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CURRENT PRACTICES IN CENTRAL VENOUS CATHETER POSITION CONFIRMATION BY POINT OF CARE ULTRASOUND: A SURVEY OF EARLY ADOPTERS

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Abstract

Purpose—Although routine chest radiographs (CXR) to verify correct central venous catheter (CVC) position and exclude pneumothorax is commonly performed, emerging evidence suggests that this practice can be replaced by point of care ultrasound (POCUS). POCUS is advantageous over CXR because it avoids radiation while verifying correct placement and lack of pneumothorax without delay. We hypothesize that a knowledge translation gap exists in this area. We aim to describe the current clinical practice regarding POCUS alone for CVC position confirmation and pneumothorax exclusion as compared to chest radiography.

Methods—We used a modified Dillman technique to conduct a brief web-based survey to Critical Care Medicine and Emergency Medicine physicians (targeted group of early adopters) evaluating the current practice related to CVC position confirmation and PTX exclusion via CXR or POCUS.

Results—Of 200 post-training clinicians contacted, 136 (68%) responded to the survey. For routine CVC confirmation and PTX evaluation, 50.7% of Critical Care Medicine physicians and

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65.4% of Emergency Medicine physicians reported using CXR alone while 49.3% and 33.1% respectively reported using CXR and ultrasound together. Though 84.6% of clinicians use ultrasound for CVC insertion “most of the time” or “always”, none use ultrasound alone for CVC position confirmation, and only 1% has used ultrasound alone for PTX exclusion.

Conclusions—Though data support its utility and advantages for POCUS as a sole modality for CVC position confirmation and PTX evaluation, POCUS is rarely used for this indication. We identified several perceived barriers towards widespread utilization suggesting areas for dissemination and implementation strategy development that will benefit patient care practices.

Keywords

ultrasound; survey; central line; pneumothorax

Introduction

Point-of-care ultrasonography (POCUS) is a rapidly developing discipline incorporated by multiple medical specialties, including Emergency Medicine and Critical Care Medicine (1). POCUS allows for rapid, bedside assessment of critically ill patients (2) and improves procedural success and safety during central venous catheter (CVC) placement, which is one of the most common procedures performed in the management of critically ill patients (3, 4). Risks during CVC insertion (5, 6) include iatrogenic pneumothorax (PTX) (up to 3.3%) and catheter malposition (up to 14%) during internal jugular vein and subclavian vein insertions (7, 8). CVC malposition may be associated with inaccuracies in hemodynamic measurements, venous thrombosis, and delays in treatment (5, 6), while PTX often requires additional monitoring and possible procedural interventions.

For over 50 years, CXR has been the standard method to evaluate CVC position and identify potential complications such as a PTX (9, 10). Mounting evidence suggests that POCUS enhances rapid decision-making, assists physicians’ diagnostic capabilities, and improves patient safety during procedures. In addition, more literature suggests that a post-procedure CXR is unnecessary when ultrasound is used to confirm catheter position and exclude pneumothorax (11, 12). In fact, data demonstrate that ultrasound provides equivalent diagnostic findings to CXR in confirming the catheter location and in excluding mechanical complications like PTX but does so faster. Finally, POCUS has advantages over chest radiography including avoidance of ionizing radiation exposure, optimized resource utilization, and decreased time to diagnosis (13). Immediate confirmation of CVC positioning allows for earlier clinical management that could affect patient outcomes, particularly in critically ill patients (14–16). A recent meta-analysis found that POCUS detected all pneumothoraces and most catheter malpositions following CVC placement while much faster than chest radiography (17).

