectively ($P = .022$). The most common complication was failure to place, occurring in 22% of all attempts. Subclavian, internal jugular, and femoral catheterization attempts were unsuccessful 26%, 25%, and 15% of the time, respectively ($P = .05$). Other complications, including pneumothorax, arterial puncture, hemothorax, and subcuta-

Table 1. Baseline Characteristics of Central Venous Catheter Attempts

Patient characteristics ^a	
Age (years) \pm SD	66.4 \pm 17.1
Female	150 (39.0%)
Body mass index (kg/m ²)	26.2 \pm 7.5
Unconscious	275 (71.4%)
Operator characteristics ^a	
PGY 1	76 (19.7)
PGY 2	124 (32.2)
PGY 3	109 (28.3)
PGY 4	43 (11.2)
PGY 5	21 (5.5)
PGY 6	8 (2.1)
Attending	4 (1.0)
Supervisor characteristics ^a	
None	119 (30.9)
PGY 1	2 (0.5)
PGY 2	21 (5.5)
PGY 3	86 (22.3)
PGY 4	54 (14.0)
PGY 5	62 (16.1)
PGY 6	33 (8.6)
Attending	8 (2.1)
Procedure characteristics ^a	
Unit	
MICU	312 (81.0)
CCU	50 (13.0)
RCU	22 (5.7)
Missing data	1 (0.2)
Catheter type	
Subclavian	218 (56.6)
Femoral	127 (33.0)
Internal jugular	40 (10.4)
Emergent	116 (30.1)
Night	101 (26.2)

PGY = postgraduate year; attending = attending physician; MICU = medical intensive care unit; CCU = coronary care unit; RCU = respiratory care unit.

a. Values are attempts (%).

neous hematoma, were much less common, and incidence rates were not significantly different between groups (Table 2). One death occurred from an asystolic arrest during the placement of an internal jugular catheter. Although it was unclear whether the death was related directly to the procedure, it was recorded as a complication.

The only patient characteristic associated with complication was gender. Among male patients, 88 of 235 (37%) CVC attempts had complications, whereas among female patients 41 of 150 (27%) catheter attempts had complications ($P = .04$). Neither a high (>30 kg/m²) nor a low (<20 kg/m²) BMI was associated with increased complications rates. Similarly, these rates were not associated with the patient's age ($P = .619$) or level of consciousness ($P = .246$).

Operator and supervisor characteristics were also analyzed. The level of training of the operator had

Table 2. Mechanical Complications by Catheter Insertion Site

	All Catheters (n = 385)	Subclavian (n = 218)	Internal Jugular (n = 40)	Femoral (n=127)	<i>P</i>
Complications	129 (33.2)	85 (39.0)	13 (32.5)	31 (24.4)	.022
Pneumothorax	5 (1.3) (n = 258)	5 (2.3)	0	N/A	.144
Arterial puncture	18 (4.7)	7 (3.2)	2 (5.0)	9 (7.1)	.257
Incorrect position	14 (3.6)	14 (6.4)	0	0	.004
Hemothorax	1 (0.3) (n = 258)	1 (0.5)	0	N/A	.361
Subcutaneous hematoma	3 (0.8)	1 (0.5)	0	2 (1.6)	.440
Death	1 (0.3)	0	1 (2.5)	0	.361
Failure to place	86 (22.3)	57 (26.1)	10 (25.0)	19 (15.0)	.051

Table 3. Mechanical Complications and Number of Attempts by Operator

	Intern (n = 76)	Resident (n = 233)	Fellow and Attending (n = 76)	<i>P</i>
Failure to place (%)	23 (30.3)	53 (22.7)	10 (13.2)	.076
Any complication (%)	30 (39.5)	83 (35.6)	14 (18.4)	.036
Complications not including failure to place (%)	7 (9.2)	30 (12.9)	4 (5.2)	.025

a significant effect on overall complication rates ($P = .036$). There was also a trend toward decreased failure rate with increased levels of training ($P = .076$) (Table 3). Attempts supervised by residents, fellows, and attendings had complication rates of 38%, 36%, and 50%, respectively, whereas unsupervised procedures had a complication rate of 25%. Thus, the level or presence of a supervisor did not have a significant effect on complication rate ($P = .122$).

