In defence of auscultation: a glorious future?

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Received 8 November 2016
Revised 9 January 2017
Accepted 10 January 2017

ABSTRACT

Auscultation of the heart using a simple stethoscope continues to be a central aspect of the cardiovascular examination despite declining proficiency and availability of competing technologies such as hand-held ultrasound. In the ears and mind of a trained cardiologist, heart sounds can provide important information to help screen for certain diseases such as valvar lesions and many congenital defects. Using emerging technology, auscultation is poised to undergo a transformation that will simultaneously improve the teaching and evaluation of this important clinical skill and create a new generation of smart stethoscopes, capable of assisting the clinician in quickly and confidently screening for heart disease. These developments have important implications for global health, screening of athletes and recognition of congenital heart disease.

INTRODUCTION

Twenty years ago, the noted cardiologist Morton Tavel wrote a provocative essay entitled 'Cardiac auscultation: a glorious past—but does it have a future?'[1] Ten years later, he updated his comments with a follow-up piece, concluding 'it *does* have a future!', in which he described a roadmap to transform auscultation using emerging technologies.[2] But here we are, another decade later, still debating the value of the stethoscope, which has been declared dead by some, fuelled simultaneously by studies showing declining auscultation skills and the superiority of echocardiography over the stethoscope.[3 4] Before sending the stethoscope to the morgue, it may be significant to note that many cardiologists, including all of my colleagues, still use theirs on a daily basis. This is interesting since they practice in settings where echocardiography is usually readily available and are certainly capable of using hand-held ultrasound (HHU) without any additional training if they felt the need. Yet they still put stethoscope to chest, whether or not an echocardiogram has been done, indicating there must still be added value in listening. Putting aside arguments that auscultation is still quicker, cheaper, more instantly and universally available than ultrasound and that using the stethoscope allows practitioners to connect with the patient in a personal, tangible way that exemplifies they care about and listen to the patient as a unique, valued individual, would and should they really continue to use it if the information itself was not at least somewhat useful? I mention cardiologists first, not because the value of the stethoscope is relevant only or even most importantly to them, but they have a unique opportunity to compare the results of their auscultation findings with echocardiography on a daily basis, allowing them to refine their skills and update their opinions as to the value of the stethoscope. This experience can lead to sensitivities and specificities over 90% for detecting pathologic murmurs,[5–8] which probably explains the reluctance of those that still auscultate to abandon something that works, but also, if there was no correlation between heart sounds and echo findings, cardiologists would likely for the same reason be among the first to discard the stethoscope.

Yet, eminent cardiologists have recently weighed in on the role of auscultation in their clinical practice. Valentin Fuster, MD, PhD, Editor-in-Chief of the *Journal of the American College of Cardiology*, pronounced the stethoscope's prognosis as 'very much alive and very necessary', citing six examples where auscultation was essential just in the previous 48 hours of his clinical practice.[9] Kim Allan Williams Sr, MD, FACC, president of the American College of Cardiology, blogged 'The stethoscope is certainly not dead. Learning to correctly interpret heart sounds reinforces the understanding of normal and abnormal physiology. The fact that doctors are failing to obtain and maintain this skill is something we should work to improve'.[10]

If auscultation still seems to have practical value for cardiologists, what can be done to enhance the value of auscultation to similar levels for all practitioners? Using large databases of heart sounds, can we speed up the learning curve, test the proficiency and create auscultation aids to make auscultation more useful? To date, almost all clinical auscultation has been done with the human ear and brain, with virtually no help from technology other than that provided by Laennec's rolled quire of paper[11] and, more recently, with electronic versions of the rolled quire, that offer basic amplification and filtering. But now technology is available and ready to revolutionise the value of auscultation while maintaining familiar, simple workflows, transforming the stethoscope into an even more efficient tool with more universal accuracy and consistency, potentially even enabling detection of abnormalities not previously appreciated by the human ear and brain.

