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Focused Cardiac Ultrasound in Place of Repeat Echocardiography: Reliability and Cost Implications

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Abstract

Background—Health care systems are increasingly moving toward models that emphasize the delivery of high-quality health care at lower costs. Rates of repeat echocardiography (two or more transthoracic echocardiographic studies performed within a short interval) are high and can contribute substantially to the cost of providing cardiovascular care. Certain findings from handheld ultrasound scans performed by echocardiographers have been shown to correlate well with findings on transthoracic echocardiography (TTE). It therefore may be feasible and cost effective to use expert focused cardiac ultrasound (eFCU) in place of repeat TTE for highly selected indications in certain settings. The aim of this study was to determine the reliability and cost implications of using eFCU in place of repeat TTE in selected inpatients.

Methods—Inpatients who underwent repeat TTE (prior TTE within 30 days) ordered for the assessment of ventricular function, pericardial effusion, or inferior vena cava collapse were prospectively enrolled. Subjects underwent eFCU in addition to TTE, and results were compared for correlation using the weighted κ statistic. The potential cost savings of using eFCU in place of TTE were modeled from the provider perspective (i.e., physicians and hospitals).

Results—Over 45 days, 105 patients were enrolled. The majority of scans were performed for assessment of left ventricular function and pericardial effusions. eFCU showed excellent correlation with TTE for most parameters, including left ventricular systolic function ($\kappa = 0.80$) and the presence and size of pericardial effusions ($\kappa = 0.81$) ($P < .001$ for both). Adoption of this eFCU protocol could save between \$41 and \$64 per study, or between \$34,512 and \$53,871 annually at the authors' institution.

Conclusions—Findings from eFCU correlate well with those from TTE when used in the setting of repeat testing for assessment of ventricular function, pericardial effusion, and inferior vena cava collapse. The judicious use of eFCU in place of repeat inpatient TTE has the potential to deliver quality cardiac imaging at reduced cost.

Keywords

Focused cardiac ultrasound; Echocardiography; Cost-effectiveness

Echocardiography is a mainstay of diagnostic cardiac imaging. It permits rapid and accurate assessment of cardiac morphology, function, and hemodynamics. However, the high growth rate in the use of echocardiography, despite cuts in reimbursement, has led to increased scrutiny regarding its appropriate use.¹ The recent development of pocket-sized handheld ultrasound devices has the potential to change how echocardiography is used in clinical practice. Studies have demonstrated efficacy of these devices in identifying cardiac pathology in diverse settings, such as critical care units, outpatient clinics, and underserved and remote populations.^{2–5} Most studies have shown good correlation between imaging findings obtained with handheld devices by level II or III echocardiographers or sonographers (i.e., expert focused cardiac ultrasound [eFCU]) versus traditional transthoracic echocardiography (TTE).^{6–8}

However, no study has assessed the feasibility of using eFCU for repeat or follow-up imaging, particularly in patients admitted to the hospital who have undergone recent diagnostic TTE. Changes in signs or symptoms, or the need to detect and correct adverse changes in cardiovascular status before they become clinically apparent, may prompt clinicians to order repeat echocardiography to assess for certain changes in cardiac function. It is possible that accurate answers to some of the discrete clinical questions prompting the ordering of repeat echocardiography could be cost-effectively provided by eFCU. Repeat testing is common; more than half of Medicare beneficiaries undergo repeat echocardiography within 3 years.⁹ Furthermore, the health care cost of repeat imaging is substantial, because Medicare spending among cardiovascular procedures has been driven largely by an increase in diagnostic imaging.¹⁰ eFCU might be cost effective when used for repeat imaging, particularly in reimbursement schemes based on episodes of care (“bundling”) or in accountable care organizations, by decreasing the need for the more resource intensive use of full-feature TTE.^{11,12} In this study, we sought to determine whether a protocol to use eFCU in place of repeat or follow-up TTE among highly selected inpatients for a limited set of indications would be feasible and to examine the differential health care costs associated with performing eFCU instead of TTE in this setting.