Clinicians currently recognize the benefit of ultrasound for procedural guidance. POCUS for CVC placement is now recognized as a best practice that is endorsed by the Agency for Healthcare Research and Quality, the National Quality Forum, and is reflected in national quality measures used for public reporting and reimbursement (18, 19). In a recent national survey, nearly all physicians (99%) who insert internal jugular CVCs daily reported using

ultrasound guidance (20). However, despite nearly a decade of data demonstrating efficacy of POCUS for *confirmation* of CVC position and exclusion of pneumothoraces (17, 21), the extent to which POCUS has been adopted for these purposes is unknown. We hypothesize that few in the medical community are likely aware of these data and even among those who are aware, CXR continues to be the routine modality used. The primary purpose of this study was to determine current practices of CVC position confirmation and PTX exclusion by POCUS alone after CVC placement as well as to determine possible barriers to using ultrasound alone for this purpose. In order to provide a “best case scenario” in estimating the wider use of POCUS, we surveyed emergency and critical care physicians across the United States most likely to be experienced in the use of POCUS and aware of the literature on its use for the purpose of CVC position confirmation and PTX exclusion.

Materials and methods

Subjects

Using an electronic mailing list from an ultrasound-focused critical care medicine society of U.S. practicing physicians and a list of Emergency Medicine and Critical Care Medicine alumni physicians from our own training programs, we invited a total of 200 post-training clinicians to participate in an online survey (Qualtrics, Provo, UT, USA). No compensation was offered for survey completion. For implementation of proven survey methodology, we employed a modified Dillman technique, which has demonstrated higher rates of survey return (initial invitation with a web link to the survey, followed by up to three weekly email reminders for non-responders) (22). All survey responses were anonymous. Our Institutional Review Board declared this study exempt from formal review and written informed consent because of the anonymous and voluntary nature of the survey.

Survey Development

The study team consisted of emergency and critical care physicians with expertise in POCUS and survey design. We developed a 10-item questionnaire based on existing literature and knowledge of current local practices. The questionnaire consisted of multiple-choice questions assessing the use of ultrasound guidance for CVC insertion and post-insertion practices. The questionnaire consisted of specific questions regarding demographics, previous POCUS training, number of CVC insertions performed, current use of ultrasound guidance for CVC insertion and position confirmation, and perceived barriers to ultrasound use for CVC position confirmation and PTX evaluation. The survey was independently pilot-tested on ten different Emergency Medicine and/or Critical Care Medicine physicians who provided feedback on the relevance, wording, validity, and clarity of each survey item, in addition to the estimated time required for survey completion. POCUS is used interchangeably with “ultrasound”. The resulting modified survey is provided in Supplemental Digital Content File 1.

Statistical Methods

The raw survey response data were digitally exported from Qualtrics. All statistical analyses were performed with R Statistical Software (Foundation for Statistical Computing, Vienna, Austria) version 3.4.0 (23). Descriptive data included proportions and 95% confidence

intervals (CIs) estimated using a percentile bootstrap method (24). Generalized Cochran-Mantel-Haenszel tests were used to test the association of ordinal variables (25, 26) such as duration of medical practice.

Results

A total of 200 participants were invited to participate in the survey with a complete survey response rate of 68% (136/200). Survey participant characteristics are presented in Table 1. Fifty-two percent of respondents have been in practice for 5 years or less. As their primary practice setting, 71% of respondents work in academics and 88% reported prior structured ultrasound training.

Current estimates of the frequency of CVC insertions after medical training are reported in Table 2. Thirty-eight percent of respondents reported placing or supervising greater than 400 supra-diaphragmatic CVCs (internal jugular and subclavian veins only). Eighty-five percent of providers reported using ultrasound routinely during supra-diaphragmatic CVC insertion (internal jugular vein and subclavian vein). CVC position confirmation practices for routine confirmation are shown in Table 3, with 49% of respondents reporting the use of both ultrasound and chest radiography together while 51% report using chest radiography only for routine CVC position confirmation. Notably, none of the survey respondents reported using POCUS *alone* as a routine method of confirming catheter positioning and only 1% reported using POCUS alone for PTX exclusion after CVC insertion.

The probability of providers using POCUS as the sole method to confirm CVC position and PTX evaluation without chest radiography are shown in Table 4. Physicians with more experience were more likely to adopt ultrasound as the sole method to confirm CVC position as compared to physicians with less experience ($p = 0.04$). No significant difference exists between physicians of differing training duration in using POCUS to exclude PTX ($p = 0.07$).