An association was sought between procedure characteristics and complication rate. The number of percutaneous punctures was significantly associated with complication rate. CVCs requiring 1 puncture had a complication rate of 17%, whereas CVCs requiring 2 punctures had a complication rate of 28%. CVCs requiring more than 2 punctures had a complication rate of 54% ($P < .001$). Catheters placed in the medical intensive care unit had a complication rate of 32%, whereas catheters placed in the respiratory care unit had a complication rate of 50%, and catheters placed in the cardiac care unit had a complication rate of 36%. These differences were not statistically significant ($P = .305$). CVCs placed during the day had a complication rate of 34%, whereas those placed at night had a complication rate of 33% ($P = .836$). There was also no significant difference in complication rate for CVCs placed emergently (38%) or electively (33%) ($P = .79$).

The gender of the patient, the site of the CVC, the level of training of the operator, and the number of

Table 4. Multivariate Predictors of Mechanical Complications

Predictor	OR	95% CI	<i>P</i> Value
More than 2 punctures	3.60	1.98-2.67	<.01
Subclavian vs other sites	2.55	1.03-6.29	.043
Female gender	1.78	1.09-2.91	.022
PGY supervisor			.312
PGY operator			.724

OR = odds ratio; CI = confidence interval; PGY = postgraduate year.

percutaneous punctures required were all significantly associated with complication rate on bivariate analysis. These 4 characteristics, along with the training level of the supervisor ($P < .2$), were entered into a multivariate logistic regression analysis, showing that the gender of the patient (odds ratio [OR] 1.78, 95% confidence interval [CI] 1.09-2.91, $P = 0.022$), subclavian line site (OR 2.55, 95% CI 1.03-6.29, $P = .043$), and number of percutaneous punctures (OR 3.60, 95% CI 1.98-2.67, $P < .01$) remained statistically significant predictors of complications (Table 4).

Thirty-six percent of all CVCs had 1 percutaneous puncture, 27% had 2 punctures, and 37% had more than 2 punctures. The internal jugular approach was more likely to require 1 skin puncture, but this was not statistically significant ($P = .38$) (Fig 1). Operators with lower levels of training generally required more skin punctures, but this also did not reach statistical significance ($P = .07$) (Fig 2).

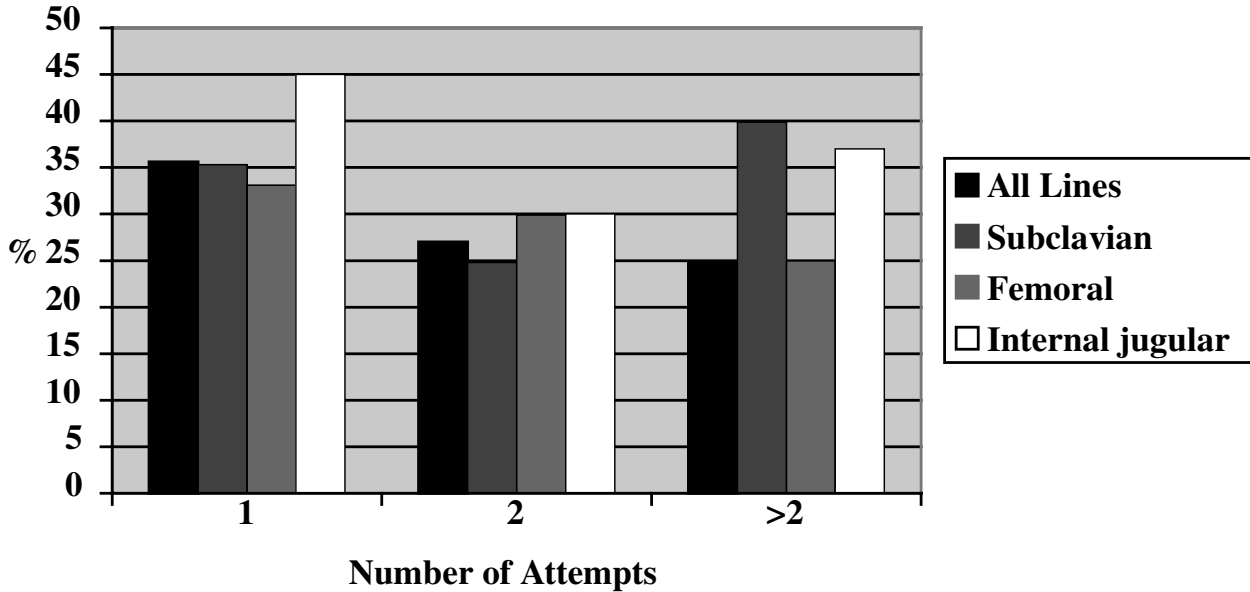


Fig 1. Number of percutaneous punctures by insertion site. $P = .382$.

