

# Ultrasound-Guided Peripheral Intravenous Access Program Is Associated With a Marked Reduction in Central Venous Catheter Use in Noncritically Ill Emergency Department Patients

Hamid Shokoohi, MD, MPH, RDMS, RDCS, Keith Boniface, MD, RDMS, RDCS, Melissa McCarthy, ScD, Tareq Khedir Al-tiae, MD, Mehdi Sattarian, MD, MBA, Ru Ding, MS, Yiju Teresa Liu, MD, RDMS, Ali Pourmand, MD, MPH, RDMS, Elizabeth Schoenfeld, MD, RDMS, James Scott, MD, Robert Shesser, MD, Kabir Yadav, MDCM, MS

From the Department of Emergency Medicine (Shokoohi, Boniface, Khedir Al-tiae, Sattarian, Liu, Pourmand, Scott, Shesser, Yadav) and Department of Health Policy and Emergency Medicine (McCarthy, Ding), George Washington University, Washington, DC; and the Department of Emergency Medicine, Baystate Medical Center/Tufts University School of Medicine, Springfield, MA (Schoenfeld).

**Study objective:** We examine the central venous catheter placement rate during the implementation of an ultrasound-guided peripheral intravenous access program.

**Methods:** We conducted a time-series analysis of the monthly central venous catheter rate among adult emergency department (ED) patients in an academic urban ED between 2006 and 2011. During this period, emergency medicine residents and ED technicians were trained in ultrasound-guided peripheral intravenous access. We calculated the monthly central venous catheter placement rate overall and compared the central venous catheter reduction rate associated with the ultrasound-guided peripheral intravenous access program between noncritically ill patients and patients admitted to critical care. Patients receiving central venous catheters were classified as noncritically ill if admitted to telemetry or medical/surgical floor or discharged home from the ED.

**Results:** During the study period, the ED treated a total of 401,532 patients, of whom 1,583 (0.39%) received a central venous catheter. The central venous catheter rate decreased by 80% between 2006 (0.81%) and 2011 (0.16%). The decrease in the rate was significantly greater among noncritically ill patients (mean for telemetry patients 4.4% per month [95% confidence interval {CI} 3.6% to 5.1%], floor patients 4.8% [95% CI 4.2% to 5.3%], and discharged patients 7.6% [95% CI 6.2% to 9.1%]) than critically ill patients (0.9%; 95% CI 0.6% to 1.2%). The proportion of central venous catheters that were placed in critically ill patients increased from 34% in 2006 to 81% in 2011 because fewer central venous catheterizations were performed in noncritically ill patients.

**Conclusion:** The ultrasound-guided peripheral intravenous access program was associated with reductions in central venous catheter placement, particularly in noncritically ill patients. Further research is needed to determine the extent to which such access can replace central venous catheter placement in ED patients with difficult vascular access. [Ann Emerg Med. 2012;xx:xxx.]

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## INTRODUCTION

### Background

Central venous catheter placement is a common procedure performed in the emergency department (ED) and the ICU. The leading indications for such placement include the need for rapid fluid resuscitation, centrally administered medications, and hemodynamic monitoring among patients with high severity of illness.<sup>1-3</sup> Central venous catheter placement is an invasive procedure and is associated with serious complications such as catheter-associated bloodstream infections, thrombosis,

great vessel damage, hematoma formation, arrhythmias, air embolism, and pneumothorax.<sup>2-4</sup> The complication rates associated with central venous catheter placement range from 5% to 19%.<sup>3,5,6</sup> Central venous catheters placed in the ED have been associated with a higher rate of catheter-associated bloodstream infections compared with those inserted on other units (24 versus 1.7 per 1,000 catheter-days).<sup>7</sup>

Despite the potential for major complications, central venous catheter placement is commonly used as an alternative to peripheral intravenous cannulation in patients with difficult

**Editor's Capsule Summary***What is already known on this topic*

Ultrasound-guided peripheral intravenous access is an increasingly available alternative to traditional peripheral intravenous placement and to central venous access, which is associated with serious potential complications. Ultrasound-guided peripheral intravenous access can be performed successfully by emergency physicians, nurses, and technicians.

*What question this study addressed*

Was initiation of an ultrasound-guided peripheral intravenous access program associated with reduction in central venous catheter use in an emergency department (ED) setting?

*What this study adds to our knowledge*

In this retrospective 6-year time-series analysis, central venous catheter use decreased among all ED patients, but particularly among noncritically ill individuals.

