

# How Useful Is Hand-Carried Bedside Echocardiography in Critically Ill Patients?

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<b>OBJECTIVES</b>	The study compared a hand-carried echocardiography (HC) device with standard echocardiography (SE) in critically ill patients.
<b>BACKGROUND</b>	Recently, small HC devices have been introduced, and early reports showed a good correlation with SE.
<b>METHODS</b>	We used HC (SonoSite, Bothell, Washington) echocardiography to evaluate critically ill patients, and we compared the results with SE obtained with state-of-the-art equipment (Sonos 5500, Hewlett-Packard, Andover, Massachusetts). Each of 80 critically ill patients was studied twice (HC and SE). The studies were done and interpreted separately in blinded fashion.
<b>RESULTS</b>	The HC device missed a clinical finding related to the reason for referral in 31% of patients. In 19% of patients a clinically important finding separate from the indication for echocardiography was also missed. The total number of patients with one or more missed findings was 36 (45%). Findings were missed by HC for several reasons. First, HC does not contain spectral Doppler, electrocardiographic, or M-mode capabilities. Two-dimensional imaging is superior on SE, with improved image processing. In addition, although HC does contain color power Doppler, it does not have true color flow Doppler imaging. Therefore, HC often failed to detect or accurately quantify valvular regurgitation.
<b>CONCLUSIONS</b>	Although the HC device was able to provide important anatomic information, the device falls far short of SE in the evaluation of critically ill patients. (J Am Coll Cardiol 2001;37:2019–22) © 2001 by the American College of Cardiology

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Portable echocardiograms performed at the bedside can help the physician to diagnose and manage critically ill patients. Standard echocardiography (SE) equipment, while excellent, is large and unwieldy. Because of this it is sometimes difficult to maneuver in a crowded intensive care unit (ICU) setting. Additionally, standard machines are generally housed in the hospital's echocardiography laboratory and are not instantly available for use.

Recently, hand-carried echocardiography (HC) devices have been introduced (1–6). These devices are attractive because of their size, portability and cost. They can be kept

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in ICU settings to be immediately available for bedside use. Our study was designed to compare the diagnostic ability of a HC device compared to a SE machine when used in critically ill patients.

## **METHODS**

Emergent portable cardiac echocardiography was performed in 80 consecutive patients located in ICUs (47 patients), stepdown units (21 patients), the recovery room (6

patients) and the emergency room (6 patients). Each patient had two complete studies performed, one using a SE machine (Hewlett-Packard [Agilent] Sonos 5500, Andover, Massachusetts) and the other using a HC device (SonoHeart, SonoSite, Bothell, Washington). The transducer on the HC device is a 15-mm broadband 2- to 4-MHz device. The two studies were performed within 2 h of each other, and both were recorded for analysis (SE was recorded on standard videotape, and HC was recorded on a mini digital videocassette).

The SE included M-mode, two-dimensional (2D), color Doppler and spectral Doppler (pulsed and continuous wave). An electrocardiogram (ECG) was recorded simultaneously. The HC included 2D and color power Doppler (M-mode, ECG, standard color Doppler and spectral Doppler are not available on this machine). In each case, the studies (SE and HC) were performed by two different experienced sonographers who were blinded to the results of the other examination. For each patient, the two studies were interpreted by two different experienced echocardiographers, and these interpretations were also blinded.

For the purposes of the present study, SE was considered to be the gold standard, and results of the SE and HC studies were compared for each patient. Two comparisons were performed for each patient. The first was done to determine the ability of HC to answer the requested clinical question (the indication for the study). The second served to determine whether either SE or HC detected any additional clinically important findings.

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**Abbreviations and Acronyms**

- 2D = two-dimensional
- ECG = electrocardiogram
- HC = hand-carried echocardiography
- ICU = intensive care unit
- LVF = left ventricular function
- SE = standard echocardiography, echocardiograms

**RESULTS**

There were 99 clinical questions (indications) from the referring physicians in the 80 patients studied. These included left ventricular function (LVF) in 38 patients (48%), native valve function in 18 patients (23%), pericardial effusion or tamponade in 16 patients (20%), prosthetic valve function in 10 patients (13%), possible endocarditis in 5 patients (6%), possible thrombus in 2 patients (3%), diastolic dysfunction in 2 patients (3%) and miscellaneous in 8 patients (10%) (the total is >100% as some patients had more than one indication for echocardiography).