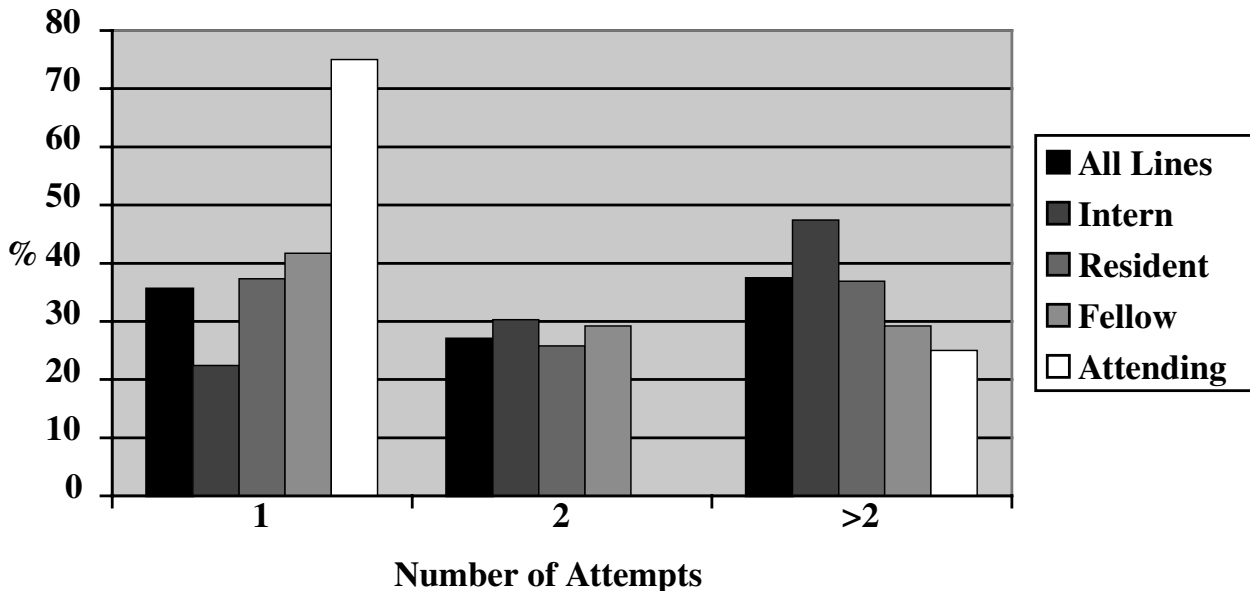


Fig 2. Number of percutaneous punctures by training level of operator. $P = .072$.

Discussion

This study reviews the mechanical complications of a large sample of all CVCs attempted over a 5-month period in 3 special care areas in our teaching hospital. The study reflects broad clinical practice with staff at different levels of training and different subspecialties. Unlike some prior studies [3,4,8,10], we had no exclusion criteria and we reviewed both emergent and nonemergent CVC attempts. We believe that this enhances the real-world applicability of our conclusions.

Our overall rate of mechanical complications was 34%, with the majority categorized as failure to place. When cases of failure to place were excluded, 14% of attempts had a complication. Overall, our rates of arterial puncture (5%), subcutaneous hematoma (1%), hemothorax (0.3%), and pneumothorax (1%) are comparable to prior publications [1,2,4,10,14-17]. Our total rate of complications excluding failure (14%) was also comparable to these studies, adding to the evidence that central venous catheterization is a generally low-risk procedure.

Three factors were found to be significantly associated with mechanical complication rate. The first factor was the attempted insertion site. The subclavian approach had the highest complication rate, followed by the internal jugular approach and then the femoral approach. These results differ from prior studies where the femoral approach had a higher mechanical complication rate [4,14]. Most of the difference is attributable to the high rate of failure of the subclavian approach in this study. Our policy for CVC insertion recommends the subclavian approach, primarily because it is associated with lower infection rates than other sites [4,11]. The femoral approach is often used in our institution as an alternative, probably because fewer procedures are required for an operator to be credentialed to perform the procedure independently.

The number of percutaneous punctures per attempt was also significantly associated with complication rates, similar to findings in other studies [2,3]. One of the largest studies found that attempts requiring more than 2 punctures had a 43% failure rate and a mechanical complication rate of 24% [2]. In our study, attempts requiring more than 2 percutaneous punctures had a 54% rate of failure or other mechanical complication. As other authors have recommended, more than 2 percutaneous punctures by the same operator at the same site should be discouraged [2].

