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RESEARCH ARTICLE

Actual use of pocket-sized ultrasound devices for cardiovascular examination by trained physicians during a hospitalist rotation

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Background: In actual clinical practice as opposed to published studies, the application of bedside ultrasound requires a perception of need, confidence in one's skills, and convenience.
Objective: As the frequency of ultrasound usage is evidence to its perceived value in patient care, we observed the pattern of autonomous use of a pocket-sized device (PSD) by ultrasound-trained residents during a night hospitalist rotation.
Methods: Consecutive internal medicine residents ($n = 24$), trained in a cardiac limited ultrasound examination (CLUE) as a mandatory part of their curriculum, were sampled on their PSD use after their admitting nights, regarding perceived necessity, deterring factors, detected abnormalities, and imaging difficulties. A detailed analysis was performed with one resident who used a PSD on every admission to compare the proportion of abnormal CLUEs and utility in patients with and without a perceived need.
Results: Residents admitted 542 patients (mean age: 55 ± 17 years, range: 17–95 years) during 101 shifts and performed CLUE on 230 patients (42%, range: 17–85%). Residents elected not to scan 312 (58%) patients due to 1) lack of perceived necessity (231, 74%), 2) time constraints (44, 14%), and 3) patient barriers (37, 12%). In the detailed analysis ($n = 71$), the resident felt CLUE was necessary in 32 (45%) patients versus unnecessary in 39 (55%) patients, with abnormality rates of 50% versus 20.5% ($p = 0.01$) and utility rates of 28.1% versus 15.4% ($p = 0.25$), respectively.
Conclusion: When unbiased residents acting as hospitalists are provided with a PSD to augment initial cardiac examination, usage is frequent and suggests clinical value in hospital medicine.

Keywords: *echocardiography*; *point-of-care ultrasound*; *hand-carried ultrasound*; *pocket-sized*; *hospitalist*; *hospital medicine*

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The advent of point-of-care ultrasound techniques and portable devices has resulted in the proliferation of non-traditional users and has generated particular interest within the hospitalist profession (1–5). Prior studies have validated the clinical utility of point-of-care ultrasound and pocket-sized devices (PSDs) (6–11), and have been instrumental in promoting the feasibility of the technique as a supplement to physical examination (1, 12–21). However, as studies have often employed motivated users or specific patient populations, the current literature may not reflect the use or utility of the device for busy practicing hospitalists, a growing group of physicians that could benefit from the use of ultrasound to improve initial bedside diagnosis and expedite subsequent triage, treatment, and referrals. The hospitalist's decision to apply point-of-care ultrasound can be affected by multiple factors that have been poorly characterized in real-world practice, such as confidence in hospitalist's skills to obtain diagnostic images, a perceived clinical need for the information obtained from the ultrasound exam, patient characteristics, and convenience (19, 20). Knowledge of the patterns and frequency of actual use of point-of-care ultrasound is essential for the hospitalists when deciding whether to undertake training courses or purchase a device for their own practice.

As a part of the admission physical exam, the cardiopulmonary evaluation can be augmented by a brief, 2-min evidence-based cardiac limited ultrasound examination (CLUE) (22). Since concerns regarding the status of the cardiopulmonary system are common in medical admissions, a trained hospitalist's use of CLUE can serve as a general marker for the willingness to apply ultrasound.

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Therefore, we sought to observe CLUE-trained physicians in their elective use of a PSD as a part of admitting cardiac evaluation during a hospitalist rotation.

Methods

The study took place at a 300-bed community hospital that is the primary hospital for an ACGME-accredited 3-year internal medicine residency with 36 residents, approved by the institutional review board. As a mandatory part of the residency curriculum, all residents had received formal training in CLUE as detailed elsewhere (16, 22, 23). The CLUE involves acquisition of six quick-look views and recognition of six evidence-based signs and can typically be performed within 2 min. The CLUE is designed to augment the physical examination for accuracy and diagnostic synthesis by providing more accurate detection of left ventricular dysfunction (cardiac dysfunction sign), left atrial enlargement (left atrial enlargement sign), interstitial edema (ultrasonic lung comet-tail sign), pleural effusions (effusion sign), right ventricular enlargement (subcostal right ventricular enlargement sign), and elevation of central venous pressures through plethora of the inferior vena cava (subcostal inferior vena cava sign) (22).

