Use of Ultrasound Guidance Improves Central Venous Catheter Insertion Success Rates Among Junior Residents

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Objectives—The purpose of this study was to determine whether junior residents had higher rates of first cannulation and overall success at central venous catheter insertions with the use of ultrasound (US) guidance compared to the landmark technique.

Methods—We conducted a secondary analysis of data from a prospective randomized controlled study of junior residents from January 2007 through September 2008, which assessed the impact of simulation training on central venous catheter insertion success rates. Blinded independent raters observed in-hospital central venous catheter insertions using a procedural checklist. Success at first cannulation and successful insertion were the primary outcomes. Secondary outcomes included rates of technical errors and mechanical complications.

Results—Independent raters observed 480 central venous catheter insertions by 115 residents. Successful first cannulation occurred in 27% of landmark compared to 49% of dynamic US-guided ($P < .01$), and 50% of static US-guided ($P = .01$) cannulations. Insertion success occurred for 55% of landmark compared to 80% of dynamic US-guided ($P < .01$) and 80% of static US-guided ($P < .01$) cannulations. Dynamic US guidance was associated with increased odds of first cannulation success compared to the landmark technique (odds ratio [OR], 2.24; 95% confidence interval [CI], 1.37–3.67) and successful insertion (OR, 3.80; 95% CI, 2.34–6.19). Static US guidance was associated with increased odds of first cannulation success compared to the landmark technique (OR, 2.59; 95% CI, 1.25–5.39) and successful insertion (OR, 3.48; 95% CI, 1.54–7.87). The results were independent of central venous catheter insertion training, patient comorbidities, and resident specialties. There was no difference related to mechanical complications between the procedures.

Conclusions—Dynamic and static US guidance during central venous catheter insertion was associated with improved in-hospital first cannulation rates and overall success rates of insertions by junior residents.

Key Words—education; procedural guidance; safety; training; ultrasound; vascular access

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Abbreviations

CI, confidence interval; ED, emergency department; ICU, intensive care unit; OR, odds ratio; US, ultrasound

More than 5 million central venous catheters are inserted yearly in the United States, with mechanical complication rates reported to occur in between 5% and 19% of insertions.[1] Central venous catheter insertions may be unsuccessful in as many as 20% of cases.[2] In response to the Institute of Medicine report *To Err Is Human: Building a Safer Health System*,[3] the Agency for Healthcare Research and Quality listed the use of real-time ultrasound (US) guidance for central venous catheter insertion as 1 of 11 practices with greatest strength of evidence to provide "clear opportunities for safety improvement."[4]

Although the Agency for Healthcare Research and Quality report specifically states that the "greatest benefit of US guidance may apply to the novice or inexperienced operator," there are few studies that looked specifically at the impact of US guidance on central venous catheter insertion in residents in training and none that examined the impact of US guidance on central venous catheter insertion by residents of different specialties and in different care environments.

We hypothesized that junior residents of different specialties who used real-time dynamic US guidance would have improved successful first venous cannulation and overall insertion success rates with fewer technical errors and mechanical complications than those using the landmark technique.

Materials and Methods

Study Design, Setting, and Selection of Participants

We conducted a secondary analysis of a prospective randomized controlled single-blind study in which we enrolled postgraduate year 1 and 2 residents over 21 months from January 2007 through September 2008. The original study randomized residents according to whether they received simulation training in US-guided central venous catheter insertion. Eligible residents included those who rotated through the emergency department (ED), medical intensive care unit (ICU), and surgical ICU at a 944-bed tertiary care teaching hospital. Resident specialties included emergency medicine, internal medicine, anesthesia, general surgery, and obstetrics and gynecology. Approval was granted by the combined hospital/university Institutional Review Board (Yale University Human Investigation Committee approval number 0605001388), and participating residents provided informed written consent. At the time of consent, residents completed a survey detailing central venous catheter insertion experience, prior central venous catheter and US training, and confidence in central venous catheter insertion with and without US.

In the original prospective study, residents were randomized to receive simulation training using US guidance, as reported previously.[5] After randomization, residents performed central venous catheter insertions under the current clinical guidelines of the ED, medical ICU, or surgical ICU. At the time of this study, attending physicians, fellows, and senior residents supervised junior residents during the insertions. The choice of insertion site and technique was made with the approval of the supervising physician.