The final factor found to be associated with complication rate was the gender of the patient. Most prior studies found equal complication rates in men and women, though 1 found that women had a higher complication rate than men [2]. In contrast, male patients had a higher complication rate than women in our study. Anatomical differences may account for these findings. Alternatively, despite the significant *P* value, the findings may be attributable to chance variation.

Residents and interns attempted 80% of the CVCs, and 3% of attempts were directly supervised or placed by attendings. The higher rate of complications in lines placed or supervised by attendings may be attributable to selection bias. It also may have been a chance finding caused by the low numbers of attempts.

Thirty percent of CVCs were placed under emergent conditions. The pressure inherent in these situations might have been expected to increase the likelihood of complications, but we found no differences in complication rates. Other studies suggested that complication rates may even be lower in emergencies, perhaps because the most experienced operator immediately available assumes responsibility [12-14]. Future studies should evalu-

ate whether infectious complications are increased in catheters inserted emergently, as operators may be less likely to adhere to sterile technique.

Twenty-six percent of CVCs were placed at night. In all intensive care units at our hospital, a resident and intern are always present on-site. All patient care units have a fellow and attending in close proximity, who are available for backup if needed. One prior study found that CVCs inserted during the night had a twofold rate of mechanical complications [4], but in our study the time of CVC placement had no effect. Perhaps some of the elective catheter insertions in patients perceived as being risky were deferred until daytime, when experienced operators might be present.

One death occurred during the placement of an internal jugular catheter. The patient was a 65-year-old man who was resuscitated from an asystolic arrest 2 days before this event. He was brought from another hospital, where a right subclavian catheter was placed that was complicated by a pneumothorax requiring chest tube placement. On transfer, a new right internal jugular CVC was planned, but immediately after the vein was cannulated and before the guide wire placed, he had an asystolic cardiac arrest and could not be resuscitated. Although the arrest occurred during the procedure, we believe that it is unrelated. A pneumothorax is very unlikely because the catheter would not have pierced the pleura, and there was a functional chest tube in place on that side. Likewise, air embolism is unlikely because the patient was on continuous positive pressure ventilation and was not making spontaneous respiratory effort.

Even though no deaths were directly attributable to CVC insertion in this study, the procedure may have a fatal outcome. The incidence of mortality from CVC placement is unknown because it is described only in anecdotal reports [18,19]. Life-threatening immediate complications of central catheters include ventricular arrhythmias, air embolism, cardiac tamponade [19-21], pneumothorax [19], hemothorax [19,20], and coronary sinus thrombosis [18]. Other serious complications include catheter-related infection with bacteremia, endocarditis, fungemia, loss of guide wire, dislodgement of caval interruption device, pseudoaneurysm, and venous thromboembolism. Although rare, the risks of serious complication or death should be explained when informed consent is obtained for the procedure.

There are several limitations of our study that may explain why some of our results differed from those in previous studies. We found that the complication rate was unrelated to the time of day of

insertion [4], experience of the operator [14], BMI [2], or age of the patient [3]. There are several possible reasons for these differences. Our database did not include previous surgeries, radiotherapy, or catheter attempts at the insertion site [2]. When investigators were not present at the time of catheter placement, complications may have been underreported. The choice of insertion site was not randomized, which probably introduced a bias of selecting perceived high-risk patients for the femoral approach. It is also likely that more experienced operators were asked to insert CVCs on patients judged to be at higher risk for complications. Postgraduate year of training is not a perfect correlate for experience, as some people at lower levels of training may have inserted more catheters than more senior staff. Finally, the study took place in 3 medical units. The results of this study may not be applicable to surgical intensive care units or other hospitals where surgeons place the majority of central catheters.

Conclusions

We found that mechanical complication rates of CVC insertion at our hospital are similar to those reported previously. Failure to place the catheter was common, but other complication rates were low. When supervised properly, residents and interns can place central venous catheters safely, yet 22% of attempts will fail. Subclavian catheters had a significantly higher rate of mechanical complications than internal jugular or femoral catheters. When one is choosing a site of insertion, this should be weighed against the low rate of infection associated with the subclavian approach. Operators should be limited to 2 percutaneous punctures, because failure and other complication rates are high with more needle passes. More studies are needed to determine methods to decrease complication rates further.

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