The list of perceived factors affecting current use of ultrasound guided CVC position confirmation and PTX exclusion are presented in Table 5 and Supplemental Digital Content 2. The most commonly reported factors preventing use of ultrasound alone during CVC position confirmation and PTX exclusion were “My hospital has a policy or protocol requiring radiography after line placement”, “Political forces in my hospital would oppose this, as I would be in the minority of performing the ultrasound protocol”, and “I do not feel adequately comfortable with my ultrasound skills to make this call” which were reported by 17%, 16%, and 14% of respondents respectively. Additional barriers included lack of awareness that ultrasound could be used in this capacity (4%), it is more convenient to obtain a chest radiograph (7%), and inertia “I don’t think of it or it is just hard to change behavior & break habits” (11%).

Discussion

To our knowledge, this is the first study that has evaluated CVC confirmation practices by POCUS alone among Critical Care Medicine and Emergency Medicine Physicians, two groups historically well versed in the CVC procedure and in the use of POCUS. In this

survey, most respondents report routinely using POCUS for CVC insertion. However, even among those who received structured ultrasound training, only half routinely use POCUS with chest radiography for CVC position and PTX exclusion and only 1% use POCUS alone to exclude a PTX. None use ultrasound alone for CVC position confirmation. In our study, lack of comfort with POCUS for this indication was the third most commonly listed barrier to implementation of POCUS for CVC position confirmation and PTX exclusion. Limited incorporation of POCUS in nonvascular applications in residency and fellowship training programs may result in lack of comfort in using ultrasound alone for these purposes after training (27). POCUS alone protocol for CVC position confirmation and PTX exclusion typically includes cardiac and lung ultrasound in addition to vascular ultrasound.

As noted, advantages to use of POCUS alone for confirmation of CVC placement in critically ill patients include efficiency (time to confirmation), reduction in ionizing radiation exposure, relocation of hospital equipment resources, and cost. A recent meta-analysis showed that ultrasound use in CVC position confirmation was feasible (98% adequate visualization), fast (reduced mean CVC confirmation time by 58.3 minutes compared to chest radiography), and accurate (could detect 4 out of 5 venous catheter malpositions) (17). The pooled sensitivity and specificity of POCUS-detected catheter malposition was 0.82 (95% CI 0.77, 0.86) and 0.98 (95% CI 0.97, 0.99), respectively, and the sensitivity and specificity of ultrasound for PTX detection were nearly 100% among the 15 studies (1553 CVC placements) included in the meta-analysis. Since that publication, several additional studies have demonstrated similar results with even better sensitivity of POCUS to detect catheter malposition (21, 28). These observational studies suggest that ultrasound is a reasonable first screening test to confirm CVC position and PTX exclusion based on its efficiency and diagnostic non-inferiority to chest radiography. In addition, a recent randomized controlled study demonstrated a reduction in the time from CVC insertion to first use with ultrasound-only CVC position confirmation and PTX exclusion compared to routine post-procedure chest radiography as well as a statistically significant reduction in chest radiograph utilization (29). While data supporting use of POCUS for CVC position confirmation and PTX exclusion as a reasonable first screen alternative to chest radiography is compelling, our study suggests that this practice does not yet enjoy widespread adoption. This study sets an important foundation for why changes in clinical practice are warranted.

Adoption of POCUS for CVC insertion was aided by national efforts to disseminate evidence, national societal guidelines, and quality measures. Though today POCUS *for CVC insertion* is considered standard of care, initially this practice had a slow rate of adoption similar to POCUS alone for CVC position confirmation and PTX exclusion. Even after many studies demonstrated improvements in CVC associated complications, time to CVC insertion, and successful first cannulation attempt, use of ultrasound for CVC insertion remained limited (3). Qualitative studies analyzing the clinical practice of CVC *insertion* and barriers to implementation of POCUS during CVC insertion, like this study, were influential in developing strategies for improved adoption (30, 31). Ultimately, the Agency for Healthcare Research and Quality (AHRQ) and other national organizations strongly recommended ultrasound guidance for all central venous cannulation to improve patient care and patient safety (31, 32). Recent data suggest that POCUS guidance for CVC insertion is still growing and is now approximately 83–85% compared to 34–44% in 2012 (18).

