Academic Emergency Medicine
Official Journal of the Society for Academic Emergency Medicine

ORIGINAL CONTRIBUTION

Use of Ultrasound Guidance for Central Venous Catheter Placement: Survey From the American Board of Emergency Medicine Longitudinal Study of Emergency Physicians

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Abstract

Objectives: The objective was to survey practicing emergency physicians (EPs) across the United States regarding the frequency of using ultrasound (US) guidance in central venous catheter (CVC) placement and, secondarily, to determine factors associated with the use or barriers to the use of US guidance.

Methods: This was a cross-sectional survey mailed to presumed practicing EPs as part of the American Board of Emergency Medicine (ABEM)'s longitudinal study of EPs. The selection process used stratified, random sampling of cohorts thought to represent four different stages within the development of the specialty of emergency medicine (EM). Multivariable logistic regression was used to identify independent factors associated with both high comfort using US guidance and high-percentage usage of US guidance.

Results: The survey was mailed to 1,165 subjects, and the response rate was 79%. The median number of years of practice was 20 (interquartile range [IQR] = 7 to 28 years). As their primary practice setting, 64% work in private or community hospitals, 60% received training in US-guided vascular access, and 44% never use US guidance in placing CVCs. Barriers differed in those who never use US and those who sometimes or always used US guidance. In those who never use US, top barriers were insufficient training (67%) and lack of equipment (25%). In those who use US, top barriers were the perceptions that US was too time-consuming (27%) and that the preferred site was not amenable to US (24%). Independent factors associated with high comfort and high-percentage use of US guidance were training in US-guided vascular access (adjusted odds ratio = 5.1 [high comfort]; 95% confidence interval [CI] = 2.6 to 10.1; adjusted odds ratio 11.1 = (high percentage); 95% CI = 5.0 to 24.8) and being a recent residency graduate.

Conclusions: Among EPs, the translation of evidence to clinical practice regarding the benefits of US guidance for CVC placement is poor and still faces many barriers. Training and education are potentially the best ways to overcome such barriers.

ACADEMIC EMERGENCY MEDICINE 2014;21:416–421

Strong evidence exists supporting the use of ultrasound (US) guidance for central venous catheter (CVC) placement compared with traditional landmark techniques, including limited support for its use in the emergency department (ED).[1-4] In 2001, the Agency for Healthcare Research and Quality included the "use

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Received July 9, 2013; revision received September 24, 2013; accepted November 2, 2013.
The authors have no relevant financial information or potential conflicts of interest to disclose.
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ISSN 1069-6563
PII ISSN 1069-6563583

doi: 10.1111/acem.12350

of real-time US guidance during central line insertion" as one of 11 practices with the strongest supporting evidence to improve patient safety.[5] Since then, numerous professional medical organizations and other government agencies have created position statements advocating for the use of US guidance in placing CVCs.[6-10]

Given this abundant backing, the use of real-time US guidance could be considered a fundamental part of CVC placement in nearly all circumstances. Nonetheless, limited literature suggests the translation of such evidence to clinical practice by emergency physicians (EPs) remains lacking.[11] To our knowledge, no study has investigated the use of US guidance for CVC placement by EPs on a national level.

The primary goal of this investigation was to survey practicing EPs across the United States regarding the frequency of using US guidance in CVC placement. Secondarily, we sought to identify barriers to the usage of US guidance and factors associated with the usage of US guidance.

METHODS

Study Design and Population

The Longitudinal Study of Emergency Physicians (LSEP) is a periodic, ongoing, cross-sectional survey of EPs at various stages in their careers administered by the American Board of Emergency Medicine (ABEM), the methods of which have been published previously.[12] A major survey and cohort resampling is conducted every 5 years, with smaller interim surveys conducted annually between major surveys.[12] The results of this study are from one of the interim surveys conducted in 2010 focused primarily on the use of US by practicing EPs to guide CVC placement. The questions that were included on the 2010 LSEP interim survey were adopted from a prior survey by two of the current study's authors (BB, JK) that surveyed EPs in the Colorado region.[11] These questions were pilot-tested during survey design by a group of EPs with experience in research design and emergency bedside US. Due to survey limitations imposed by ABEM, the lead authors (BB and JK) selected the most pertinent questions for inclusion in the ABEM survey from the pilot survey.[11] Based on intriguing results from the regional survey, ABEM selected pertinent questions for inclusion in the national LSEP annual interim survey. This study was deemed exempt from review by the Colorado Multiple Institutional Review Board.