METHODS

Study Population

This was a prospective, single-center, nonrandomized intervention study. All inpatients for whom TTE was ordered by their primary treatment teams were screened for eligibility. Patients who had undergone previous TTE within the past 30 days, as either inpatients or outpatients at our institution, were then identified as potential candidates for enrollment. Patients for whom repeat TTE was ordered for the assessment of left ventricular (LV) size or systolic function, right ventricular (RV) size or systolic function, screening or follow-up for pericardial effusion, or assessment of inferior vena cava (IVC) collapse were included in the study. Patients in whom cardiac tamponade was a clinical concern were excluded. Because

of a lack of spectral Doppler on the handheld ultrasound device (and therefore limited ability to provide accurate diagnosis of other disorders, such as valvular pathology), all other indications were also excluded. Indication for repeat TTE was determined by clinical information on the electronic order provided by the primary treatment team; if the indication was vague, personnel from the echocardiography laboratory contacted the ordering provider to determine the study indication. On the basis of the 2011 appropriate use criteria for echocardiography,¹³ the appropriateness of each repeat study was determined from review of the medical record. Patients who were in a surgical or respiratory critical care unit and/or had undergone cardiac surgery during the admission were excluded because many patients in these settings have difficult imaging windows. The study was approved by the local institutional review board.

eFCU and Transthoracic Echocardiographic Protocol

All patients underwent eFCU in addition to repeat TTE ordered by the primary treatment team. TTE was performed with either a Philips iE33 (Philips Medical Systems, Andover, MA) or a GE Vivid7 or Vivid 9 (GE Healthcare, Fairfield, CT) machine by an experienced sonographer and interpreted offline by a level III echocardiographer on ProSolv Cardiovascular Client (Fujifilm, Tokyo, Japan) software with all routinely available parameters. eFCU was performed on the same day as repeat TTE (within 12 hours) with a VScan pocket ultrasound device (GE Healthcare). eFCU was performed and interpreted by level II echocardiographers who were blinded to the repeat trans-thoracic echocardiographic images and reports. eFCU examinations were tailored specifically to address the ordering indication, but the determinations of LV size and systolic function, RV size and systolic function, presence or absence of pericardial effusion, and assessment of IVC collapse were made for every scan. Typically, two or three views in each of the parasternal, apical, and subcostal views were obtained. Images were interpreted in real time and documented immediately after scanning, similar to the methods used in other focused cardiac ultrasound studies.⁴

Data Collection and Definitions

Demographic data collected included patient age and body mass index. VScan parameters included image quality, LV size, RV size, LV and RV systolic function, LV ejection fraction (LVEF), pericardial effusion or thrombus and chamber compression, and IVC collapse with inspiration (Table 1). All eFCU parameters were assessed qualitatively. Quantification of transthoracic echocardiographic parameters was not mandatory and was left to the discretion of the reader.

Statistical Analysis

Continuous variables are presented as mean $\pm$ SD. Agreement between categorical variables on TTE and eFCU (LV size, RV size, LV and RV systolic function, presence and size of pericardial effusion, presence of chamber compression, and IVC collapse with inspiration) was calculated by the weighted κ statistic. On the basis of the classification of Fleiss,¹⁴ κ values > 0.75 were interpreted as representing excellent agreement, 0.61 to 0.74 as good agreement, 0.41 to 0.6 as fair agreement, and < 0.4 as poor agreement. Correlation of LVEF

between eFCU and TTE was calculated using the Spearman rank-order correlation coefficient. Bland-Altman analysis was used to evaluate bias.¹⁵ *P* values < .05 were considered statistically significant.

Cost Analysis

We modeled the differential costs of performing eFCU versus TTE using a provider-perspective (defined as the local hospital and physician operating jointly, not just the physician) microeconomic analysis, similar to methods used in other economic analyses of cardiovascular procedure use.^{16,17} First, the cost of the ancillary services required to perform limited or follow-up inpatient TTE was estimated. Specifically, this included the average labor costs of sonographers and patient transporters (derived from 2013 wage data from the Bureau of Labor Statistics),¹⁸ and echocardiography laboratory overhead (derived from our institutional data and from the American Society of Echocardiography's recommendations for quality echocardiography laboratory operations).¹⁹ Fixed costs of TTE (i.e., machine, depreciation, software platform, archiving) were not included, because these costs would have already been incurred at the time of implementation of a protocol using eFCU. Next, a per-scan estimate of the cost of eFCU equipment was calculated on the basis of purchase price (\$7,900) and estimated depreciation (3 years) of the Vscan device. The cost of eFCU failure (i.e., poor imaging windows requiring use of full-feature TTE) was calculated on the basis of the ancillary costs of TTE and the failure rate of eFCU.