To achieve the widespread adoption of POCUS alone for CVC position confirmation and PTX exclusion, similar dissemination and implementation efforts will be needed. The first step is to assess the current practices and determine the barriers against widespread adoption. Of the ten potential barriers offered in the survey, respondents cited hospital policy or politics, standard of care, and lack of comfort as the most common reasons for not using ultrasound alone as opposed to chest radiography for CVC position confirmation and PTX exclusion. It is interesting to note that respondents who reported confidence using ultrasound for CVC insertion reported lack of confidence in using POCUS for CVC confirmation. Studies show that physicians can perform focused ultrasound examinations capably after a short intensive training period and can demonstrate improved comfort after training (33). Ultrasound guided CVC confirmation protocols can be easily taught to physicians and as knowledge translation occurs, it should be associated with increased comfort, thus gaining widespread implementation, and eventually become part of standard practice. Perceived convenience of chest radiography as compared to ultrasound was not a strongly reported barrier. This may be because the respondents are already familiar with POCUS and do not perceive this as an inconvenience.

Notably, only 4% reported that they did not know that ultrasound could be used in the manner, suggesting that knowledge dissemination is not the major barrier in this population mostly likely to use POCUS. We hypothesize that three crucial elements to attaining widespread acceptance of POCUS by the clinician include: 1) ultrasound knowledge and skill competence, 2) comfort, and 3) confidence (34). Understanding these processes may be useful in early adoption of ultrasound guided CVC position confirmation and PTX exclusion. In addition, clinicians should investigate whether their hospitals indeed have policies related to CVC position confirmation and whether these specify confirmation with chest radiography, and if so, hospitals and national specialty groups should consider reevaluating these guidelines and policies. More work is needed to identify and understand the factors that facilitate or hinder change in this clinical practice, particularly in this target group who represent early adopters of POCUS. This study and future work will help inform selection of theoretical frameworks for implementation strategies that will improve adoption of this evidence-based clinical practice recommendations.

Our study has limitations. the survey is a small sample of practicing Emergency Medicine physicians and/or Critical Care Medicine physicians most likely to use POCUS for CVC confirmation and who represent a population of potential early adopters to POCUS for this indication. It is possible that physicians who use ultrasound guidance during CVC placement preferentially responded to the survey, which may have skewed our results but in light of our results and prior findings, we think this is unlikely. We attempted to solicit responses from a broad geographical distribution in the US, but the survey was not designed to be nationally representative. Though these are self-reported data, we have no reason to believe that responses are inaccurate or include systematic biases. Our survey was only distributed among participants in the United States. It is possible that the practice patterns regarding CVC position confirmation and PTX exclusion may be different in other countries, where austere conditions could conceivably make use of POCUS even more compelling where available. Finally, though we did perform pilot testing, we were unable to present psychometric data for this survey instrument. Our results reflect attitudes and self-reported

behaviors rather than observed behaviors and are subject to recall bias. However, surveys were anonymous to encourage accurate responses and our response rate is similar to published expectations on survey response rates (35).

Emerging evidence suggests that a post-procedure CXR is unnecessary when ultrasound is used to confirm catheter position and exclude pneumothorax. In fact, data demonstrate that ultrasound provides equivalent diagnostic findings to CXR in confirming the catheter location and in excluding PTX but does so faster. Yet few in the medical community are likely aware of the strength of this cumulative data and even among those who are aware, CXR continues to be the routine modality used. This study highlights the current clinical practices and attitudes toward ultrasound guided CVC position confirmation and PTX exclusion among providers (emergency medicine and critical care medicine) most likely to use POCUS for these purposes. Our data suggests that the translation of evidence to clinical practice in this area by emergency medicine and critical care medicine physicians is limited, and we have identified some basic perceived barriers to implementation. This is an important determinant as efforts to address barriers at the provider and system levels are needed to increase the adoption of POCUS only for CVC position confirmation and PTX exclusion. A more comprehensive national survey, and/or use of qualitative research methods, might be useful in identifying factors that could influence the implementation of ultrasound-guided CVC position confirmation and PTX exclusion protocols among a general pool of providers. Future work might also focus on cost-effectiveness and hospital resource re-allocation implications of ultrasound versus chest radiography after CVC insertion.