The ABEM selected 1,165 participants thought to be currently practicing in emergency medicine (EM) or an EM subspecialty as this was the target intended for the survey. This cohort was selected in 2008 based on methods detailed in the original LSEP.[12] The selection process used stratified, random sampling of cohorts thought to represent four different stages within the development of the specialty of EM.[12]

Survey Content and Administration

A paper-based survey and an identical Internet-based equivalent were used to collect data. A letter containing the paper-based survey and the Internet link was sent out in 2010 as one of the three targeted LSEP interim surveys for that year.[12] A copy of the paper-based survey questions and allowable responses is available online (http://www.abem.org/PUBLIC/_Rainbow/Documents/Final_EM_Srvy_Results.pdf). No additional descriptions or definitions were provided on the survey instrument. The first two questions of the survey were used to determine if the respondent was in fact the target population sample. If not, these respondents were excluded.

Data Analysis

Data were cleaned and processed by researchers at ABEM and provided as a Microsoft Excel (Microsoft, Redmond, WA) data file. Data were then imported into SAS v9.2 (SAS Institute Inc., Cary, NC) for analyses. Descriptive data included proportions and 95% confidence intervals (CIs) or medians with interquartile ranges (IQRs), ranges, or 95% CIs where appropriate. Medians and 95% CIs were estimated using a percentile bootstrap method with 2,500 repetitions.[13] Response rate was calculated using the numerator as eligible responses and the denominator as the combination of eligible responses and subjects with unknown eligibility multiplied by an eligibility factor estimating the proportion of potentially eligible subjects.[14] This eligibility factor was calculated from all respondent data using the formula eligible subjects divided by the combination of eligible and ineligible subjects.

Multivariable logistic regression was used to estimate the association between two outcomes and pertinent variables. One outcome was "high comfort," defined as those answering "very comfortable" on a four-point ordinal scale question (choices were very comfortable, comfortable, uncomfortable, very uncomfortable) asking about comfort with using US to place CVCs. The other outcome was "high percentage," defined as those answering that they placed ≥90% of all CVCs using US guidance in normal practice. Variables selected for the model were training in US-guided vascular access, primary practice setting, affiliation with a residency program, Level I trauma center status, annual volume of ED, and years in EM practice since graduating from residency. These variables were selected based on scientific plausibility of association with our outcomes. Collinearity was screened for using correlation statistics. No interaction terms were assessed. We attempted no imputation of missing data. We also assessed prior to modeling the total number of positive outcomes to reduce the likelihood of overfitting our models using the general guidance of greater than or equal to 10 positive outcomes per covariate.[15] Hosmer-Lemeshow test and c-statistic were reported to estimate model fit. All analyses were performed using SAS v9.2 (SAS Institute Inc., Cary, NC) or Stata v10.1 (StataCorp LP, College Station, TX).

RESULTS

There were a total of 1,165 surveys mailed, of which 919 subjects responded to the survey, with 224 (24%) of these responding online. In 53 of 919 surveys (6%), the subjects stated they had retired or changed to non-EM jobs and thus were considered ineligible. Thus we received 866 eligible surveys, for a response rate of 79%.

Demographic characteristics are found in Table 1 for eligible respondents. As their primary practice setting, most (64%) work in private or community hospitals. Nearly half (48%) work in Level I or Level II trauma centers, and most do not work with residents. Years of experience practicing EM postresidency varied from 0 to 60 years, but the histogram of these data showed that there were multiple relative peaks in the data at 2, 7, 12, 17, 22, and 26 years of experience postresidency (data not shown). Three questions were used to elicit information on US training, and three questions were then used to elicit information on the use of US guidance for placement of CVCs.

US Training and Education

Most respondents, 651 of 845 (77%), indicated they had received US training in at least one application; 21 of 866 (2%) respondents did not answer this question (Figure 1). The top three applications in which respondents received training were focused assessment with sonography for trauma (FAST, 93%; 95% CI = 91% to 95%), vascular access (78%; 95% CI = 75% to 81%), and abdominal aorta (78%; 95% CI = 75% to 81%). Overall, 510 of 845 (60%) respondents specified that they had received training in US-guided vascular access.