The HC device was able to evaluate 84 of 99 clinical questions (85%) (Table 1). Fifteen percent of questions could not be evaluated because of the HC device's lack of spectral Doppler capability. The unanswerable questions included 10 cases of prosthetic valve function, 2 of diastolic dysfunction, 1 severity of aortic stenosis, 1 degree of left ventricular outflow obstruction and 1 constrictive pericarditis. The SE was configured to answer all of the clinical questions.

Of the 84 clinical questions for which HC was configured to evaluate, it correctly evaluated 72 questions (86%) and missed findings relevant to the clinical question in 12 (14%) as compared with SE (Table 2). The missed clinical findings included LVF (6 findings), native valve function (4 findings), cardiac tamponade (1 finding) and left atrial thrombus (1 finding). There were two cases (2%) in which relevant findings were seen on HC and not on SE (both LVF).

Furthermore, beyond the 99 clinical questions asked, HC failed to diagnose 17 clinically significant findings in 15 patients (19%) diagnosed by SE (Table 3). The lack of spectral Doppler was the reason for not seeing four findings (pulmonary hypertension in three patients, two severe and one moderate, and the degree of left ventricular outflow tract obstruction in one patient). For the other 13 findings, HC had the configuration necessary to diagnose them but did not. These findings not seen by HC included significant mitral regurgitation in nine patients (severe in three, moderate to severe in two, and moderate in four), LVF in two

**Table 1.** Is the Hand-Carried Device Configured to Evaluate the Clinical Question? (n = 99)

	Yes	No
HC	84 (85%)	15 (15%)
SE	99 (100%)	0 (0%)

HC = hand-carried echocardiography; SE = standard echocardiography.

**Table 2.** Did the Hand-Carried Device Answer the Clinical Question for Which It Was Configured? (n = 84)

	Yes	No
HC	72 (86%)	12 (14%)
SE	82 (98%)	2 (2%)

HC = hand-carried echocardiography; SE = standard echocardiography.

patients, moderate tricuspid insufficiency in one patient and moderate aortic regurgitation in another.

In summary HC, when compared to SE, did not answer 27% of the 99 clinical questions asked by referring physicians (HC was not configured to answer 15%, and it also missed 12% of the findings that it was theoretically capable of detecting). Moreover, SE, and not HC, was able to diagnose additional clinically significant findings in 19% of patients. In nearly half of the patients (45%), HC missed one or more findings (primary and/or additional) (Table 3).

**DISCUSSION**

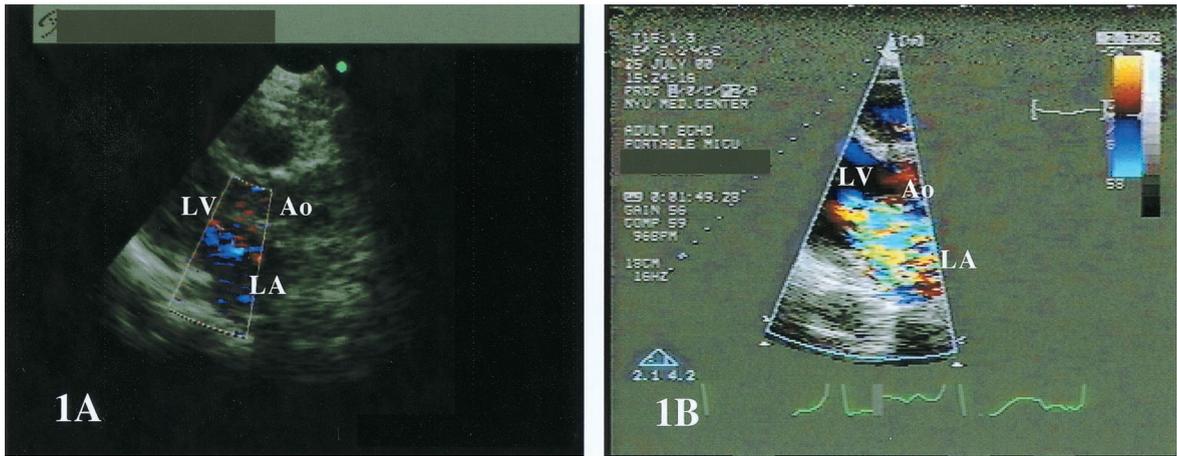
**Previously reported uses of HC.** Small, HC devices have recently been introduced, with favorable early reports in the outpatient setting (1), when used on hospital rounds (2), and in a small cohort of ICU patients (3). It has been shown to augment the results of physical examination in 25 patients referred for echocardiography (4) and in 35 patients examined on hospital rounds (2). Some of these reports have shown a good correlation between HC and SE for the evaluation of wall motion (5,6) and valvular regurgitation (5).

