Handheld Ultrasound: Accurate Diagnosis at a Lower Cost?

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Cardiovascular physical examination has changed little since the 19th century, but medical practice, in the meantime, has changed substantially. The diseases we treat, the circumstances of patient evaluation, the ages and comorbidities of patients, the availability of diagnostic testing, and the implications of missed diagnoses in an era of effective therapy all pose challenges. The traditional bedside diagnostic method is a subjective process that is strongly operator dependent, has both low interobserver and test-retest consistency, and can be hard-copied, stored, and transmitted to others only incompletely and with difficulty (1). In addition to its fundamental limitations, the process is often performed poorly, with a high error rate (2). In contrast, diagnostic imaging has marched on with a strong evidence base that is subjected to repeated scrutiny and testing; we can detect the pathophysiologic analogs of jugular venous distention, gallops, pulmonary crackles, and pericardial function rubs, all bastions of the physical examination that could not be obtained from testing in a former era. In addition, imaging provides other information that physical examinations cannot, and this incremental information has important therapeutic implications. Although limited to 2-dimensional and color Doppler imaging, handheld ultrasound (HHU) devices provide high image quality, and previous work has shown the diagnostic content of studies performed with these systems is analogous to that of high-end ultrasound systems (3,4). Previous studies have documented the ability of medical students, medical residents, cardiology fellows, emergency department physicians, and surgical intensive care unit staff members to gather HHU information as an adjunct to the physical examination (4–6). HHU is a part of clinical training at many medical schools, and as these students graduate and move through the workforce, the reign of the stethoscope will be seriously threatened (7). Some would say this change is overdue.

The report by Mehta et al. (8) in this issue of JACC confirms the value of HHU as a diagnostic tool, but it takes us in a new direction as well. One consequence of the limitations of physical examination is its indiscriminate replacement by laboratory testing, leading to an expensive and inefficient process of “rarely appropriate” testing on high-end echocardiographic machines. What if HHU were the prelude to such testing? In this study, HHU was performed using a pocket-sized, battery-operated device (VScan, GE Healthcare, Little Chalfont, United Kingdom) that provides B-mode and color Doppler images but no spectral Doppler data. The investigators studied 250 patients referred for echocardiography for the investigation of common indications (cardiac function, murmur, stroke, arrhythmias, and some miscellaneous indications). Cardiologists completed a report (including suggestions for additional testing) after physical and HHU examination. HHU correctly identified 117 of 142 patients with abnormal findings on standard echocardiography, compared with 67 correctly identified by physical examination (82% vs. 47%, p < 0.0001). Predictably, this was most marked in patients with significant valve disease (71% vs. 31%, p = 0.0003). The investigators went on to examine the implications for further testing; this was suggested in 89 patients after physical examination, at least one-third more than after HHU (p < 0.0001). In addition to these findings, which are consistent...
TABLE 1 Where Should HHU Go in the Future?

<table>
<thead>
<tr>
<th>Existing Data</th>
<th>Future Needs</th>
<th>How to Progress</th>
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</thead>
<tbody>
<tr>
<td>Repeat testing</td>
<td>Limited data</td>
<td>Addition of spectral Doppler quantification, automation</td>
</tr>
<tr>
<td>Incidental findings</td>
<td>HHU more accurate than physical examination</td>
<td>Does it matter? Can we recognize findings as incidental and stop further investigations?</td>
</tr>
<tr>
<td>False positives</td>
<td>HHU finds more information than physical examination</td>
<td>How does the clinician integrate these findings?</td>
</tr>
<tr>
<td>True positives</td>
<td>HHU finds more true abnormalities than physical examination</td>
<td>Would these have been found anyway during course of normal strategies? How did knowing them change practice and outcomes?</td>
</tr>
</tbody>
</table>

HHU — handheld ultrasound; RCT — randomized controlled trial.

with previous research, these investigators undertook cost modeling to show that the complete (initial evaluation plus downstream) cost of the HHU-based evaluation was $644.43, compared with $707.44 for the evaluation based on the physical examination. These results are analogous to those of Greaves et al. (9), who performed an evaluation of HHU and full echocardiographic evaluation in 157 consecutive inpatients. In that study, the sensitivity and specificity of HHU for the prediction of normal results and normal left ventricular function were, respectively, 74% and 96%, and 81% and 100%. Greaves et al. (9) calculated that HHU screening before inpatient echocardiography would have reduced their echocardiography department’s workload by 29%, with a saving of approximately £150 per patient.

