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Time to Add a Fifth Pillar to Bedside Physical Examination
Inspection, Palpation, Percussion, Auscultation, and Insonation

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Inspection, palpation, percussion, and auscultation have been the 4 pillars of clinical bedside medicine. Although these basic methods of physical examination have served us well, traditional bedside examination, for a number of reasons including diminishing interest and expertise, performs well less than what is required of a modern diagnostic strategy. Improving the performance of physical examination is vital given that it is crucial to guide diagnostic possibilities and further testing. Current efforts at improving physical examination skills during medical training have not been very successful, and incorporating appropriate technology at the bedside might improve its performance. Selective use of bedside ultrasound (or *insonation*) can be one such strategy that could be incorporated as the fifth component of the physical examination. Seeing pathology through imaging might improve interest in physical examination among trainees, and permit appropriate downstream testing and possibly superior decision making. Current ultrasound technology makes this feasible, and further miniaturization of ultrasound devices and reduced cost will allow for routine use at the bedside. It is time to have a wider debate and a possible consensus about updates required to enhance current paradigms of physical examination.

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Invited Commentary

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For centuries, inspection, palpation, percussion, and auscultation have been the cornerstone of clinical bedside medicine. An ancient scroll from Charaka, written 2500 years ago, emphasized learning from "one who knows also how to use his hands, has the requisite instruments and all his senses about him."[1] The hands and senses inspect, palpate, and even percuss to make a diagnosis, and these practices have been faithfully transmitted over generations. Hippocrates[2] also insisted on using "sight, hearing, and touch." Unchanged patterns of examination have continued to be practiced, with one advance offered by the advent of the stethoscope about 200 years ago. These basic methods of physical examination have served us well, but their efficacy has been held as self-evident. Robust evaluation of the accuracy and precision of physical examination is lacking. While the benefit of physical examination is obvious in many conditions (such as dermatological diseases and some neurological diseases including Bell palsy or Parkinson disease), traditional bedside examination shows suboptimal performance in other conditions. This is especially true in cardiac diseases[3,4] where physical examination, historically, has been highly valued.

Can we improve on the usual physical examination techniques? Modern technology, such as imaging, has allowed us to often see rather than guess what is wrong with the patient and should be able to supplement bedside physical examination. However, a number of factors, such as uncertain costs, training issues, time limitations, and possibly nostalgia, seemingly prevent marrying technology with current physical examination practices. Our premise is that while physical examination cannot and must not be replaced by technology, it could be enhanced by incorporating the right technology at the bedside.

We believe that incorporating imaging will become a much-needed enhancer of the traditional techniques. This could be attained most efficaciously through selectively using bedside ultrasound imaging (or *insonation*) as the fifth component of the physical examination, after inspection, palpation, percussion, and auscultation. Miniaturization of ultrasound into self-sufficient transducers paired with the ubiquitous cell phones would blur the lines between physical examination and technology (**Figure**).

How Good Is the Physical Examination?

Hippocratic writings emphasized clinical perception by the "sight, touch, hearing, smell, taste, and the understanding."[2] This continued rather unchanged for 2 millennia, picking up new signs on the way but only using physicians' own physical senses until the arrival of the stethoscope. The antiquity and low direct cost of a physical examination has allowed it the luxury of being grandfathered into medical practice without the usual critical review that new diagnostic technologies must face. The stethoscope, the central lynchpin of physical examination, has also enjoyed a similar privilege. The likes of Aubrey Leatham, Samuel Levine, Paul Wood, and Proctor Harvey kept the art of auscultation alive for generations of medical students and clinicians. Everyone still agrees that good physical exami-