**Limitations of HC compared to SE.** However, it is not surprising that in our cohort of critically ill patients the results for HC and SE are frequently discordant. Critically ill patients are often difficult to image because of the inability to position them well, lack of cooperation, ambient light, tachypnea, artificial ventilation, surgical wounds, bandages, chest tubes and other factors. The state-of-the-art equipment used for SE has the ability to overcome some of these problems. The use of different transducer frequencies can improve the image, as can the use of second harmonics. Timing of events in the cardiac cycle is also possible with SE, which is equipped with both ECG and M-mode capabilities, and this may aid in the interpretation of

**Table 3.** Patients in Whom Findings Were Missed (n = 80)

	HC	SE
Patients with missed 1° finding	25 (31%)	2 (3%)
Device configured	9 (11%)	2 (3%)
Device not configured	15 (19%)	0 (0%)
Both	1 (1%)	0 (0%)
Patients with missed additional finding	15 (19%)	0 (0%)
Device configured	11 (14%)	0 (0%)
Device not configured	2 (3%)	0 (0%)
Both	2 (3%)	0 (0%)
Total patients with 1 or more missed findings (1° and/or additional)	36 (45%)	2 (3%)

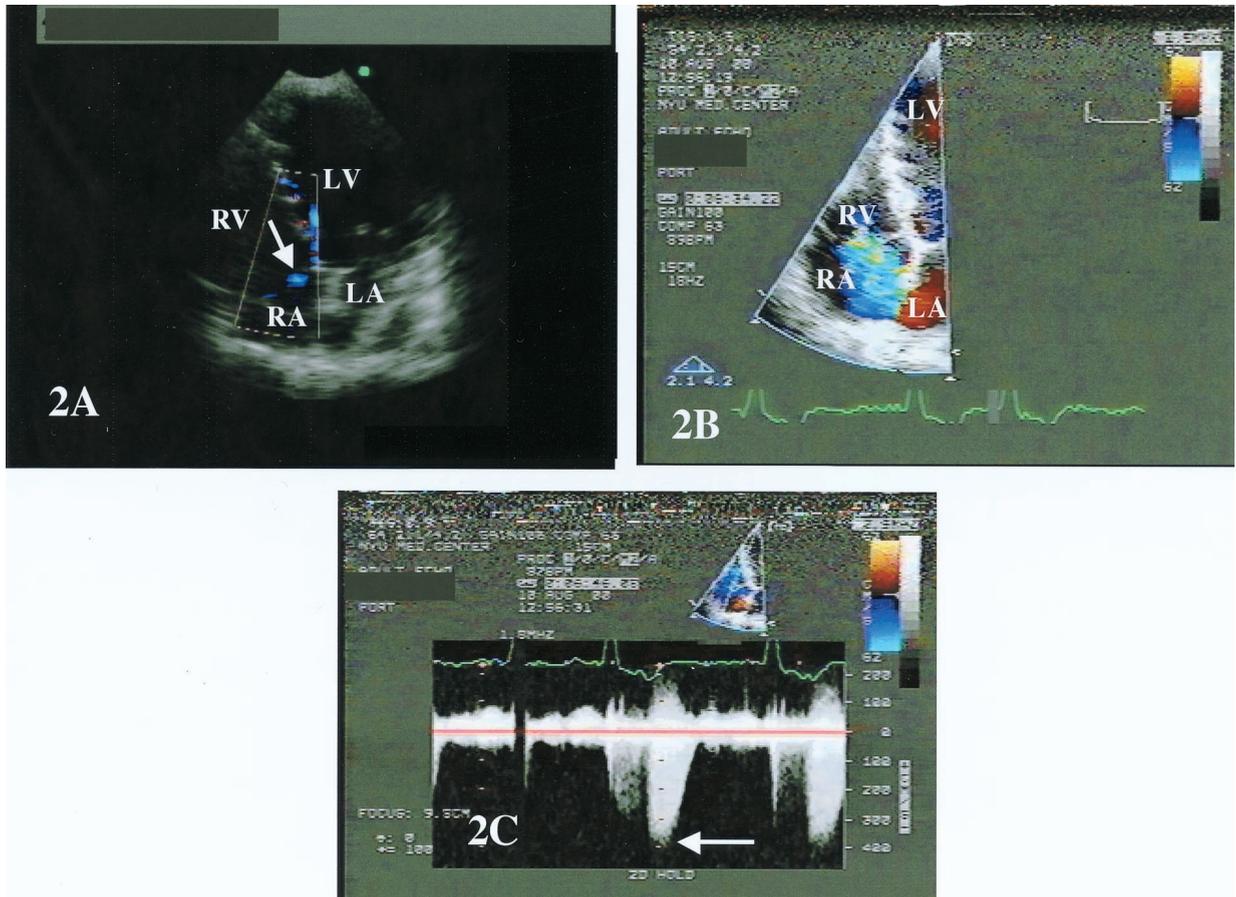
1° finding = finding related to question raised by referring doctor; HC = hand-carried echocardiography; SE = standard echocardiography.