SEEING IS NOT ALWAYS BELIEVING

The proponents of replacing the stethoscope with HHU proclaim seeing is believing,[12] and understandably so, since instead of listening to the sounds created by aortic stenosis (AS), why not just look at an image created by ultrasound reflection from the diseased valve itself? Instead of listening for a murmur indicating the presence of a ventricular septal defect (VSD), why not just look at the septum during the course of your physical examination to see if there is a defect or not? At face value this makes good sense, and certainly most cardiologists when suspicious of AS or a VSD will obtain an echo

To cite: Thompson WR. *Heart Asia* 2017;**9**:44–47. doi:10.1136/heartasia-2016-010796

as an essential part of the evaluation to confirm their suspicions and provide important morphologic and hemodynamic information to appropriately manage the patient. But likewise, cardiologists know from experience how challenging and potentially frustrating it can be at times to obtain, review, measure, document and archive cardiac images, especially when a simple listen can mean no imaging is necessary. Seeing while performing an echo is sometimes initially believing, until on further review, when less preoccupied with obtaining the images, the initial impression is revised. This takes time and focus, skill and experience. This is not easily taught in a short course, and proficiency for performing this task is only gained after much experience, similar to auscultation. Thus, while the workflow of routine use of HHU may initially appear comparable to the traditional physical examination when measured without additional time spent re-examining images, mistakes of omission and commission will be made following that paradigm. Although consensus guidelines have attempted to differentiate focused cardiac ultrasound (FCU) used as part of the physical examination from traditional echocardiography, important practical concerns are raised by the expert writing group.[13] 'The implications of following-up on abnormalities detected by routine use of FCU at the time of physical examination, many of which would be false positives, needs to be considered. In addition, the potential impact of failure to refer symptomatic patients for complete echocardiographic evaluation, because of a "normal" FCU physical examination, needs to be considered. The infrastructure to educate and train all physicians who perform physical examination in FCU would be a massive undertaking'.

There are of course potential appropriate uses for HHU, such as in the emergency room or intensive care unit where the pretest probability of heart disease is increased and the additional training required to develop the skills needed to perform and interpret these studies is therefore justifiable. Likewise, in areas with high risk of rheumatic heart disease, incremental benefit of screening with echocardiography over auscultation has been demonstrated.[14] However, even for those settings, simply solving the problems of miniaturisation, cost and initial training is only a helpful start towards creating a useful tool that works well as a supplement to existing echo resources. Images contain information that can definitively diagnose diseases. As such, the tolerance for underdiagnosis or overdiagnosis even in the hands of non-cardiologists should be low, and despite consensus guidelines to the contrary,[13] archiving these images may ultimately be desirable and required for optimising patient care through review and comparison to prior studies and to justify and review actions or inactions taken as a result, with all the associated costs and requirements of video data management and storage. In fact, a significant shortcoming of traditional auscultation has been the lack of a saved record of the heart sounds for documentation and comparison, and advocating imaging without archiving would create similar problems.

CAN HEARING BE BELIEVING TOO?

Hearing, in the appropriate situations, is also believing and can be sufficient, even if not as sensitive, specific or fully informative as ultrasound. In practice, if the goal is to quickly screen for an abnormal valve or septum among patients at low risk for having disease, the incremental value of imaging does not stand up quite as well against auscultation. Additionally, once a definitive diagnosis is made by echo, in many cases enough can be surmised by a quick follow-up auscultation to make repeat imaging at every subsequent encounter unnecessary and of no incremental benefit. Cardiologists, as the traditional gatekeepers of echocardiography, may have in the past been more likely to perform an echo on patients even when they had low suspicion of heart disease, as overuse of technology was not as big a concern as possibly missing pathology, no matter how unlikely, and additional testing was incentivised. But times are changing and current mandates are to optimise outcomes with the dual goal of reducing diagnostic errors *and* unnecessary testing. The American Society of Echocardiography has recently developed consensus guidelines for appropriate use of echo in adult and paediatric patients.[15 16] Among the appropriate uses of echo is to look for heart disease in adults and children with a pathologic murmur. Pathologic murmurs are only known to be present if someone has listened to the patient with a stethoscope. If recently convened groups of experts in both adult and paediatric cardiology have concluded that echocardiography needs to be justified, and a gateway justification involves the use of auscultation, how can we abandon the stethoscope? Also, even though these guidelines were meant to inform referral decisions for echocardiography as a diagnostic test and not as part of the physical examination as in FCU, images are the product of both the complete and the focused echo, whether or not the ultrasound device is large or hand-held. Thus, if imaging is not deemed an appropriate diagnostic test for some referral reasons by knowledgeable experts, is it logical to think it should be considered necessary and appropriate for every routine physical examination?