In the medical and surgical ICUs, participants used a Site Rite US system (Bard Access Systems, Salt Lake City, UT). In the ED, they used a Hawk 2 102 XDI system (B-K Medical, Herley, Denmark) or an Envisor system (Philips Healthcare, Andover, MA). All participants used multilumen central venous catheter kits with Arrow-Howes Blue FlexTip CA-15703 catheters (Arrow International, Reading, PA).

This secondary analysis reports on the success rates of first cannulation and overall success of central venous catheter insertion based on the use of US-guided and landmark techniques. Therefore, the patient assignment and insertion technique chosen were not randomized for this analysis.

Data Collection and Outcome Measures

From 8 AM to midnight daily, blinded independent raters observed central venous catheters inserted by residents in the ED, medical ICU, and surgical ICU. The raters were blinded to the level of training of the operator and to the study hypotheses. The raters were rigorously selected and trained before the onset of the study. They completed 4 hours of training: a 2-hour didactic session and a 2-hour testing session, including observation of 5 of 10 choreographed central venous catheter insertion videotapes and completion of the same 50-point procedural checklist that was used in the study. The raters were hired on the basis of their ability to accurately assess the duration of the procedure to within 1 minute, validating the checklist to within 95% accuracy, and detecting technical errors/complications to within a 3% margin of error.[6] The raters collected data on the resident performing the insertion, indications for the insertion, patient characteristics, and the procedure itself. When a decision to insert a central venous catheter occurred, residents contacted the raters via an electronic pager. Enrollment reminders were taped to the front of all catheter kits in the ED and ICUs. The raters completed a 50-point procedural checklist[6] for all observed insertions, with data points for performance including the site chosen for catheter insertion, the type of catheter used (triple lumen, antibiotic-coated triple lumen, or cordis), the use of US guidance, the number of venous cannulation attempts, and insertion success. They recorded technical errors including breaks in sterile technique, improper positioning of the patient, removal of the hand from the guide wire during any portion of the procedure, inability to thread the wire, inability to flush all ports, improper suturing of the catheter, and improper sterile dressing. The raters also documented immediate mechanical complications (arterial puncture and transient arrhythmia).

We calculated the patients' Acute Physiology and Chronic Health Evaluation II scores[7] and retrospectively reviewed chest radiographic results for complications such as transient catheter malposition, pneumothorax, and hemothorax.

For the procedure, the independent raters recorded the site of cannulation (internal jugular, subclavian, or femoral vein) as well as the cannulation technique. The cannulation techniques were defined as follows:

1. Landmark only—identification of the target vein determined by anatomy only without the use of US;
2. Static US—identification and marking of the target vein by nonsterile US guidance followed by sterile insertion without the use of US guidance during cannulation;
3. Dynamic US—cannulation of the target vein with direct visualization of the needle entering the vein by a sterile US probe (either in the short or long axis or both); and
4. Landmark failure before US guidance—a failed initial attempt by the landmark technique followed by dynamic US guidance.

Primary outcome measures were first venous cannulation success and the overall catheter insertion success rate for the resident. Successful cannulation was defined as the return of venous blood into the cannulation needle, whereas the cannulation attempt referred to each needle pass. We defined overall success as catheter insertion with venous blood return in all 3 catheter ports. Secondary outcome measures were the rate of technical errors and complications as determined by the independent rater's procedural checklist evaluation and retrospective chart review.

If the resident could not successfully insert the catheter, the supervising physician assumed responsibility. The supervising physician determined the limit on the number of attempts by the operator in real time. The independent rater collected data on the number of cannulation attempts and whether the insertion was successful or aborted. If a second resident participating in the study attempted the procedure after a failed attempt, the rater recorded the attempt as an independent procedure.

Primary Data Analysis

These data were collected as part of a randomized trial with the resident as the unit of randomization.[5] The prior intervention (ie, simulation training in central venous catheter insertion) was applied at the resident level, and outcomes were measured at the patient level; thus, patients were nested within residents. We enumerated descriptive statistics for the following characteristics of the residents: age, sex, specialty, postgraduate year, prior central venous catheter experience/training, and self-reported confidence in central venous catheter insertion. We also enumerated and compared the following characteristics of the patients on whom procedures were performed according to the cannulation technique: age, sex, hospital unit, central venous catheter indications, and risk factors for complications. We reported categorical data as frequencies and compared differences between groups using the χ^2 or Fisher exact test. We reported continuous data as the mean and standard deviation or the median and interquartile range and tested for bivariate differences between groups using analysis of variance. We adopted a type I error rate (α) of .05.