Regarding the number of hours of US training, 131 of 796 (16%) respondents said that they had 0 hours of US training; 70 of 866 (8%) did not answer this question, including 29 of 866 (3%) who already answered to a prior question that they had no US application training. Respondents who reported nonzero hours of training had median 20 hours of US training (IQR = 10 to 48 hours; range = 1 to 7,500 hours; 95% CI = 20 to 24 hours).

When asked about US educational resources used, 655 of 823 (80%) respondents reported using at least one educational resource; 43 of 866 (5%) did not answer this question (Figure 2). The top three educational resources used were US courses (67%; 95% CI = 64% to 71%), textbooks (49%; 95% CI = 45% to 53%), and training during residency (44%; 95% CI = 40% to 48%).

Use of US to Guide CVC Placement

Respondents reported placing anywhere from 0% to 100% of their CVCs using US guidance; 361 of 814 (44%) said 0%, 317 of 814 (49%) said at least 50%, 160 of 814 (20%) said at least 90%, and 73 of 814 (9%) said 100%. Fifty-two of 866 (6%) did not answer this question. Excluding respondents who never use US

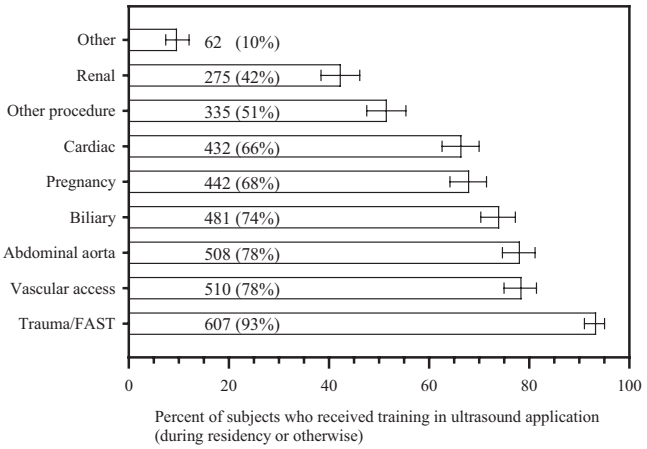

Figure 1. Respondent US training experience of respondents who received any US training at all (n = 651). FAST = focused assessment with sonography for trauma; US = ultrasound.

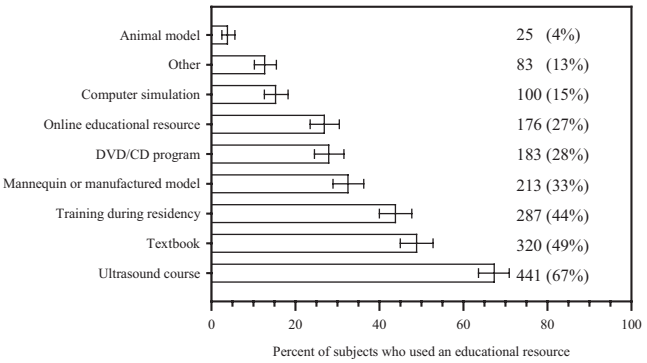

Figure 2. Respondent use of US educational resources of respondents who received any US training at all (n = 655). US = ultrasound.

Table 1
Demographic Characteristics of Survey Respondents Currently Practicing in EM or an EM Subspecialty (N = 866)

Question	n (%)
In what area(s) do you currently work?*	
EM	793 (92)
EM subspecialty	54 (6)
Urgent care	121 (14)
Critical care EM	23 (3)
Missing	15 (2)
What is your primary practice setting?	
City/county/public hospital	118 (14)
Private/community hospital	552 (64)
University hospital	100 (12)
Other†	75 (9)
Missing	21 (2)
What is your hospital's trauma designation?	
Level I	193 (22)
Level II	229 (26)
Level III	184 (21)
Level IV	47 (5)
Level V	29 (3)
Missing/unknown	184 (21)
What is the annual volume of your ED?‡	50,000 (30,000–72,000)
Missing	57 (7)
Do EM residents work in your department?	272 (31)
Missing	34 (4)
How long (yr) have you practiced EM (since completing residency training)? median (IQR)	20 (7–28)
Missing	51 (6)

IQR = interquartile range.
*Sum of percentages may exceed 100% as respondents asked to "circle all that apply."
†Includes military and government hospitals, rural hospitals, urgent care centers, and free-standing clinics.
‡Median (IQR) visits per year.

guidance, the median was 75% (IQR = 25% to 90%; 95% CI = 50% to 75%).