*How this is relevant to clinical practice*

This single-site study provides some evidence that an ultrasound-guided peripheral intravenous access program may reduce the need for central venous access in ED patients who would otherwise require it.

peripheral vascular access. Ultrasound-guided peripheral intravenous access may reduce the need for central venous catheter placement among patients with difficult vascular access.<sup>8-11</sup> A number of studies have reported successful ultrasound-guided peripheral intravenous access after multiple failed attempts without ultrasonography.<sup>9-13</sup> One study randomized patients to ultrasound-guided peripheral intravenous access versus the traditional approach and found that the successful placement of a peripheral intravenous line was significantly higher when guided by ultrasonography (97%) compared with the traditional approach (33%).<sup>14</sup>

**Importance**

Ultrasound-guided peripheral intravenous access has been described as a feasible and safe method of obtaining vascular access.<sup>12-14</sup> In most US EDs, technicians and nurses are primarily responsible for obtaining peripheral intravenous access. Several studies have found that ultrasound-guided peripheral intravenous access can be effectively performed by physicians, nurses, and technicians in the ED setting.<sup>8-12,14-16</sup> The successful placement of peripheral intravenous lines may reduce the number of unnecessary central venous catheter placements, particularly in noncritically ill patients. We

designed and implemented an ultrasound-guided peripheral intravenous access program with the objective of training emergency medicine residents and technicians to perform ultrasound-guided peripheral intravenous access in patients with difficult intravenous access.

**Goals of This Investigation**

The objective of this study was to determine the central venous catheter placement rate during the implementation of an ultrasound-guided peripheral intravenous access program in our ED. We hypothesized that there would be a significant reduction in the central venous catheter rate among noncritically ill patients with the successful implementation of such a program.

**MATERIALS AND METHODS****Study Design**

This was a retrospective cohort study using a time-series analysis of the monthly central venous catheter rate among patients who received a central venous catheter between 2006 and 2011 during the implementation of an ultrasound-guided peripheral intravenous access program in an academic urban ED. Our institutional review board approved the study.

**Setting and Selection of Participants**

The study took place in an academic, urban ED affiliated with a 371-inpatient-bed teaching hospital with an emergency medicine residency program. In 2011, the annual census of the study ED was 74,436. The ED primarily serves adult patients. All patients who visited the study ED during January 1, 2006, and December 31, 2011, were included in the study.

Organized training for all emergency medicine residents in ultrasound-guided peripheral intravenous access began in July 2005. All emergency medicine residents received a 2-day training session for ultrasonography during the first week of their residency that included didactics and hands-on practice on ultrasound-guided peripheral and central venous catheter placement. Skills were reinforced on a required 2-week emergency medicine ultrasonographic rotation later in the first year of emergency medicine residency. Mastery of this technique was a required skill for all emergency medicine residents.

The ED technician-performed ultrasound-guided peripheral intravenous access program was started in January 2008. ED technicians were offered a 2-hour training session multiple times from January through June 2008 in groups of 3 to 5 ED technicians per instructor, covering principles of ultrasonography, the use of ultrasonography to identify and cannulate veins, and the upper extremity venous anatomy. The sessions included having the technicians trace veins with ultrasonography on live models' arms and practice intravenous insertion on gel phantoms (Blue Phantom, Kirkland, WA). By July 2008, all 19 technicians then working in the ED were trained to perform ultrasound-guided peripheral intravenous

access. This training became part of the required orientation for incoming ED technicians. The program has been continued for both incoming residents and ED technicians so that there are providers in the ED at all times who can perform ultrasound-guided peripheral intravenous access in patients with difficult vascular access.

Before the implementation of the ultrasound-guided peripheral intravenous access program, a common approach was for an ED technician or the primary nurse to try placing a peripheral intravenous 2 or 3 times and then yield to more experienced staff for further attempts. Beyond that, the nursing staff might ask the emergency medicine resident or attending physician if the patient was a candidate for central venous catheter placement. Currently, in patients with known difficult peripheral intravenous access or those who have had 2 to 3 failed attempts by experienced ED staff, nurses use ultrasound-guided peripheral intravenous access themselves or enlist an emergency medicine resident or attending physician to perform the procedure. After unsuccessful ultrasound-guided peripheral intravenous access attempts by a resident or attending physician, the patient becomes a candidate for central venous catheter placement.