As the primary outcome measures of the analysis, we used patient-level dichotomous variables to indicate success or failure at first cannulation and success or failure of the catheter insertion. To assess the effect of the cannulation technique on outcomes, we used a 2-level hierarchical logistic regression model with the patients (level 1) nested within the residents (level 2). We considered patient characteristics as level 1 covariates and resident characteristics as level 2 covariates. We analyzed secondary outcomes by multilevel logistic regression to assess the effect of the cannulation technique on the occurrence of technical errors and mechanical complications. We conducted all analyses using SAS version 9.2 software (SAS Institute Inc, Cary, NC).

Results

Between January 7, 2007, and September 30, 2008, we recruited 199 postgraduate year 1 and 2 residents to participate in the original study, and 184 residents chose to participate. Prior central venous catheter training, US experience, and confidence levels reported by the participating residents are shown in Table 1.

Independent raters observed 480 central venous catheter insertions performed by 115 residents (mean, 4.3 ± 4.0; median, 2.5 procedures per resident) participating in the study. There were 50 central venous catheters inserted with static US guidance, 245 with dynamic US guidance, and 149 with the landmark technique. Of the 184 residents participating in the study, 70 did not perform any central venous catheter insertions during the study period. Characteristics of the patients for whom central venous catheters were inserted are described in Table 2. The ED and medical ICU were more likely to use dynamic US, and the landmark technique was used more frequently in the surgical ICU ($P < .01$). Patients undergoing mechanical ventilation or receiving parental nutrition were more likely to have catheters inserted by the landmark technique ($P < .01$).

Primary Outcomes

The success rates for first cannulation were 48.8% (95% confidence interval [CI], 43.1%–54.5%) for dynamic US, 50.0% (95% CI, 36.1%–63.9%) for static US, and 26.9% (95% CI, 19.7%–34.0%) for the landmark technique (Table 3). Dynamic US guidance was independently and significantly associated with success at first cannulation compared to the landmark technique with an odds ratio (OR) of 2.24 (95% CI, 1.37–3.67). Similar results were observed for the use of static US guidance compared to the landmark technique (OR, 2.59; 95% CI, 1.25–5.39). The overall success rates for central venous catheter insertion were 90.5% (95% CI, 87.2%–93.9%) for dynamic US, 86.0% (95% CI, 76.4%–95.6%) for static US, and 81.2% (95% CI, 74.9%–87.5%) for the landmark technique. Overall, the use of dynamic US guidance was associated with successful catheter insertion compared to the landmark technique (OR, 3.80; 95% CI, 2.34–6.19). Static US guidance was also associated with successful catheter insertion when compared to the landmark technique (OR, 3.48; 95% CI, 1.54–7.87). Moreover, the use of dynamic US guidance was associated with reduced odds of aborted procedures compared to the landmark technique (OR, 0.41; 95% CI, 0.22–0.75). These results were independent of the following 3 variables: (1) study assignment for the randomized controlled trial; (2) patient comorbidities; and (3) resident specialty.

Table 1. Baseline Characteristics of The Residents (n = 184)

Characteristic	Value
Specialty, n (%)	
Emergency medicine	34 (18.5)
Internal medicine	105 (57.1)
General surgery	19 (10.3)
Obstetrics and gynecology	8 (4.3)
Anesthesia	18 (9.8)
Postgraduate year at enrollment, n (%)	
1	86 (46.7)
2	98 (53.3)
Prior CVC insertion experience	
Total prior insertions, median (IQR)[a]	5 (2–10)
No prior insertions, n (%)	29 (16.9)
>50 insertions, n (%)	0 (0)
Prior US-guided insertions, median (IQR)	2 (0–6)
Prior training, n (%)	
CVC training	161 (87.5)
US training	155 (84.2)
Competency-based US guided CVC training	89 (48.4)
Confidence level in CVC insertion, median (IQR)[b]	
Skills without US, median	4 (2–6)
Skills with US, median	7 (4–8)

CVC indicates central venous catheter; IQR, interquartile range; and US, ultrasound.

[a]Middle 50% range of values (ie, difference between first and third quartiles or 25th–75th percentiles).

[b]Likert scale (1–10).

There was a difference in success at first cannulation between the ICUs, where the Site Rite system was used, and the ED, where the Philips system was used. In the ED, there was a 47.8% first cannulation success rate, whereas in the ICUs, this rate was 36.4% ($P = .01$). Likewise, for overall insertion success, catheters inserted in the ED had a success rate of 76.9%, and the ICU success rate was 67.4% ($P = .02$).