As a part of the general residency curriculum, all residents participate in a 'night hospitalist' rotation for 2 weeks, twice during their second and third years of residency, in which they solely admit patients in an independent fashion over a 12-h nocturnal shift. Consecutive senior residents were provided with a pocket-sized ultrasound device (Vscan with Duoprobe, GE Healthcare, Wauwatosa, WI, USA) during this rotation, in which they were instructed to use the device to perform the CLUE independently and autonomously, whenever they felt it was necessary to provide 'good patient care'. A convenience sample of 542 patients was obtained over 14 months by meeting with the post-call resident on Monday and Friday mornings after their admitting shifts. Use of the device by the residents was tabulated to better understand the value of providing the device during an admitting shift in a community hospital. It is a retrospective review, and analysis of this usage database forms the basis of this report. Residents understood that their use of the device had no effect on their course evaluation and were not separately incentivized nor compelled by any attending to specifically use the PSD. No billing charge was submitted for any ultrasound use. Of the 36 residents in the program, 25 had already been scheduled for the night hospitalist rotation prior to the study's design and this schedule was not changed. When residents were sampled, each admitted case was briefly reviewed (age, gender, and chief complaint) and the resident was asked whether he or she performed a CLUE and his/her reasoning for the same. The primary reason for not performing a CLUE was categorized as whether there was 1) a lack of perceived necessity, 2) a lack of time, or 3) the presence of patient barriers, such as poor cooperation, pain, and inaccessible or infected imaging sites. In addition, the resident was asked the CLUE results and whether any view was technically difficult to obtain. Residents were blinded to their colleagues' frequency of use and difficulties in imaging.

The resident was informed of an admission by a doctor–doctor conversation with the physician in the emergency department who had evaluated the patient. Many patients had already received extensive pre-admission diagnostic studies in the emergency department, often including laboratory data, chest x-ray, EKG, and CT scans, which were available for review by the resident prior to his/her evaluation of the patient.

Detailed analysis

In a pre-planned analysis, one resident, the 13th to participate, utilized a PSD on all patient admissions during his rotation. This resident was questioned after each night's admitting shift regarding which patients he felt, prior to imaging, would benefit from a CLUE, whether imaging abnormalities and difficulties existed, and if there was immediate post-imaging clinical utility from the CLUE. Clinical utility was considered as a change of management, defined as a treatment change or referral for further testing based upon the CLUE results, or significant reassurance directly attributable to the CLUE, defined as improving certainty for the provisional diagnosis when previously less than 'moderately certain'. To evaluate the accuracy of resident-detected CLUE abnormalities and diagnoses, examination of the electronic medical record was performed after discharge for information provided by formal echocardiography, other imaging studies, and discharge diagnoses. The use data obtained from this resident was included in the overall analysis.

Statistics

Patient age and the number of patients admitted per resident were reported as mean $\pm$ standard deviation. Fisher's exact test was used to compare the proportion of abnormalities and clinical utility in patients both with and without perceived indications. Calculations were made using Prism 5 (Graph Pad Software, La Jolla, CA). A p-value of ≤ 0.05 was considered significant.