Using only nonmissing data (6% missing), for the subgroup of respondents who had vascular access training (n = 502), the median percentage of CVCs placed under US guidance was 50% (IQR = 5% to 90%; range = 0% to 100%; 95% CI = 50% to 50%); for those respondents who had no vascular access training (n = 310), the median was 0% (IQR = 0% to 0%; range =0% to 100%; 95% CI = 0% to 0%).

Regarding comfort with using US guidance to place CVCs, 399 of 797 (50%) respondents were either very comfortable or comfortable with using US to guide CVC placement. The rest were either uncomfortable or very uncomfortable. Sixty-nine of 866 (8%) did not answer this question.

Using only nonmissing data (10% missing), for the subgroup of respondents who were either very comfortable or comfortable with using US to guide CVC placement (n = 397), the median percentage of CVCs placed with US guidance was 75% (IQR = 25% to 90%; range = 0% to 100%; 95% CI = 65% to 75%). For the subgroup of respondents who were either uncomfortable or very uncomfortable with using US to guide CVC placement (n = 382), the median percentage of CVCs placed with US guidance was 0% (IQR = 0% to 0%; range = 0% to 100%; 95% CI = 0% to 0%).

Finally, when asked to identify barriers to the use of US to guide CVC placement, 127 of 803 (16%) said that they always use US guidance, indirectly implying no barriers to its use. Sixty-three of 866 (7%) did not answer this question. Of the remaining respondents (Figure 3), the top three perceived barriers selected were insufficient training (45%; 95% CI = 41% to 49%), too time-consuming (26%; 95% CI = 23% to 30%), and lack of correct equipment and preferred body site not amenable to US usage tied for third (19%; 95% CI = 16% to 22%).

Using nonmissing data (10% missing), for the subgroup of respondents who placed either some or all of their CVCs using US guidance (n = 441), 125 of 441 (28%; 95% CI = 24% to 33%) perceived no barriers to US guidance, and the top perceived barrier among the remaining respondents was that US was too time-consuming (121 of 441, 27%; 95% CI = 23% to 32%; Figure 4). For the subgroup of respondents who placed 0% of their CVCs using US guidance (n = 341), one of 341 (0%; 95% CI = 0% to 2%) perceived no barriers to US guidance, and the top perceived barrier among the remaining respondents was insufficient training (228 of 341, 67%; 95% CI = 62% to 72%; Figure 5).

Regression Analysis

In multivariable logistic regression analysis, we found that, independent of other variables, receiving training in US-guided vascular access had the strongest association with both high comfort in using US to place CVCs and high percentage of CVCs placed using US in practice (Table 2). Also independent of training in US-guided vascular access, being a recent residency graduate (5 years or less) was important for both high comfort and high percentage use of US for placing CVCs. Practioner's affiliation with a residency program had a 2.3 times greater odds of using US in a high percentage of all CVCs placed.

DISCUSSION

Ultrasound guidance for CVC placement is beneficial, time-efficient, and safe compared to landmark methods.[1–4] Despite the strength of evidence for greater than

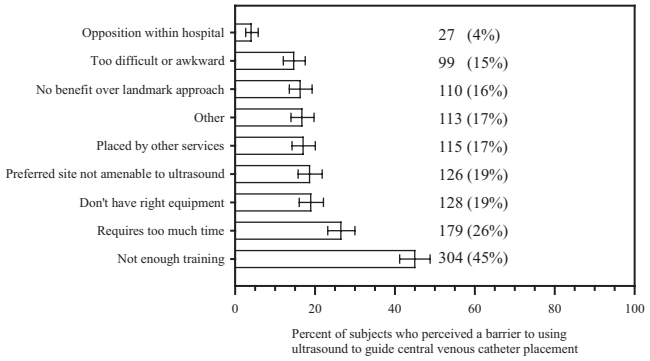

Figure 3. Respondent perceived barriers to the use of US to guide CVC placement of those who perceived any barriers (n = 676). CVC = central venous catheter; US = ultrasound.