Secondary Outcomes

There was a greater degree of nonadherence to standard precautions with the use of both static US (46%) and dynamic US (41.7%) guidance than with the landmark technique (17.5%). These findings were statistically significant for both dynamic US (OR, 3.57; 95% CI, 1.98–6.45) and static US (OR, 4.72; 95% CI, 2.09–10.69) compared to the landmark technique (Table 3). Dynamic US guidance had increased odds of insertion step errors compared to the landmark technique ($P = .004$). There was no statistical difference in the number of mechanical complications or breaks in sterile technique between the 3 groups.

The average number of insertion attempts was 2.6; however, this number was positively skewed by several large values. The range between the largest number of attempts (n = 27) and smallest (n = 1) was 26 attempts. The median number of attempts was 2 (interquartile range, 2). The point-biserial correlation for success per insertion attempt was –0.527 ($P < .01$), indicating that procedures that involved more attempts were less likely to be successful than procedures with fewer attempts. Of the 494 procedures documented, the time to completion was available for 409. The average time to completion was 22 minutes, with the distribution of completion times positively skewed toward several large values. The range between the largest time to completion (122 minutes) to the shortest time (4 minutes) was 118 minutes.

Of 494 procedures, data on use of a short-axis view were available for 472. A short-axis view was used for 320 procedures (67.8%). Data on use of a long-axis were available for 470 procedures. A long-axis view was used for 60 procedures (12.8%). Joint use occurred in 60 procedures.

Discussion

This study included nearly 500 central venous catheter insertions and to our knowledge was the largest prospective observational study of central venous catheter insertions by junior residents of varied specialties evaluating the rates of

first attempts and overall success in US- versus landmark technique-guided central venous catheter insertion. We showed that improved success rates for first cannulation and overall central venous catheter insertion success were independently associated with the use of US. The marked improvement in first-attempt and overall success shown by this study indicates that US guidance should be a routine part of central venous catheter insertions.

Limitations

Although our independent raters were available during defined periods for consecutive enrollment, they were not available between midnight and 8 AM, and it is possible that the characteristics of the operators and patients would be different during these hours. Although we attempted to capture all catheters inserted during enrollment periods, there were instances in which the raters were not paged or paged late for some catheter insertions; therefore, we may have missed data on central catheter insertions that were more time critical and that may have had different characteristics from those of the insertions we did observe. Another limitation was the accurate determination of total insertions during the study period. As part of our study design, we attached numbered packets with the data collection forms on all central venous catheter kits in the ED and ICUs. On the basis of billing data and ICU blood culture surveillance data, we surmise that approximately 1500 central venous catheters were inserted over the 21-month period.

Table 2. Baseline Characteristics of the Patients in Whom Central Venous Catheters Were Inserted (n = 494)

	Patients, n (%)				
Characteristic	**Total (n = 494)**	**Landmark[a] (n = 149)**	**Static US[b] (n = 50)**	**Dynamic US[c] (n = 295)**	***P***
Age, y, mean (SD)	62.0 (18.0)	63.5 (18.5)	61.6 (17.8)	61.3 (17.8)	.76[d]
Male	230 (46.9)	77 (52.0)	24 (48.0)	129 (44.2)	.29[e]
Location					
Emergency department	255 (51.6)	33 (6.7))	32 (6.5)	190 (38.5)	
Medical intensive care unit	139 (28.1)	23 (4.7)	17 (3.4)	99 (20.0)	<.0001[e]
Surgical intensive care unit	100 (20.2)	93 (18.8)	1 (0.2)	6 (1.2)	
Indications					
Hypovolemia	176 (35.9)	49 (33.1)	18 (36.0)	109 (37.2)	.70[e]
Parenteral nutrition	21 (4.3)	12 (8.1)	0 (0)	9 (3.1)	.014[e]
Access for vasoactive medications	207 (42.2)	56 (37.8)	26 (52.0)	125 (42.7)	.21[e]
Hemodynamic monitoring	317 (64.6)	92 (62.2)	34 (68.0)	191 (65.2)	.71[e]
Cardiopulmonary arrest	12 (2.4)	3 (2.0)	3 (6.0)	6 (2.1)	.27[f]
Difficult peripheral access	148 (30.1)	42 (28.4)	17 (34.0)	89 (30.4)	.75[e]
Long-term IV access	128 (26.1)	49 (33.1)	12 (24.0)	67 (22.9)	.065[e]
Risk factors					
Anatomic					
Short, broad neck	118 (24.0)	36 (24.3)	15 (30.0)	67 (22.9)	.55[e]
Clinically severe obesity	81 (16.5)	28 (18.9)	6 (12.0)	47 (16.0)	.49[e]
Severe malnutrition	37 (7.5)	11 (7.4)	7 (14.0)	19 (6.5)	.18[e]
Local scarring	44 (9.0)	13 (8.8)	6 (12.0)	25 (8.5)	.73[e]
History of CVC insertion	128 (26.1)	50 (33.8)	12 (24.0)	66 (22.5)	.037[e]
Patient setting					
Mechanical ventilation	188 (38.3)	97 (65.5)	11 (22.0)	80 (27.3)	<.0001[e]
Emergency: impending cardiac arrest	23 (4.7)	7 (4.7)	5 (10.0)	11 (3.8)	.15[e]
Comorbidities					
Bullous emphysema	6 (1.2)	0 (0)	2 (4.0)	4 (1.4)	.058[f]
Coagulopathy	90 (18.3)	27 (18.2)	10 (20.0)	53 (18.1)	.95[e]
APACHE II score, mean (SD)	19.6 (9.2)	20.7 (8.3)	19.0 (8.3)	18.9 (8.5)	.12[d]