The physician cost of performing eFCU versus TTE was then estimated in two different ways. The first model used the physician component of the relative value unit (RVU) for limited or follow-up TTE (Current Procedural Technology code 93308, 0.53 RVUs, national average physician fee schedule payment of \$26).^{20–22} We did not include the technical component of the RVU, because Medicare reimburses inpatient hospital stays on the basis of an episode of care for a diagnosis-related group (and not directly for procedures performed such as TTE). Because recent guideline documents have discouraged the practice of billing for eFCU as limited echocardiography,²³ the physician cost for eFCU in this model was considered to be zero. However, because the performance of eFCU requires physician time and labor, even though eFCU is recommended to be a nonbillable procedure, we attempted to incorporate an estimate of physician cost in a second model using the mean hourly wage estimate of physicians and surgeons from the Bureau of Labor Statistics.¹⁷ Sensitivity analyses were performed by varying the assumptions of physician salary and time required to perform and interpret the eFCU examination. Finally, the potential cost savings per year at our institution was calculated on the basis of the number of eFCU examinations performed per day.

RESULTS

Patients, Indications, and Image Quality

Over a period of 45 days, a total of 105 patients met the inclusion criteria and were enrolled in the study (mean, 2.3 ± 0.8 patients/day). Of the 105 patients, 18 (17%) underwent their initial studies as outpatients and 87 (83%) as inpatients (91% during the same hospitalization). Demographics, transthoracic echocardiographic characteristics, and

indications for repeat TTE are provided in Table 2. The majority of indications for repeat TTE were for assessment of LV systolic function (49 of 105 [47%]) or pericardial effusion (45 of 105 [43%]). Of the 105 eFCU examinations performed, 82 (78%) were appropriate, 13 (12%) were inappropriate (rarely appropriate), six (6%) were of uncertain appropriateness (may be appropriate), and four (4%) could not be rated because of insufficient information in the medical record. The eFCU failure rate was 8%: of the 105 eFCU examinations performed, eight (one for LV function, four for pericardial effusion, two for RV size and function, and one for IVC collapse) had insufficient image quality to provide clinically meaningful information. The mean time to perform the eFCU examination and document the results was 15.2 ± 3.3 min.

Agreement between eFCU and Transthoracic Echocardiographic Findings

Overall, findings between eFCU and TTE correlated well (Table 3, Figure 1). Excellent correlations were observed for LV systolic function ($\kappa = 0.80$, $P < .001$), LV size ($\kappa = 0.76$, $P < .001$), RV size ($\kappa = 0.77$, $P < .001$), and pericardial effusion ($\kappa = 0.81$, $P < .001$) and the presence of chamber compression ($\kappa = 1.00$, $P < .001$). Good correlations were observed for RV function ($\kappa = 0.65$, $P < .001$) and IVC collapse ($\kappa = 0.64$, $P < .001$). There were no clinically important findings on repeat TTE that were missed by eFCU. With regard to LVEF, eFCU and TTE showed excellent agreement using the Spearman correlation coefficient ($r = 0.96$, $P < .001$; Figure 2). A Bland-Altman plot for LVEF (Figure 3) showed a small positive bias for the estimation of LVEF with eFCU compared with TTE (bias = 1.3%; 95% CI, -8.1% to 10.7%), with a normal distribution.