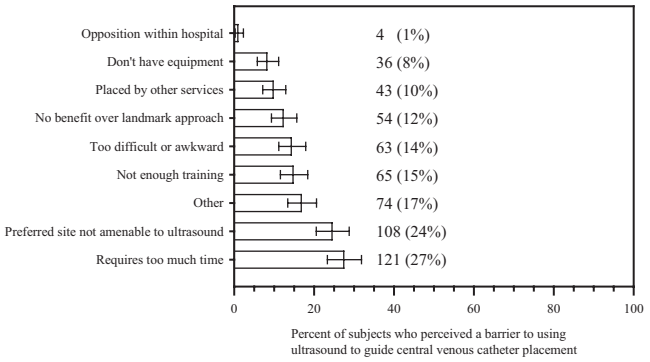

Figure 4. Respondent perceived barriers to the use of US to guide CVC placement of those who placed either some or all CVCs using US guidance (n = 441). CVC = central venous catheter; US = ultrasound.

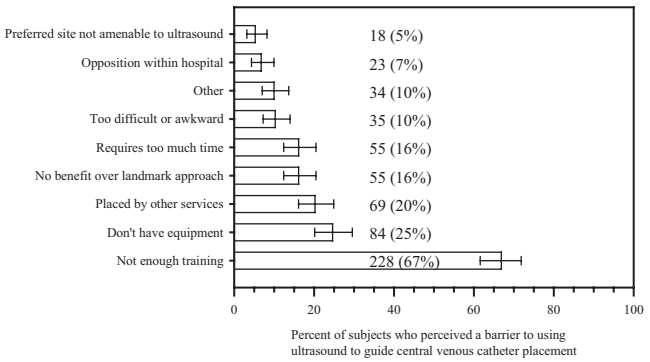

Figure 5. Respondent perceived barriers to the use of US to guide CVC placement of those who placed none of their CVCs using US guidance (n = 341). CVC = central venous catheter; US = ultrasound.

Table 2
Factors Associated With EP Having a High Comfort* With Using US to Guide CVC Placement or Placing a High Percentage† of CVC Using US Guidance

Variable	AOR	95% CI
Using "high comfort" as outcome*		
Received training in US-guided vascular access	5.1	2.6–10.1
Primary practice setting		
City/county/public hospital	1.1	0.6–2.1
Private/community hospital	Reference	
University hospital	1.9	1.0–3.7
Other‡	1.0	0.4–3.0
Affiliated with residency program	1.4	0.8–2.4
Level I trauma center	1.3	0.7–2.5
Annual volume of ED		
<30,000	Reference	
30,000–49,999	0.9	0.4–1.8
50,000–69,999	0.8	0.4–1.7
70,000–99,999	0.7	0.3–1.5
≥100,000	1.3	0.6–3.1
Years in practice since completing residency		
≤5	Reference	
6–10	0.3	0.1–0.5
11–20	0.1	0.1–0.2
21–30	0.1	0.0–0.1
>30	0.0	0.0–0.1
Using "high percentage" as outcome†		
Received training in US-guided vascular access	11.1	5.0–24.8
Primary practice setting		
City/county/public hospital	0.9	0.5–1.7
Private/community hospital	Reference	
University hospital	1.1	0.6–1.9
Other‡	0.6	0.2–1.9
Affiliated with residency program	2.3	1.4–3.8
Level I trauma center	1.4	0.8–2.4
Annual volume of ED		
<30,000	Reference	
30,000–49,999	1.7	0.8–3.5
50,000–69,999	1.3	0.6–2.8
70,000–99,999	0.8	0.4–1.8
≥100,000	1.0	0.4–2.3
Years in practice since completing residency		
≤5	Reference	
6–10	0.4	0.2–0.8
11–20	0.6	0.3–1.1
21–30	0.6	0.4–1.1
>30	0.4	0.2–0.8

AOR = adjusted odds ratio; CVC = central venous catheter; US = ultrasound.
*High comfort was derived from a four-point ordinal scale survey question where the choices were very comfortable, comfortable, uncomfortable, and very uncomfortable. High comfort was defined as those respondents answering very comfortable. Hosmer-Lemeshow test = 0.27; c-statistic = 0.86.
†High percentage was defined as those respondents who answered that they placed ≥90% of all CVCs using US guidance. Hosmer-Lemeshow test = 0.44; c-statistic = 0.80.
‡Includes military and government hospitals, rural hospitals, urgent care centers, and free-standing clinics.

a decade,[1,16] we were alarmed that 44% of respondents said they never use US guidance for CVC placement, and of respondents who had US training in vascular access, only a median of 50% used US guidance in practice. The barriers to such translation are important to understand. We found that the barriers to use of US guidance for CVC placement differ between EPs who never use US and EPs who sometimes or always use US.