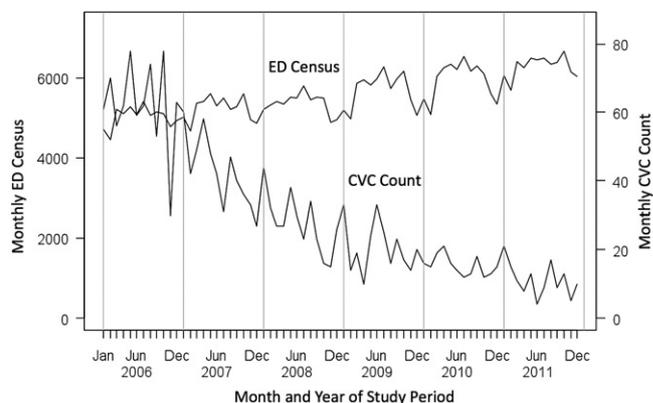
### Methods of Measurement

We identified all patients who had central venous catheter placement during the course of their ED stay between 2006 and 2011 by querying our electronic health record, ED Pulsecheck (Picis, Wakefield, MA). The record has a dedicated field for providers to document central venous catheter placement, which is relied on for billing purposes. For all patients treated in the ED (regardless of whether a central venous catheter was placed), we also extracted from the record each patient's age, sex, Emergency Severity Index (ESI)<sup>17</sup> triage acuity score, and disposition. The data were exported from the reporting function of the electronic health record to a Microsoft Excel 2007 spreadsheet (Microsoft, Redmond, WA).

We used the ED disposition data to classify patients into 4 disposition categories: (1) admitted to an ICU or directly to the operating room; (2) admitted to a telemetry bed; (3) admitted to a medical/surgical floor bed; or (4) discharged home. Patients receiving central venous catheters were classified as noncritically ill if their disposition was admission to telemetry, medical/surgical floor, or discharged home directly from the ED; patients were considered critically ill if their disposition was admission to an ICU or directly to the operating room.

### Primary Data Analysis

The primary outcome for this study was the central venous catheter placement rate. The total number of patients who had a central venous catheter placed each month of the study period served as the numerator. The total number of patients treated in the study ED during each month of the study served as the denominator. We modeled the central venous catheter placement rate as a function of time (ie, each month of the study period) with a log linear regression model. The time



**Figure 1.** Total ED volume and total number of central venous catheters placed, by month throughout the study period. CVC, Central venous catheter.

coefficient from the regression model is an estimate of the average monthly change in the central venous catheter rate during the study period.

To estimate the monthly change in central venous catheter placement for noncritically ill and critically ill patients, we separately modeled the central venous catheter rate for the following patient subgroups: those admitted to telemetry, those admitted to an inpatient floor, those discharged home from the ED, or those admitted to critical care or the operating room.

Finally, we assessed the monthly central venous catheter placement rates for autocorrelation (the extent to which central venous catheter placements are correlated with each other within a 1-month period) by examining each model's residuals and calculating the Durbin-Watson statistic.<sup>18</sup> All analyses were conducted with SAS software (version 9.2; SAS, Inc., Chicago, IL). Graphs were constructed in R version 2.14.1 (R development Core Team 2011, available at <http://www.R-project.org>) or Microsoft PowerPoint 2007 (Microsoft).

## RESULTS

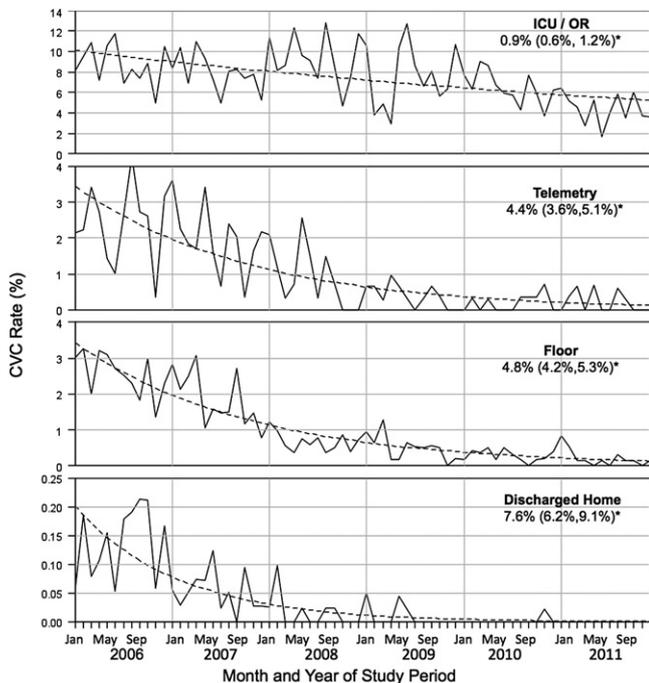
During the 6-year study period, a total of 401,532 patients were treated in the study ED, of whom 1,583 received a central venous catheter (0.39%). Figure 1 displays the total monthly ED census and the total monthly number of central venous catheters placed during the study period. The annual ED census increased by 24% during the 6-year period, whereas the overall central venous catheter placement rate decreased by 80%, from 0.81% in 2006 to 0.16% in 2011. The age, sex, and ED disposition of the study population remained stable throughout the study period (Table).