Despite literature demonstrating its efficacy, use of ultrasound alone for CVC position confirmation and PTX evaluation, even among experienced providers with training in POCUS, is very low. This study confirms the need for strategic interventions to improve the dissemination and adoption of POCUS for CVC catheter position confirmation and PTX exclusion. Understanding the reasons for lack of adoption of ultrasound is critical to effective dissemination and implementation strategies. Participants identified several barriers to this practice, suggesting a number of potential areas for development in the quest to change clinical practice.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1**Participant Demographics**

Survey Response (N=136)	N	Percent	95% CI
Current Position *			
Physicians 5 years in practice	71	52	44.1 – 61.5
Physicians 6 – 10 years in practice	35	26	17.7 – 35.0
Physicians > 10 years in practice	30	22	14.0 – 31.3
Received structured US training during residency/fellowship †	119	88	83.1 – 93.4
Residency/Fellowship Training ‡			
Emergency Medicine	78	33	26.9 – 40.0
Critical Care Medicine	70	30	23.5 – 36.6
Anesthesiology	28	12	5.6 – 18.6
Internal Medicine	22	9	3.0 – 16.1
Surgery	14	6	0 – 12.6
Emergency Ultrasound	8	3	0 – 12.6
Other §	14	6	0 – 10.1
Current Employment Site ‡			
Academic Setting	102	71	64.3 – 79.0
Community Setting	41	29	21.7 – 36.3
Urban Setting	34	60	47.4 – 72.4
Suburban Setting	19	33	21.1 – 46.1
Rural Setting	4	7	0 – 19.8
Current Employment Region *			
West Region (CA, WA, OR, NV, UT, CO, ID, MT, WY, AK, HI)	19	15	7.2 – 24.4
Southwest Region (AZ, NM, OK, TX)	7	6	0 – 14.8
Midwest Region (IL, IN, IA, KS, MI, MN, MO, NE, ND, OH, SD, WI)	66	53	44.8 – 62.0
Southeast Region (SC, VA, WV, NC, MS, AR, TN, FL, GA, AL, KY, LA)	12	9	1.6 – 18.8
Northeast Region (ME, VT, NH, MA, RI, CT, DE, MD, PA, NY, NJ)	21	17	8.8 – 26.0

N- number of respondents; CI- confidence interval; US- ultrasound

* - single mandatory answer selection

† - Structured training defined as ultrasound course completion, dedicated rotation during residency/fellowship program, or > 5 dedicated ultrasound lectures

‡ - multiple answer selection; at least one selection mandatory

§ - Cardiac Anesthesiology, Nephrology, Emergency Medical Services, Family Medicine, Pulmonary, Infectious Diseases, Neurology, Medical Toxicology, Addiction Medicine

Table 2

Frequency of central venous catheter placement and ultrasound guidance

Number of CVC placed/supervised*	N (Percent)	95% CI
50	2 (1.5)	0 – 10.8
51–100	15 (11.0)	2.9 – 20.3
101 – 400	67 (49.3)	41.2 – 58.6
>400	52 (38.2)	30.2 – 47.6
Frequency of US guided CVC placement *	N (Percent)	95% CI
Never	0 (0.0)	0 – 9.3
Sometimes	10 (7.3)	0 – 16.7
About half the time	11 (8.1)	0 – 17.4
Most of the time	65 (47.8)	39.7 – 57.1
Always	50 (36.8)	28.7 – 46.1