Figure. Concept and Design of Available Hand-Held Ultrasound Devices

Each of the many available devices has unique attributes and inherent limitations. The earliest designs included a dedicated ultrasound platform combined with display screen, such as VScan Extend (GE Healthcare) (A), connected to the transducer by a fixed cord. The transducers may carry one or both of deep rectangular head for visceral organ imaging and shallow linear probe for lung and vessel imaging. Other device formats have offered 1 to 3 somewhat bulkier transducers with inbuilt ultrasound platforms, such as Philips Healthcare (Lumify) (B), sector array 1 to 4 MHz, 2 to 5 MHz curved, and 4 to 12 MHz linear array, that communicate through a USB-enabled cord with standard handheld android or iPhone operating system–based tablets or phones as the display units. The progressive transducer design development has resulted in cordless transducers, such as Clarius Tri Scanner (C), that make adjustments in software to convert a curved array scanner traditionally designed for visceral scanning, into a virtual phased array for heart imaging and virtual linear array for line placements. The ultrasound transducer communicates with the display unit through direct WiFi or AirPlayAirdrop sans internet availability. The cost of the handheld devices range between US $5000 and $15 000, which is still prohibitive for use as personal devices. An innovative transducer has replaced piezoelectric crystals with a capacitive micromachined ultrasonic transducer chip that produces ultrasound at 1 to 10 MHz, enabling the entire body to be imaged; the chip is bonded to a complementary metal-oxide semiconductor chip, which takes on most of the compute functions (Butterfly Network, shown here exposed ultrasound-on-a-chip) (D); this has also broken the $2000 cost barrier. Further, boutique transducers are being conceptualized; for example, a thimblelike finger-mounted transducer (Sonivate Medical, E) would provide a hands-on extension of the physical examination that may enhance the patient experience. All devices allow cloud upload for image storage and recall. All images were provided by the respective manufacturers.

nation skills are indispensable, but even expert advocates of physical examination accept that the test performance characteristics of physical examination have been less than adequately studied and could be better.[3]

The limited available evidence suggests that physicians are using far less physical examination than in the past, they do not perform well when tested for its use, most practitioners (including cardiology fellows and faculty) are not proficient with the use of the stethoscope, and intense training efforts do not seem to make them better users.[5-9] Dwindling resources, time constraints on learning physical examination in the face of an ever-increasing load of medical information, a retiring generation of gifted teachers without skilled replacements, and the increasing complexity of disease have contributed to the underperformance of physical examination. In addition, a tendency to defer the diagnosis to the availability of supposedly better diagnostic methods (such as imaging) has diminished the desire among trainees to seek this art. Physical examination in some situations, such as annual health examinations, can be an example of unfocused testing where it scans multiple systems for pathology and is often not tailored to specific diagnosis. Further, like any test, it is affected by Bayesian probability[10,11] and is prone to diagnostic errors and false-positive findings that generate unnecessary downstream testing.[12] It is often forgiven because physical examination is erroneously thought to cost little. Errors with physical examination do not generate as much consternation as a false-positive imaging test result. The former is passed off as uncertainty

of the art of medicine that would eventually be salvaged by downstream testing, often with imaging. Not surprisingly, both patients and physicians at all levels of training or expertise prefer diagnostic testing for more objective data, while their confidence in the utility of physical examination is low.[10,11]

Is Insonation or Bedside Ultrasound Examination the Solution?

A richer physical examination with a greater likelihood of correct diagnosis might rectify what master clinicians have lamented about declining physical examination skills and bring back the confidence of patients in bedside physical assessment. A major limitation for trainees in getting excited about the physical examination is that it feels, from much daily experience, inaccurate and unrewarding for making a complete diagnosis in most patients, as opposed to its clear value in establishing pretest probability and subsequent plan of action. The brilliance of master clinicians at the bedside who clinched the diagnosis is a rare occurrence now, and late stage of diseases where such clues became apparent are increasingly infrequent. Incorporating technology that has both better positive and negative predictive values into physical examination at the bedside should improve diagnostic ability and also replenish the lost interest in physical examination. In the long run, evidence that it works and makes bedside evaluation easier for both the patient and the clinician is far more likely to increase interest in physical examination than countless hours of lamenting the lost art or insisting on repeated retraining in current formats.