Cost Analysis

The labor cost of TTE using the physician RVU model was \$73.16, while the labor, device, and failure costs of eFCU totaled \$8.99 for the physician RVU model and \$32.05 for the physician wage model (Table 4, Figure 4), translating to a potential cost savings of \$64.17 and \$41.11 per scan, respectively, by using eFCU. For the physician wage model, we performed two sensitivity analyses. First, we allowed an additional 10 min to perform the eFCU examination and compare it with the prior study, and second, we increased the physician wage to \$150/hr. In both analyses, the use of eFCU still led to cost savings over TTE (savings of \$25.73 and \$26.67 per study, respectively). On the basis of the number of eFCU examinations performed in our study, protocolized use of eFCU in place of TTE at our institution would have led to savings of \$53,870.72 annually using the physician RVU model and \$34,511.85 annually using the physician wage model.

DISCUSSION

We found that findings on eFCU correlated very well with TTE when used in a selected population of inpatients undergoing repeat TTE for discrete clinical indications. Use of eFCU in these settings could produce significant cost savings to health care providers and may be of particular interest for providers participating in accountable care organizations that strive to reduce costs without compromising the quality of services delivered.

Rates of echocardiography have significantly outpaced the overall growth in health care services over the past several years, at least in part because of the increasing incidence of repeat imaging.⁹ Rates of repeat echocardiography are high not only in fee-for-service health care systems but also in health systems with near universal health care and fixed global budgets. This finding suggests that repeat imaging occurs not primarily because of fee-for-service incentives but rather because of uncertainty in diagnosis and practice patterns that rely heavily on sophisticated diagnostic technology.^{24–26} There is little doubt that the high incidence of repeat imaging carries a significant health care cost, and efforts to reduce this burden may be beneficial to providers and insurance payers alike. In this study, we provide data to support a novel method of using eFCU to replace repeat echocardiography in certain, highly defined settings. Used appropriately, this method may have the potential to provide clinicians with the requested information at reduced cost.

The use of eFCU in the setting of repeat imaging for the specific indications included in our study is a natural extension of prior work. Studies comparing eFCU with TTE have consistently shown good correlation for findings related to structure and function. In our study, the vast majority of indications for repeat TTE were for assessment of LV systolic dysfunction or pericardial effusion. Prior studies have also shown eFCU to be very effective at assessing these findings. In particular, the NaUSiCa study by Galderisi *et al.*⁷ showed κ statistics of 0.91 and 1.00 for LV systolic dysfunction and pericardial effusion, respectively. Our study extended this work to show excellent correlation for RV size and good correlation for RV function and IVC collapse, suggesting that these parameters may be evaluated effectively by eFCU as well. Two prior studies that evaluated RV size, RV function, and IVC size by focused cardiac ultrasound showed only reasonable correlation with TTE.^{27,28} One study involved noncardiologists who underwent a training program, and another analyzed eFCU examinations performed in the acute care setting and included patients in intensive care units, who were excluded from our study.

Clinical situations in which eFCU might be most beneficial in replacing repeat TTE among inpatients are those for which there is a specific clinical question that cannot be accurately answered by physical examination alone and for which eFCU has proven ability to identify or effectively rule out pathology. Common examples from our study include reassessment of LV function in patients undergoing chemotherapy with cardiotoxic agents and screening for pericardial effusions in patients who have undergone percutaneous cardiac procedures such as catheter ablations. Other studies have shown that focused cardiac ultrasound may be helpful in determining volume status to guide therapy among patients admitted with acute decompensated heart failure.²⁹ Importantly, in our study, there were no clinically important findings on TTE that were missed by eFCU. This is likely because we restricted the use of eFCU to patients with recent full TTE and specific indications for repeat imaging. The use of eFCU for less restrictive indications (i.e., in patients without a recent full-feature TTE, patients in the intensive care unit setting, and hospitalized patients requiring assessment of valvular lesions) could prove detrimental to clinical care and add to cost. Programs using eFCU should be under the auspices of a full-feature echocardiography laboratory to ensure proper training of the eFCU operator and to ensure the ready availability of full-feature echocardiography for those patients with inadequate imaging windows by eFCU.