**Figure 1.** Systolic frame, long axis parasternal views in a patient with dyspnea: (A) hand-carried echocardiography (with color power Doppler); (B) standard echocardiography (with color Doppler). Note that severe mitral regurgitation was seen easily by standard echocardiography (B) and not by hand-carried echocardiography (A). Ao = aorta; LA = left atrium; LV = left ventricle.

suboptimal images (e.g., timing of color jets and diastolic collapse of the right heart chambers in tamponade). Furthermore, color power Doppler (used in HC) lacks variance, which makes the identification of high-velocity,

turbulent jets more difficult (Fig. 1). Color power Doppler is a technique that measures the mean amplitude of the Doppler signal, not the Doppler shift as in standard color Doppler. Therefore, velocity is not measured and color



**Figure 2.** Systolic frame, apical four-chamber views in another patient with dyspnea: (A) hand-carried echocardiography (with color power Doppler) (arrow points to tricuspid regurgitation); (B) standard echocardiography (with color Doppler). Note that severe tricuspid regurgitation was seen easily in the right atrium by standard echocardiography (B) and not by hand-carried echocardiography (A). In addition, this patient has severe pulmonary hypertension (note continuous-wave Doppler with a 4-m/s velocity of tricuspid regurgitation [arrow] on standard echocardiography (C); this indicates a pulmonary artery systolic pressure of approximately 75 mm Hg). This critical information could not be obtained with hand-carried echocardiography, which lacks spectral Doppler. LA = left atrium; LV = left ventricle; RA = right atrium; RV = right ventricle.

power Doppler is non-aliasing. Although this may be advantageous for imaging low-flow states (as in tumor vessels) it is disadvantageous in imaging valvular regurgitant jets where aliasing serves to clearly outline these jets (7). Even in outpatients, one study did not find a good correlation between HC and SE with respect to the diagnosis of valvular regurgitation (1).

In addition, the footprint of the HC transducer is larger than that of SE, and this makes it difficult to place it in an intercostal space for the location of the best echocardiographic window. Furthermore, the lack of spectral Doppler is an important limitation of HC, as vital clinical findings such as pulmonary hypertension (Fig. 2), inflow or outflow obstruction, and signs of restriction or constriction may be missed without it.

In our study, significant pathology that was not related to the primary indication for the study was frequently diagnosed by SE and missed by HC. For example, a patient referred for possible left ventricular systolic dysfunction was found to have normal wall motion on both HC and SE; however, moderate tricuspid regurgitation and pulmonary hypertension (pulmonary artery systolic pressure of approximately 60 mm Hg) were found with SE and both were missed by HC. Therefore, the HC study could have been misleadingly reassuring to the referring physician as it reported normal wall motion.

Our major finding was that compared to SE, the HC device missed a significant finding in 36 critically ill patients (45%). The primary reasons for this were lack of sensitivity of the color power Doppler feature as compared to color Doppler flow imaging on SE for the detection of significant valvular regurgitation (14 patients), image-quality problems, leading to underdiagnosis of LVF (7 patients), pericardial tamponade (1 patient), and intracardiac thrombus (1 patient). In addition, the lack of a spectral Doppler feature is clearly a limitation of the HC system as currently configured, as demonstrated by the fact that important findings were not detected in 20 patients.

**Study limitations.** It is possible that clinical findings may have been missed by both HC and SE. In addition, although the reviewers were blinded to the results of the other study, they were not blinded to the type of machine used to record the study they were reviewing, as it was obvious from the taped images. This could have introduced bias. In addition, this study did not evaluate outcomes or the potential effect of HC or SE on patient management.

**Conclusions.** Hand-carried ultrasound technology has the potential to provide rapid, readily available and important clinical information in critically ill patients. Although the HC device was able to provide important anatomic information, the device falls far short of SE in the evaluation of critically ill patients. It is hoped that improvements in miniaturization techniques will lead to improved imaging and Doppler capabilities.

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