The most promising technology that could improve accuracy of diagnosis at the bedside is point-of-care ultrasound[13] using small handheld systems (Figure). It would be best to think of these handheld ultrasound devices as an extension of the stethoscope. This arguably provides better meaning to the Hippocratic insistence of using "sight, touch, hearing… and understanding"[2] at the bedside, a focused interrogation that may add no more than 5 to 10 minutes to the physical examination. Miniaturization has allowed development of pocket-contained systems that can blend seamlessly into the bedside physical examination. Such miniaturized ultrasound devices have been subjected to more rigorous scrutiny than traditional physical examination alone. They have been found to be superior in various settings and when used by a diversity of health care professionals.[4,14-24] This supports the contention that it may be the time to designate insonation as the next pillar of physical examination. When Rene Laennec developed the stethoscope (*stethos*, chest and *scope*, to see), it must have been named so because auscultation could allow a physician to indirectly "look" into the chest when there were no other means to do so; however, the classical stethoscope involves listening rather than looking and should have been called a *stethosphone*. Gastroscope, colonoscope, otoscope, laryngoscope, or ophthalmoscope are all instruments that are able to visualize the target organ, and now that we have an ultrasound probe, we are closer to a true stethoscope that would allow us to actually look into the chest.

The use of the handheld systems without carefully defining how best to use them has caused some anxiety that these devices were meant to replace physical examination, and this confusion might have slowed its adoption. Bedside imaging should not be thought of as replacing or even displacing current practice of physical examination but additive for understanding physiology and pathology and an internal validation of physical findings. It is meant to be used thoughtfully and selectively to answer specific questions at the bedside, rather than substituting full echocardiographic studies if subsequently needed.

How Does Bedside Insonation Compare With Physical Examination and Standard Ultrasound Examination?

Bedside ultrasound imaging not only performs better than physical examination alone but also offers a more accurate diagnosis at a lower cost.[4] In a study of 250 patients referred for full echocardiographic examination, insonation allowed for accurate identification of the abnormality in 82% vs 47% with physical examination. It allowed superior detection of valve disease (71% vs 31%; $P < .001$), reduced downstream testing (56% vs 82%; $P < .001$), and resulted in cost savings. Insonation as a part of physical examination also helped uncover additional pathologies not otherwise evident by physical examination and allowed reclassification of patients leading to change in treatment strategy in up to one-fifth. Addition of ultrasound imaging to the standard bedside physical examination has performed particularly better for correctly identifying the presence of less severe disease.[4,15-17] It is increasingly being adopted by internists[18]; it has proved to be cost-effective,[19] has allowed discharge of patients from clinic,[15] and helped predict likelihood of hospitalization, particularly in patients with heart failure.[20]

A number of studies have demonstrated that bedside ultrasonography compares favorably with a standard echocardiographic study.[21,22] The bedside imaging missed 4% of the major findings, but among the patients in whom the cardiologist did not see a need for a full echocardiographic examination, insonation helped detect unsuspected major abnormalities missed by the physical examination alone in 17%.[21]

Physicians at different levels of training and experience greatly improved their diagnostic performance beyond history, physical examination, and electrocardiogram after a brief training for bedside ultrasonography.[23] A study of first-year medical students trained only for 18 hours in ultrasound imaging[24] demonstrated that they were able to detect pathology in 75% of patients with known cardiac disease, while board-certified cardiologists using stethoscopes could do so only in 49%. The diagnostic specificity of the students (85%) was greater than the cardiologists (75%). Similarly, internal medicine residents using bedside imaging were able to improve their diagnostic assessment of left ventricular function and hypertrophy and valvular disease. While medical students and inexperienced physicians can be rapidly trained in insonation, amount of training required to achieve optimal results under widespread clinical use is a subject of intense discussion.

Incorporation of Insonation in Clinical Practice

If the results of incorporating insonation within the spectrum of physical examination are sufficiently convincing, why has it not been widely accepted? We often make a mistake of pitting current physical examination and insonation as an either/or situation. Many phy-

sicians have become concerned that introducing technology at the bedside will somehow diminish the rich tradition of examination using just our senses, which we have preserved for centuries. This debate is often possibly clouded by fears that insonation might displace or diminish methods that have served us well[7,25] or that it would contribute to further decline in physical examination skills. Anecdotes of occasional cases where imaging missed the diagnosis have also been used as proof for the primacy of physical examination.[26] This debate has also generated multiple opinion pieces.[8,27] In reality, it should not be a bedside imaging vs stethoscope or auscultation vs insonation debate, but a debate about using methods that enhance establishing a correct diagnosis rapidly and inexpensively. Insonation is a complement to our senses at the bedside and should be evaluated as a part of the physical examination protocol.