Increased use of eFCU per the protocol in this study could lead to a significant reduction in spending on noninvasive cardiac imaging. From 2000 to 2008, the largest area of growth among services provided by cardiologists was noninvasive imaging, which also represented the majority of allowed charges by cardiologists to Medicare.¹⁰ Our analysis showed that between \$34,511.85 and \$53,870.72 might be saved annually at our institution by using eFCU in place of TTE for these selected indications. The cost savings remained significant after models were adjusted to allow more time to perform eFCU and a higher physician wage rate. These findings are consistent with those of prior studies that have found similar decreases in cost and utilization. Trambaiolo *et al.*³⁰ found that routine outpatient use of eFCU could reliably reduce referrals for TTE, translating to significant cost savings. Greaves *et al.*¹² showed similar results among inpatients. Although our study was not designed to evaluate outcomes, other studies have shown that use of eFCU may lead to more rapid diagnosis and initiation of appropriate treatment, providing further evidence that judicious use of eFCU could provide quality care in an efficient manner.³¹ In an era when the US health care system is shifting toward bundled payments and accountable care organizations that reward efficient and high-quality care, the use of eFCU per our protocol could be an effective tool to deliver quality care at reduced cost.

Limitations

The limitations of eFCU must be taken into account before any protocol advocating its use is implemented. The lack of spectral Doppler, smaller display screen with lower resolution, and lack of acquisition modifications such as the ability to zoom make definitive characterization of certain pathologies, such as valvular disease, inappropriate for eFCU scope of practice. Furthermore, care should be taken to ensure that eFCU is indeed appropriate to perform in place of TTE, potentially by requiring the ordering clinician to succinctly describe any specific concerns or ongoing symptoms that prompted the ordering of a follow-up examination. However, when used judiciously and in the context of repeat imaging for very specific indications such as screening for changes in LV systolic dysfunction or pericardial effusion, eFCU has the potential to deliver quality cardiac imaging at reduced cost.

We made several assumptions in our cost analyses that were representative of practice patterns at our institution, such as sonographer and patient transport time, that may not be representative of practices elsewhere. Our cost analysis did not take into account the possibility of diagnostic errors using eFCU that might lead to excess costs. However, we attempted to minimize this possibility in the study design by using eFCU only for repeat TTE (and not for baseline evaluation of cardiac structure and function), only for the specific indications studied, and excluding patients in critical care units. It is also possible that because of the inability of care providers to accurately convey the precise clinical concerns that prompted ordering of repeat limited TTE, LV function was chosen as an indication even though reassessment of other parameters because of ongoing symptoms was desired. Most of the pericardial effusions in our study were small and did not require TTE to rule out cardiac tamponade. The number of repeat studies ordered at our institution may not be representative of ordering practices and patient populations elsewhere. We studied only eFCU by cardiologists with level II training in performance and interpretation; focused

cardiac ultrasound by noncardiologists or cardiologists with level I training may be more commonly used in some settings. eFCU parameters were assessed qualitatively and not quantitatively.

CONCLUSIONS

Findings from eFCU correlate well with findings from TTE when used in the setting of repeat testing for focused goals of assessing ventricular size and function, pericardial effusion, and IVC collapse. The use of eFCU in place of repeat inpatient TTE for these discrete indications has the potential to deliver quality cardiac imaging at reduced cost. These findings may be particularly useful to health systems transitioning to accountable care models.

Abbreviations used

eFCU	Expert focused cardiac ultrasound
IVC	Inferior vena cava
LV	Left ventricular
LVEF	Left ventricular ejection fraction
RV	Right ventricular
RVU	Relative value unit
TTE	Transthoracic echocardiography

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Figure 1.

Example images from eFCU (*left*) and TTE (*right*). (**A**) A patient status post atrial fibrillation ablation to rule out peri-cardial effusion, (**B**) a patient with metastatic cancer and a trace pericardial effusion, (**C**) a patient status post cardiac transplantation for follow-up of RV size and function, and (**D**) a patient with ischemic cardiomyopathy for follow-up of LV systolic function.

Figure 2.

Correlation of eFCU and TTE for the assessment of LVEF. eFCU and TTE showed excellent correlation for LVEF using the Spearman correlation coefficient ($r = 0.96$, $P < .001$), indicating the potential feasibility of replacing TTE with eFCU for assessment of LVEF in certain patients.

Figure 3.