Not all totals equal 494 because of missing data for some patients. APACHE indicates Acute Physiology and Chronic Health Evaluation; CVC, central venous catheter; IQR, interquartile range; IV intravenous; and US, ultrasound.

[a]Initial attempt by landmark that failed, then an attempt with real-time US guidance.

[b]Localization of the vein with US guidance and then cannulation without US guidance.

[c]Cannulation of the vein with direct visualization by US imaging of the needle entering the vein.

[d]Analysis of variance.

[e]χ^2 test.

[f]Fisher exact test.

Our study population may not accurately reflect the general junior resident population at other academic institutions. Half of the residents in this study received competency-based training in US-guided central venous catheter insertion on a partial-task trainer as part of the original prospective randomized study.[5] This prior study did show that simulation both increased the overall success rate and was associated with increased US use, as would be expected. However, the ORs were calculated using logistic regression analysis to control for simulation training and determined that US guidance success was an independent predictor of first-pass and overall success.

Among specialties, we did find that emergency medicine residents were more likely to choose US for insertion of central venous catheters, likely because emergency medicine residents receive more training in US overall, including procedural US, as a standard part of their residency education, and emergency medicine faculty may be more comfortable and proficient with US than other specialties. However, our regression analysis showed that US was independently associated with improved success regardless of specialty. In addition, residents were more successful at catheter insertion with the Philips US machine than the Site Rite machine, indicating that a higher-quality US system may influence success rates in the clinical setting.

A study that offered independent rater coverage 24 hours a day would likely yield stronger results. In addition, more vigorous independent rater determination of the use of short- versus long-axis US views may help clarify the most successful method for central venous catheter insertion in the clinical setting. It would also be useful to evaluate the degree of skill decay over the course of the study and to determine whether it affects first-attempt cannulation success or the complication rate.

Interpretation of Results

Our study did not show a significant difference in complication rates, although our overall complication rate was much lower than reported elsewhere in the literature (ie, 5%–26%),[8,9] which may have limited our ability to discern a difference. The literature clearly shows that increased and failed cannulation attempts are associated with increased complications.[1,10–12] In one study, 28% of patients had complications after a failed catheter insertion

Table 3. Results of Independent-Rater–Observed Hospital Central Venous Catheter Insertions (n = 494) Performed by Residents Using Landmark Cannulation, Static Ultrasound-Guided Cannulation, or Dynamic Ultrasound-Guided Cannulation