Results

Twenty-four residents admitted 542 patients over 101 admitting shifts (12 h per shift), averaging 15.8 ± 5.2 patients per resident (range: 5–26) and 5.4 admissions per shift (range: 1–8). Patient age was 55 ± 17 years (range: 17–95). The CLUE was performed in 230 patients, 42% of cases, with a wide individual resident use range: 17–85%. The CLUE was not performed in 312 patients, or 58% of cases. The most frequent reason why a CLUE was

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Table 1. Reported CLUE abnormalities and difficulties in imaging

	C (cardiac/LV dysfunction)	L (left atrial enlargement)	U (ultrasonic lung comets)	E (pleural effusions)	S (IVC plethora or RV enlargement)
	n (% of total)	*n* (% of total)	*n* (% of total)	*n* (% of total)	*n* (% of total)
Abnormality	53 (23)	88 (38)	58 (25)	36 (16)	34 (15)
Difficult view	36 (16)	36 (16)	5 (2)	28 (12)	84 (37)

Note: The table shows the distribution of CLUE abnormalities ($n = 269$) and distribution of technically difficult images ($n = 189$) displayed by each CLUE finding category (CLUES), as reported by residents.
IVC, inferior vena cava; LV, left ventricular; RV, right ventricular.

not performed was that the resident felt the case lacked a clinical need to perform the CLUE, which accounted for 231 patients, or 74% of the 'not performed' cases. This category included cases in which the CLUE would not have provided useful information pertaining to the patient's presenting symptoms as well as cases in which the data that the CLUE could provide were already known through other laboratory or imaging studies either in past records or from current studies performed in the emergency room evaluation. Otherwise, time constraints were felt to have prevented PSD use in 44 patients, accounting for 14% of the cases in which a CLUE was not performed. Patient factors, mainly lack of patient cooperation, accounted for 37 patients, or 12% of not performed cases.

In the 230 patients in whom the CLUE was performed, residents identified a total of 269 CLUE abnormalities (Table 1). The most frequently identified CLUE finding was left atrial enlargement, which was seen in 88 (38%) studies. This was followed by ultrasonic lung comets in 58 (25%) studies, left ventricular dysfunction in 53 (23%) studies, pleural effusions in 36 (16%) studies, and right ventricular enlargement or inferior vena cava plethora in 34 (15%) studies. Residents felt 101 patients (44% of the imaged patients) had at least one difficult view, totaling 189 difficult views (16% of total views) that could not be adequately obtained. The subcostal view was the most difficult view accounting for 84 of the failed views (37% of all patients) and was followed by 36 views (16% of patients) for left ventricular dysfunction, 36 views (16% of patients) for left atrial enlargement, 28 views (12% of patients) for pleural effusions, and finally, only 5 views (2% of patients) for ultrasonic lung comets.

Detailed analysis

In the detailed analysis, one resident admitted 71 patients over 11 admitting shifts. The patients had a mean age of 51 ± 18 years (range: 17–89 years). The resident felt the CLUE would be useful in 32 of 71 patients, or 45% of cases. The patient age and the percentage of patients felt to potentially benefit from CLUE were similar in this subpopulation compared with the overall cohort. Of the cases felt to be necessary versus unnecessary, the resident identified CLUE abnormalities in 50% (16/32) of necessary versus 20.5% (8/39) of unnecessary use ($p = 0.01$). Clinical utility was perceived in 28.1% (9/32) of necessary versus 15.4% (6/39) of unnecessary use ($p = 0.25$; Table 2). In the accuracy analysis of patients in whom CLUE was felt to be necessary, post-discharge chart review showed concordance in 81% (26/32) cases when compared with formal echocardiography, CT imaging, and discharge diagnoses. The resident's CLUE findings were discordant in only two (6%) cases, while four (12%) cases were indeterminate.