CVC- central venous catheter; CI- confidence interval; US- ultrasound

* Excluding femoral catheters, emergency conditions (cardiac arrest or severe shock) and intraoperative line placement

Table 3**Routine Confirmation Practices**

Survey Response	N (%)	95% CI
Routine method to confirm catheter position after CVC placement *		
Routine method to confirm catheter position after CVC placement * No additional confirmation step		
Ultrasound alone	0 (0)	0 – 9.0
Chest radiography alone	69 (50.7)	42.6 – 59.7
Ultrasound AND chest radiography together	67 (49.3)	41.2 – 58.3
Routine method to exclude PTX after CVC placement *		
No additional confirmation step	1 (0.7)	0 – 9.3
Ultrasound alone	1 (0.7)	0 – 9.3
Chest radiography alone	89 (65.4)	58.1 – 74.0
Ultrasound AND chest radiography together	45 (33.1)	25.7 – 41.7

CI- confidence interval; CVC- central venous catheter; PTX- pneumothorax

* Excluding femoral catheters, emergency conditions (cardiac arrest or severe shock) and intraoperative line placement

Table 4

Probability of providers using POCUS for CVC confirmation (CVC position and pneumothorax evaluation without chest radiography)

US as sole method to confirm CVC position *	Never	Sometimes	Most of the time	Always
Attending Physician (<5 years in practice)	94.4	5.6	0	0
Attending Physician (6–10 years in practice)	91.4	5.7	0	2.9
Attending Physician (>10 years in practice)	76.7	13.3	6.7	0
Method to exclude PTX †	No additional confirmation step	Ultrasound alone	Chest radiography alone	Ultrasound AND chest radiography together
Attending Physician (<5 years in practice)	0	1.4	54.9	43.7
Attending Physician (6–10 years in practice)	2.9	0	80.0	17.1
Attending Physician (>10 years in practice)	0	0	73.3	26.7

POCUS- point of care ultrasound; CVC- central venous catheter; US- ultrasound; PTX- pneumothorax

* -Survey question: *Excluding femoral catheters, emergency conditions (cardiac arrest or severe shock) and intraoperative line placement, how often do you use bedside ultrasound as the sole method to confirm catheter position (without chest radiography) AFTER you perform/supervise a central line insertion?* Difference between physicians of differing training duration using US as the sole method to confirm CVC position without chest radiography by generalized Cochran-Mantel-Haenszel tests ($p = 0.04$).

† - Survey question: *Excluding emergency conditions (cardiac arrest or severe shock) and intraoperative line placement, what is your routine method to exclude a procedure-related pneumothorax AFTER a central line has been placed?* Difference between physicians of differing training duration using US to exclude PTX by generalized Cochran-Mantel-Haenszel tests ($p = 0.07$).

Table 5

Barriers to ultrasound use for routine CVC confirmation.

Survey Response*	Percentage (%)	95% CI
My hospital has a policy or protocol requiring radiography after line placement	17	11.5 – 21.8
Political forces in my hospital would oppose this, as I would be in the minority of performing the ultrasound protocol	16	11.2 – 21.4
I do not feel adequately comfortable with my ultrasound skills to make this call	14	9.2 – 19.4
Medicolegal concerns	13	7.8 – 18.0
Inertia: I don't think of it/it is just hard to change behavior & break habits	11	5.8 – 16.0
I lack sufficient ultrasound confidence to make this call	10	4.8 – 15.0
It is more convenient to get a chest radiograph	7	2.4 – 12.6
Other [†]	6	0.7 – 10.9
I wasn't aware/didn't appreciate that this was an option	4	0 – 9.2
Ultrasound is not as sensitive as chest radiography in evaluation of position or pneumothorax	2	0 – 6.8
No barriers, I currently use ultrasound and NOT chest radiography for confirmation	0	0 – 5.5

CVC- central venous catheter, CI- confidence interval

* - multiple selections permitted

[†] - A full list of other barriers listed in supplemental digital content