In the current era of attention to appropriate use and cost of testing, the results of the HHU testing are interesting in that they might improve selection of patients for definitive, laboratory echocardiography. The performance of inappropriate testing remains stubbornly high (between 10% and 20%) (10), reflecting a cohort of patients in whom clinicians consider that testing might be useful even if the indication for testing is rarely appropriate. When funding is likely to be tied to appropriate use, the use of HHU might provide a triage process for the definitive test. This study is an important step forward, but we may need more evidence to justify the desertion of the current referral process. The modeling presented by Mehta et al. (8) shows us the cost of evaluating the patient rather than informing management—or changing outcome. The threshold for further investigation may differ by individual and by region, reflecting physician preference as well as local practice patterns. Some of the identified findings might not have necessitated clinical decisions because of the patient’s age and comorbidities. Thus, a cost-effectiveness model (evaluation of cost against survival or quality of life after reasonable decisions about management) could be more informative than the cost-utility model. Although less critical for replacing a physical examination, some redesign of these devices may improve confidence in the diagnostic process. The availability of spectral Doppler would facilitate the clinical evaluation of heart failure with preserved ejection fraction and aortic stenosis, the prevalence of which is rapidly increasing. Similarly, easier image archiving would be helpful. Finally, the training aspect must be considered, especially in countries where sonographers rather than cardiologists are involved in image acquisition. Although the efficacy of HHU with training greatly improved the clinical diagnostic skills of medical students and junior doctors, over and above history, physical examination, and electrocardiographic findings in some studies (5,6,11), this has not been a uniform finding (12). A model in which HHU supports incomplete and possibly inaccurate physical examination is different from a model in which HHU is a gatekeeper to the echocardiography laboratory. The extent of the training required may not be trivial (13), and these imaging skills may not be uniformly attainable (14). However, the editors of iJACC believe strongly that as HHU becomes an important part of medical education, and residents routinely use HHU in day-to-day clinical practice, the training aspect will become moot.

Subsequent studies should provide further assessment of cost-effectiveness, perhaps by randomizing patients and examining not only subsequent costs but also outcomes. The existing evidence is based on
studies comparing physical examination with HHU, using a full echocardiographic machine as the arbiter of “truth.” This has served us well in terms of defining the accuracy of imaging with HHU, questions about training and operator ability, and possibly cost utility; what is not clear is whether the extra findings obtained with HHU are clinically significant, whether they need to be acted upon, and whether doing so changes outcomes. We now need answers to a different series of questions (Table 1); the endpoints should be comparing strategies and outcomes, not the performance of HHU against physical examination, with the referee being findings from a full-fledged system.

Irrespective of its merits in the decision-making process for test selection, the paper by Mehta et al. (8) acts as a timely reminder of the value of HHU. The growth of HHU is likely, irrespective of the cost-effectiveness of the use of the devices, as portable ultrasound is adopted in medical education. As its use spreads to most medical specialties, and machine costs decrease, more specialty societies will create guidelines and training pathways in ultrasound use. Primary care clinicians are likely to increasingly use focused examinations to gain immediate and management-changing information about their patients. In the meantime, cardiologists who trained in a former era may recognize that the incorporation of HHU may return physical contact to the cardiology consultation, as doctors spend more time at the bedside, reversing a secular trend that spans several decades (15,16). Perhaps the wider adoption of HHU will have an added benefit on the patient-doctor relationship.

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