Discussion

The current study demonstrates that ultrasound-trained internal medicine residents would autonomously elect to

Table 2. Detailed analysis with detected abnormalities and perceived clinical utility

	Patients	Abnormalities		Clinical utility	
	n (%)	*n*	%	*n*	%
Indicated	32 (45%)	16	50 [32.7–67.3]*	9	28.1 [12.5–43.7]
Not indicated	39 (55%)	8	20.5 [7.8–33.2]*	6	15.4 [4.1–26.7]
Total	71				

Note: The table shows detailed analysis ($n = 71$) to compare reported abnormalities and clinical utility from CLUE in patients both with and without perceived indications.
*$p = 0.01$; [95% CI].

perform a CLUE using a PSD on a significant proportion (42%) of patient admissions during a hospitalist rotation, even after initial evaluation by the emergency room physician and review of electronic medical records. From the detailed analysis, the data suggest that a resident's decision on whom to perform a CLUE is marked by a higher rate of CLUE abnormalities (50% versus 20%), supporting the clinical decision to perform the CLUE. The CLUE provided accurate and pertinent clinical information, based upon a very high concordance with results of subsequent formal echocardiography, other standard imaging studies, and clinical diagnoses at the time of discharge. These data are the first to observe the actual use pattern of a PSD for hospital admissions and can be used to understand real-world utility and worth of using such a device to augment initial patient evaluation.

Prior studies have demonstrated that hospitalists can be trained in point-of-care ultrasound, but little data exist on real-world utilization in hospital admissions. Unlike the present study, prior studies may have been biased by the use of motivated physicians (21), often eager to learn and apply the technique, or the enrollment of specific patient populations, such as those already referred for echocardiography (2, 3, 18). Actual use is dependent on multiple factors that are rarely studied, including physician familiarity and confidence in the techniques, patient characteristics, and convenience. In a study to investigate the diagnostic influence of a PSD when used by six variably trained medical residents on inpatient admissions (14), the residents imaged, despite the study protocol, only 45% of the 446 cases 'randomized' to undergo PSD imaging. The authors attributed this bias to 'busy working hours, in-hospital logistics and resident instruction to prioritize standard diagnostics'. The present study was able to observe unselected residents acting as hospitalists with over 1 year of specific ultrasound training, in their autonomous and unbiased use of a pocket-sized ultrasound device on typical patients admitted to a community hospital. Interestingly, we found an equivalent percentage of 'elective' usage, in 42% of 542 cases, suggesting a trained physician would likely apply a PSD to augment his or her bedside cardiopulmonary exam at least 1–4 times per shift and likely hesitate to spend valuable time imaging patients where the diagnostic yield was felt to be low or where no new information would be obtained.

The willingness or reluctance of the admitting physician to use PSD imaging for 'soft' indications, such as in screening physical examination or confirming what was already known, is likely responsible for the large variation of resident use (17–85%) noted in the study and the higher proportion of patients placed in the subjective reason category of 'not needed'.

While this study has implications for general medical use of point-of-care ultrasound, there exist limitations. The reluctance to image was categorized using subjective self-reporting by the residents and could be related more to the resident's comfort with the technique than the true validity of the reason for not imaging. Although all residents complete the same training program and document an equivalent level of competency, it is possible that the resident who participated in the detailed analysis was especially skilled or motivated which may have increased his or her specific accuracy or affected his or her pattern of use. However, this resident, who imaged all patients, reported that he would have employed PSD in 45% of his cases, which is similar to the mean of the overall group (42%), which attests for the lack of bias in overall resident usage. Similarly, the possible bias that all residents, by being aware of which days they would be sampled, could have subsequently increased their frequency of use, is a minimal concern. Residents knew that their ability to admit and care for multiple admissions overnight was the overall endpoint used in the course's evaluation of their performance, which may also have countered unnecessary PSD use. We feel such issues of time and efficient data collection represents the true, 'real-world' considerations of an unbiased physician acting as a hospitalist.

In summary, when trained residents acting as hospitalists are provided with a pocket-sized ultrasound device for autonomous use in cardiac evaluation, usage is frequent. The current observational study may lay the foundation for future studies to evaluate physician biases and how they may affect studies of patient outcomes in point-of-care ultrasound.

Conflict of interest and funding

All authors had access to the data and a role in the writing of the manuscript. Also, there are no funding sources and pertinent conflicts to disclose.

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