Figure 2 displays the average change in the central venous catheter rate during the study period by ED disposition. For all subgroups, a time-series analysis, adjusted for monthly ED census rates, revealed that there was a significant decrease in the rate of central venous catheter placement. However, the reduction was much greater for noncritically ill compared with critically ill patients. For patients admitted to telemetry or the

**Table.** Demographic characteristics of ED patient population throughout the study period (January 2006 to December 2011).

Characteristic	Study Period, %						
	Overall, N=401,532	2006, N=60,239	2007, N=62,700	2008, N=64,335	2009, N=68,391	2010, N=71,431	2011, N=74,436
<b>Age, y</b>							
<35	39	38	39	39	40	38	39
35–54	38	39	39	38	37	38	36
55–74	18	18	17	18	18	19	20
≥75	5	5	5	5	5	5	5
Male sex	47	47	48	48	46	47	46
<b>Emergency Severity Index level</b>							
1	0.3	0.3	0.4	0.3	0.4	0.4	0.6
2	14	9	13	13	17	15	18
3	46	44	43	47	45	48	45
4 or 5	40	47	44	40	38	37	36
<b>ED disposition</b>							
Admitted to ICU/OR	3	3	3	3	3	3	3
Admitted to telemetry	6	6	5	6	6	5	5
Admitted to floor	11	13	12	11	10	10	11
Discharged home	80	78	80	80	81	82	81

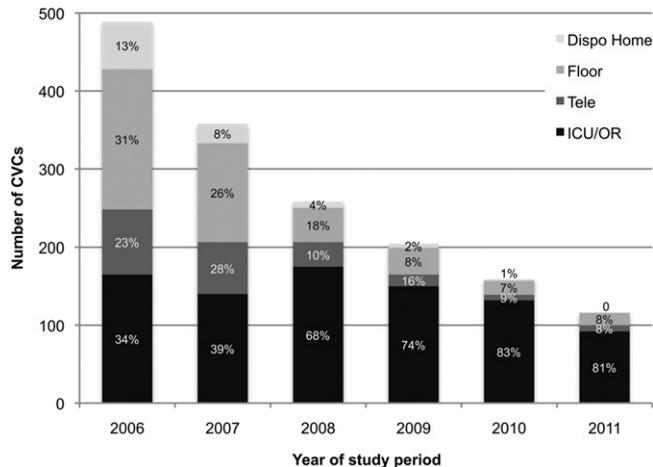
OR, Operating room.



**Figure 2.** Actual monthly central venous catheter rate (solid line based on observed data) and predicted monthly central venous catheter rate (dashed line estimated with log linear regression) by ED disposition.

\*Average monthly decrease (95% CI). OR, Operating room.

floor, the average monthly decrease in the central venous catheter rate was 4.4% (95% confidence interval [CI] 3.6% to 5.1%) and 4.8% (95% CI 4.2% to 5.3%), respectively (Figure 2). For patients discharged home directly from the ED, the average monthly decrease was 7.6% (95% CI 6.2% to 9.1%).



**Figure 3.** Percentage distribution of central venous catheters placed, by ED disposition and study year. *Dispo Home*, Home disposition; *Tele*, telemetry.

In contrast, the average monthly decrease in central venous catheters placed among critically ill patients was smaller (0.9%; 95% CI 0.6% to 1.2%). By 2011, there were no central venous catheters placed in patients who were discharged home. For all regression models, the values of the Durbin-Watson statistic were greater than 2, indicating no evidence that the central venous catheters placed within the same month were correlated with one another.

Figure 3 shows the percentage distribution of central venous catheter placements during the study period by ED disposition. The proportion of central venous catheters placed among critically ill patients steadily increased, from 34% in 2006 to 81% in 2011, because fewer central venous catheterizations were performed in noncritically ill patients.

## LIMITATIONS

The results of this study must be interpreted in the context of the following limitations. First and most important, we did not track the total number of either traditionally placed peripheral intravenous lines or ultrasound-guided peripheral intravenous access lines placed during the study period. Therefore, it is not possible to demonstrate that the reduction in the central venous catheter placement rate occurred because the ED residents and technicians substituted ultrasound-guided peripheral intravenous access for central venous catheter.

Second, we did not measure the number of failed attempts to cannulate a peripheral vein with the standard technique before an ultrasound-guided peripheral intravenous access and during those access attempts.

Third, although there have been no institutional changes in our central venous catheter placement practices during the study period, there may have been other secular trends in emergency medicine practice influencing the central venous catheter placement that are unaccounted for, which may have biased our results.