Measure	Landmark,[a] n (%) of Procedures (n = 149)[d]	Static US,[b] n (%) of Procedures (n = 50)[d]	Dynamic US,[c] n (%) of Procedures (n = 295)[d]	Landmark vs Dynamic US, OR (95% CI)	*P*	Static vs Dynamic US, OR (95% CI)	*P*
Success at first cannulation	40 (26.9)	25 (50.0)	144 (48.8)	0.45 (0.27–0.73)	.0013	1.16 (0.60–2.21)	.66
CVC insertions							
Success per insertion attempt	82 (55.0)	40 (80.0)	236 (80.0)	0.26 (0.16–0.43)	<.0001	0.92 (0.42–2.01)	.83
Overall success	121 (81.2)	43 (86.0)	267 (90.5)	0.41 (0.22–0.75)	.0043	0.57 (0.23–1.41)	.22
Aborted	28 (18.8)	7 (14.0)	28 (9.5)	2.44 (1.33–4.49)	.0043	1.77 (0.71–4.41)	.22
Technical errors							
US preparation	NA	8 (16.0)	37 (12.5)	NA	NA	1.48 (0.62–3.51)	.37
Standard precautions	26 (17.5)	23 (46.0)	123 (41.7)	0.28 (0.16–0.51)	<.0001	1.32 (0.67–2.63)	.43
Insertion steps	93 (62.4)	32 (64.0)	221 (74.9)	0.52 (0.33–0.81)	.004	0.55 (0.29–1.05)	.07
Break in sterile technique	22 (15.0)	6 (12.2)	54 (18.5)	0.79 (0.45–1.40)	.42	0.52 (0.20–1.40)	.20
Mechanical complications							
Pneumothorax	2 (1.4)	0	0	NA	NA	NA	NA
Transient arrhythmia[e]	14 (10.0)	6 (12.8)	20 (7.4)	1.53 (0.69–3.37)	.29	1.67 (0.57–4.90)	.35
Transient catheter tip malposition[f]	3 (2.1)	3 (6.4)	16 (5.6)	0.38 (0.11–1.36)	.14	1.21 (0.33–4.41)	.77
Arterial puncture	7 (4.8)	4 (8.5)	9 (3.1)	2.06 (0.68–6.19)	.20	2.65 (0.74–9.50)	.14
Total	26 (17.4)	13 (26.0)	45 (15.3)	1.31 (0.75–2.30)	.35	1.73 (0.81–3.70)	.16

CI indicates confidence interval; NA, not applicable; OR, odds ratio; and US, ultrasound.

[a]Cannulation based on anatomic landmarks only, no use of US.

[b]Visualization of the vein with US guidance and then cannulation without US guidance.

[c]Cannulation of the vein with direct visualization by US imaging of the needle entering the vein.

[d]In some cases the denominator is lower because not all measures applied to all patient procedures observed.

[e]Nonsustained ventricular tachycardia due to the guide wire being advanced into the right ventricle; some data are missing for this measure, which affects the total.

[f]Catheter tip beyond the superior vena cava–right atrial junction on chest radiography, requiring catheter repositioning.

compared to only 7.2% after a successful catheterization.[11] The same study showed a 4.3% complication rate with 1 pass versus 24.0% with more than 2 passes. Two meta-analyses have shown a significantly lower failure rate for US-guided central venous catheter insertion in an ICU setting, and others have shown that the use of dynamic US guidance improves the operator's success on the first attempt[13–19] and decreases the number of complications.[11,14,16,18,19]

There was no difference in the number of catheter-related infections between the 3 catheter insertion methods based on a review of blood surveillance cultures. Over the 21 months of our study, there were 21 line infections, for an incidence rate of 1.4%. Five central venous catheters were inserted by residents participating in our study. We are therefore unable to make any conclusions with regard to the impact of US on central venous catheter infections. The category of minor complications that we documented included hematomas and breaks in sterility. There was no statistical difference between the US and non-US groups when comparing minor complications.

Most prior studies looking at US guidance for central venous catheter insertion included attending physicians rather than junior resident physicians[20]; however, the Agency for Healthcare Research and Quality report noted that inexperienced operators may derive more benefit from US guidance.[2] One small study of 16 emergency medicine physicians showed improvement in central venous catheter insertion skills on a model after hands-on training; however, in-hospital catheter insertion performance was not assessed.[21] Another study showed that operator experience in US, rather than experience in central venous catheter insertion, is the bigger factor in determining success rates.[22] Our study, including only junior residents as primary operators, reinforces the finding that less experienced operators showed improved performance with US guidance. It showed that both the overall use of US and specific training in US had merit: junior residents who received further training in US guidance methods did better than those who did not, and those who had more experience with US overall did better than those who did not.

In our study, US-guided central venous catheter insertion had a higher rate of success for the first attempt and a decreased number of cannulation attempts independent of the amount of US training, patient comorbidities, or resident specialties. In addition, there was no statistical difference in the time to insert a catheter with and without the use of US. The choice of whether to use US was also independent of the patient's severity of illness as measured by the Acute Physiology and Chronic Health Evaluation II score.

In conclusion, this study shows that junior resident use of dynamic and static US guidance for central venous catheter insertion increases overall success and success on first attempts compared to catheter insertion using the landmark technique. Training in procedural US and the use of US guidance for central venous catheter insertion should be considered the standard of care.

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