For EPs who never use US, adequate training and equipment appear to be the key barriers to focus on. Both would require a significant investment on the part of the hospital or institution to overcome. Yet, it remains unclear what is the most effective training method, although our data suggest that US courses are the most common. Additionally, the question remains as to what equipment would be most ideal for CVC placement, as each machine and US probe has advantages and disadvantages related to factors such as mobility, size, speed, image quality, and ease of use. Simply spending money without considering such factors would be short-sighted.

For EPs who sometimes or always use US, better training and better education appear to be the key barriers. The top two reasons given as barriers to the use of US were that it requires too much time and that the preferred body site was not amenable to US, both of which are not supported by recent evidence, which suggests the need for dissemination of this evidence and perhaps continuing US education.[1-4] The benefit of US for the internal jugular site is strongest;[1,2,4] however, even for the subclavian and femoral sites, the evidence favors use of US.[1,3] Even in the situation of cardiac arrest, where EPs may argue time is most critical, US has been shown to be time-efficient.[17]

When we examined which factors might be independently associated with use of US for CVC placement, despite affiliation to a residency program and recent graduation from residency being important, training in US-guided vascular access was overwhelmingly the most important independent factor both for high comfort with and for high percentage of US use for CVC placement. This would suggest that the vast majority of practicing EPs who work at non–residency-affiliated EDs, and graduated residency over 5 years ago, may still significantly benefit from focused training in US-guided vascular access and that such benefits would have dramatic effects on patient safety and efficiency of care regarding CVCs.

To give an example, according to the National Hospital Ambulatory Medical Care Survey in 2010,[18] approximately 161,000 ED visits resulted in CVC placement. Using our results, 44% (i.e., 70,840) CVCs would be placed without US by EPs. Using recent ED data from Leung and colleagues,[2] by using US in these 44%, we could potentially reduce complications by 1,346 to 16,152 each year nationwide.

LIMITATIONS

The survey responses were self-reported; thus unknown errors or bias may have resulted from this. Stratified sampling designs using equal or proportional sample sizes are known to have the ability to influence both the results and the validity of the analysis.[19] In an attempt to keep survey questions brief, questions may have been left ambiguous. It is possible, therefore, that survey questions may have been misinterpreted from their original intent. For example, training in US-guided

vascular access may have been misinterpreted to be inclusive of peripheral venous access, and some may have answered this question with that in mind rather than referring specifically to central venous access. Even though stratified random sampling was implemented with the goal of obtaining responses from EPs in different stages of development and in various regions of the United States, these results may not be as generalizable to certain specific groups or regions of the country.

We had limited data on nonrespondents. When we graphed the histograms of the ages of nonrespondents (figure not shown) and compared this against the years in practice of respondents using all available data, we noted that there was a similar spread across the years. This comparison assumed that all nonrespondents were traditional students through the end of residency, which may not be entirely true. We noted that relatively fewer recent graduates were in the nonrespondent group; thus it is possible that our data were slightly biased toward opinions of recent graduates as a result.

For our multivariable logistic regression analysis, we noted potentially significant levels of missing data (16% for high comfort, 15% for high percentage). We chose not to impute data given that we had limited covariates to aid in the imputation. However, it is possible that these missing data could bias the results of our regression analysis, and thus, the results should be interpreted with some caution until they can be independently validated in other similar studies.

CONCLUSIONS

Among emergency physicians, the translation of evidence to clinical practice regarding the benefits of ultrasound guidance for central venous catheter placement is poor and still faces many barriers. Training and education are potentially the best ways to overcome such barriers.

The authors acknowledge and thank Jenny Ritter and Chad Russ with the American Board of Emergency Medicine for their expertise and assistance compiling and processing the data.

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