Fourth, the total number of central venous catheters placed may be underestimated among patients for whom the procedure was not properly documented. However, in our practice environment, this is considered a rare phenomenon and likely did not vary across the study period.

Fifth, this study reflects a single center's experience and may not be generalizable to other EDs, particularly those institutions with less procedural ultrasonographic experience among the physicians and ED technicians.

Sixth, we did not evaluate the effect of the reduction in central venous catheter placement rates on patient outcomes (eg, incidence of complications, time to intravenous access, length of stay in ED or hospital), nor did we assess the financial effects of this central venous catheter reduction.

## DISCUSSION

During a 6-year period in which the acuity of our ED patient population remained stable, we observed a remarkable reduction in the central venous catheter placement rate. The only major practice change we introduced was the training of cohorts of emergency medicine residents and technicians in the use of ultrasound-guided peripheral intravenous access among patients with difficult peripheral venous access. Although the central venous catheter placement rate decreased significantly in all patient subgroups, the change was much greater among noncritically ill patients. By the last year of the study period, there were no central venous catheters placed in patients discharged home from the ED, which resulted in a steady increase in the proportion of central venous catheters placed in critically ill patients.

The significant central venous catheter rate reduction in this study has potentially major implications for patient safety: avoiding central venous catheterization by placement of a peripheral intravenous line is an effective way to minimize central venous catheter complications and

complication-related costs. The implications for the rate of central venous catheter placement in the ED and similar settings with a high prevalence of such placement could be dramatic. As many as 5,000,000 central venous catheters are placed in the United States each year; about 15% of these patients experience complications.<sup>3,5,7,19,20</sup>

Avoiding central venous catheter placement by using ultrasound-guided peripheral intravenous access as an alternative to difficult peripheral intravenous access spares patients from both short- and long-term central venous catheter complications, including serious catheter-related infections. In a systematic review of more than 200 prospective studies, point incidence rates of catheter-associated bloodstream infections were reported to be lowest in peripheral intravenous lines (0.1%; 0.5 per 1,000 intravenous-days) compared with the short-term central venous catheters (4.4%; 2.7 per 1,000 catheter-days).<sup>21</sup> Ultrasonographic guidance may improve the success rate of peripheral intravenous placement, with lower rates of complications, including arterial puncture, hematoma, needle contact with peripheral nerves and paresthesias, infiltration, and infection.<sup>14,15,22</sup> In addition, performing an ultrasound-guided peripheral intravenous access may result in a shorter time to intravenous access compared with the time required for a central venous catheter placement, which could lead to faster diagnosis and treatment and decreased patient throughput time.

This study does not provide direct evidence that the ultrasound-guided peripheral intravenous access program caused the reduction in the central venous catheter rate. However, this is an area in need of rigorous research. To our knowledge, there have only been 2 small randomized controlled trials that have directly compared the success rates of peripheral intravenous lines guided by ultrasonography versus not guided by ultrasonography among adult ED patients, and the results have been conflicting.<sup>14,15</sup> Furthermore, neither study compared outcomes among admitted patients, so it is not clear whether the failure rate of peripheral intravenous lines placed by ultrasonography are similar to those placed without ultrasonography. Whether the central venous catheter placement rate (and the complications associated with it) can be reduced through the use of ultrasound-guided peripheral intravenous access remains an important clinical research question.

In conclusion, the central venous catheter placement rate at our ED dramatically decreased with the implementation of an ultrasound-guided peripheral intravenous access program, particularly among noncritically ill patients. Further research is needed to determine whether the use of ultrasound-guided peripheral intravenous access reduces the central venous catheter rate among noncritically ill patients who have a central venous catheter placed because of difficult peripheral access rather than for critical medical reasons.

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**Author contributions:** HS and KB conceived the study, designed the data analysis, and conducted the educational processes. HS, KB, TKA, MM, RD, and KY participated in data collection. MM, RD, and KY revised the study design, conducted statistical analysis, and contributed to the article revisions. TKA, MS, YTL, AP, and ES assisted with the emergency medicine residents and ED technician training and assisted with data collection. TKA assisted with the institutional review board process. JS and RS critically reviewed the article. HS, KB, and KY drafted the article, and all authors contributed substantially to its revision. HS takes responsibility for the paper as a whole.

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**Address for correspondence:** Hamid Shokoohi, MD, MPH, RDMS, RDCS, E-mail [hshokoohi@mfa.gwu.edu](mailto:hshokoohi@mfa.gwu.edu) or [hshokoohi@gmail.com](mailto:hshokoohi@gmail.com).

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