Bland-Altman plot of the assessment of LVEF. Compared with TTE, the assessment of LVEF by eFCU showed only a small positive bias (bias = 1.3%; 95% CI, -8.1% to 10.7%), with a normal distribution, indicating good agreement between the two tests for assessment of LVEF per the study protocol.

Figure 4.

Per-study cost difference between eFCU and TTE. Cost analysis showed that the labor cost of performing TTE was \$73.16, compared with \$32.05 for eFCU in a wage-based model and \$8.99 for eFCU in an RVU-based model.

Table 1

eFCU protocol: parameters and grades

Parameter	Grade
Image quality	Adequate Inadequate
LV size	Normal Enlarged
RV size	Normal Mildly enlarged Moderately enlarged Severely enlarged
LV systolic function	Normal Mildly reduced Moderately reduced Severely reduced
RV Systolic Function	normal mildly reduced moderately reduced severely reduced
LVEF	Percentage
Pericardial effusion/thrombus	None Trace Small Medium Large
Chamber compression	No Yes
IVC collapse with inspiration	>50% <50%

Table 2Patient demographics, indications for repeat TTE, and echocardiographic characteristics ($n = 105$)

Variable	Value
Demographics	
Age (y)	59 $\pm$ 15
Body mass index (kg/m ²)	29 $\pm$ 5
Repeat TTE indication	
LV systolic function	49 (47%)
Pericardial effusion	45 (43%)
RV size or function	9 (9%)
Volume status	2 (1%)
Repeat TTE parameters	
LVEF (%)	52 $\pm$ 18 (55)
LV systolic function	
Normal	59 (56%)
Mildly reduced	17 (16%)
Moderately reduced	10 (10%)
Severely reduced	19 (18%)
LV size	
Normal	86 (82%)
Enlarged	19 (18%)
RV systolic function	
Normal	69 (66%)
Mildly reduced	19 (18%)
Moderately reduced	10 (10%)
Severely reduced	2 (2%)
Not well seen	5 (5%)
RV Size	
Normal	67 (64%)
Enlarged	32 (30%)
Not well seen	6 (6%)
Pericardial effusion	
None	74 (71%)
Trace	17 (16%)
Small	11 (10%)
Medium	2 (2%)
Large	1 (1%)
Chamber compression	1 (1%)
IVC collapse	
>50%	41 (39%)

Variable	Value
<50%	45 (43%)
Not well seen	19 (18%)

Data are expressed as mean $\pm$ SD, as mean $\pm$ SD (median), or as number (percentage).

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Table 3

Agreement between eFCU and TTE for selected imaging parameters

Variable	κ	<i>P</i>
LV systolic function	0.80	<.001
LV size	0.76	<.001
RV function	0.65	<.001
RV size	0.77	<.001
Pericardial effusion	0.81	<.001
Chamber compression	1.00	<.001
IVC collapse	0.64	<.001

Table 4

Labor and device costs for TTE and eFCU

Variable	TTE (RVU model)	eFCU (RVU model)	eFCU (wage model)
Labor/laboratory			
Physician			
Time (h)	—	—	0.25
Cost	26.00	0.00	92.25/h
Subtotal	26.00	0.00	23.06
Sonographer			
Time (h)	0.75	0.00	0.00
Cost (per hour)	31.93	0.00	0.00
Subtotal	23.95	0.00	0.00
Transporter			
Time (h)	0.5	0.00	0.00
Cost (per hour)	16.42	0.00	0.00
Subtotal	8.21	0.00	0.00
Overhead			
Cost	15.00	0.00	0.00
Labor/laboratory total			
Cost	73.16	0.00	23.06
Vscan			
Device			
Cost/scan	0.00	3.14	3.14
eFCU failure			
Cost/scan	0.00	73.16	73.16
Failure rate	0.00	8%	8%
Subtotal	0.00	5.85	5.85
Vscan total			
Cost	0.00	8.99	8.99
Total			

Variable	TTE (RVU model)	eFCU (RVU model)	eFCU (wage model)
Cost	73.16	8.99	32.05

All costs, subtotals, and totals expressed as dollars.