New technology has always had detractors, and history is witness to instances where new technology was often stymied shortly after its introduction. This happened even with the stethoscope. Sir James MacKenzie, an esteemed British cardiologist during the early years of 20th century, is quoted to have said "[it] not only for one hundred years hampered the progress of knowledge of heart affections, but had done more harm than good, in that many people had had the tenor of their lives altered, had been forbidden to undertake duties for which they were perfectly competent, and had been subject to unnecessary treatment because of its findings."[28,29] The blood pressure cuff was felt not only to "intervene between patient and doctor" but also to "dehumanize the practice of medicine."[30] The electrocardiogram was derided by none other than the leading physical examination proponent Samuel Levine in as late as 1949 that "greater the time spent in taking 3 electrocardiographic leads (… later 9 and now 12) the less time is left to elicit an adequate history or to auscultate the heart properly."[28]

Considerable work must still be carried out to understand the full clinical implications of incorporating insonation as the fifth pillar of physical examination. Its incorporation will need to show improved selection of patients for downstream testing. At the same time, pricing trajectory for ultrasound imaging during examination and how it affects the economics of the clinical enterprise will need to be determined to put this technology in context at the bedside. In addition, insonation, presumably more than physical examination alone, might uncover many more incidental findings and early-stage disease unrelated to the clinical question that brought the patient to the clinician; this might have added clinical and resource implications. Thoughtful training on how to formulate a question that is best answered accurately with bedside imaging, how to determine when an incidental finding needs further evaluation, and, most importantly, how to integrate findings accrued from insonation into the information obtained from history and physical examination, must be the cornerstone of its use. Teaching paradigms should emphasize the chain of information: a patient's history informs the physical examination, and both together inform and drive the use of bedside imaging. Finally, questions remain about how best to impart training to the users at various levels of expertise. Initial findings suggest that participation in a short but focused course is effective for both medical students and junior residents,[23,31-34] but training requirements and challenges associated with it should not be underestimated.

Bedside Technology and Patient-Physician Relationship

Patients greatly value an ongoing, in-person relationship with their physicians. For a variety of reasons, physicians have been able to spend less and less time at the bedside over the last several decades.[5,35] Incorporation of insonation in the physical examination may have an added benefit of actually prolonging direct physical contact time between patient and physician and thereby enhancing their relationship. Proponents of the stethoscope portray it as a pivotal moment in patient-physician interaction and fear that adding technological devices may make the physical examination less personal and take away the magic of human interactions. This argument may have had some validity if one was discarding the stethoscope, but is not the case in the current model where insonation comes, if necessitated by the clinical question, after the use of stethoscope. Both physicians and patients would not respect physical examination if it were not diagnostic and just pro forma; insonation proffering visible proof of pathology might make patients more compliant with advice. Giving a more accurate diagnosis and asking for focused high probability onward testing will do far more to the patient-physician relationship than any amount of scattershot physical examination. Additionally, the 5 to 10 minutes of contact with the patients while performing the bedside imaging examination will add to the patient experience, allow for asking more focused questions, and uncover findings that used to be missed earlier such as asymptomatic low ejection fraction and left ventricular hypertrophy seen in stage B heart failure or effusions not causing hemodynamic compromise.

Conclusions

From the evidence, it may be concluded that an appropriate inclusion of insonation in physical examination allows us to "learn to see, learn to hear, learn to feel, and know by practice," as Sir William Osler has put it,[2] more completely and accurately than the standard physical examination. We believe that the most practical enhancement to bedside physical examination could be provided by incorporating handheld ultrasound devices. The imaging-assisted physical examination must be considered as a part of the bedside examination for situations in which it can add value. It is emphasized that bedside imaging is neither meant to replace physical examination nor full-scale imaging if needed subsequently. It is time to add a fifth pillar to the armamentarium of modern physical examination, insonation, with a miniaturized, portable handheld device.

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