In the paediatric echocardiography laboratory at Johns Hopkins, we perform over 10 000 echocardiograms annually. In 2014, we did 1383 first-time echocardiograms on outpatients aged under 18 years, 183 (13%) of which were ordered because of a heart murmur with no other signs or symptoms of heart disease (M. Cartoski, personal communication). Of these, the murmur description had features of an innocent murmur in 86, all but one of which had either no heart disease or minor abnormalities not requiring follow-up. Of the 97 with a pathologic murmur, 55 had significant findings requiring either surgery, cardiac catheterisation or cardiology follow-up in the next 2 years. This group constituted by far the largest percentage yield of abnormal findings among all the reasons for first-time outpatient echo, highlighting the value of auscultation as an important screening tool in paediatrics to discover heart disease before onset of symptoms. These data also show that distinguishing innocent from pathologic murmurs is needed in order to avoid unnecessary echocardiograms, especially in paediatrics where 60%–70% of patients have innocent murmurs yet <1% have congenital heart disease. Improving auscultation skills and developing alternative ways to analyse heart sounds would help the busy clinician to screen for patients with pathologic murmurs.

WHAT SHOULD WE BE DOING WITH THE STETHOSCOPE INSTEAD OF TRADING IT IN FOR A HAND-HELD ULTRASOUND DEVICE?

First, a consensus statement with expert review and opinion of the current status, merits, pros and cons of cardiac auscultation with recommendations regarding appropriate use of auscultation would be helpful in guiding training decisions, manpower allocation and industry poised to develop strategies to assist in the transformation of auscultation.

Next, training should be re-evaluated using these guidelines with the goal of developing new paradigms indicating what specifically needs to be taught and how to best evaluate competency for recognising those findings. Finley[17] has published an excellent review of current methods for improving cardiac

auscultation. Recent studies show specific difficulties for learning certain findings,[18] the confirmation of which could lead to a realistic, goal-oriented statement of the specific aims of auscultation training. We are beginning to understand the biologic mechanisms involved in learning to recognise heart sounds, which may eventually lead to technological innovation to enhance auscultation training given inherent limitations of the human ear and brain.[19] Training and proficiency testing modules are now available, including websites with large collections of heart sounds (https://murmurQuiz.org), recordings demonstrating key findings (Heart Songs—American College of Cardiology) and multimedia training programmes (http://www.Blaufuss.org), but studies addressing the clinical impact of these efforts are currently lacking.

Algorithms have been developed over the past 20 years using advanced signal processing and artificial intelligence methods, borrowing knowledge from submarine detection and speech recognition technologies, with sensitivities and specificities approaching that of the experienced clinician.[20–23] These advances may in the near future allow the practitioner to listen to heart sounds with an electronic stethoscope while simultaneously analysing the sounds for feature content predictive of pathology. Similar to automated ECG diagnosis, the result will be an automated 'reading' of the heart sounds with creation of an archived recording and visual representation for future retrieval and comparison. However, in order for these methods to become clinically useful, a standardised, rigorous testing method must first be developed. A large testbed of heart sounds should be assembled with careful attention to recording technique, anonymised and thoroughly vetted clinical information associated with each set of sound files and ground truth echocardiography data along with expert description of the recorded sounds. Regulatory agencies such as the Food and Drug Administration as well as industry and clinicians would then be able to compare new algorithms to existing ones to determine incremental improvements and validate performance claims without the time and expense of first having to assemble large cohorts of patients or gather new data, which may not be comparable to datasets used to validate prior art.

Once algorithms have acceptable accuracy in clinical practice, they will reduce variability inherent in unassisted auscultation making it possible to avoid unnecessary and costly referrals and diagnostic testing. Enhanced auscultation will play an important role in routine clinical practice, pre participation evaluation of athletes to detect signs of hypertrophic cardiomyopathy and screening for patients with valvar or congenital heart disease in resource-limited areas.

CONCLUSION

This past week, I reviewed an echo done by one of our experienced paediatric sonographers on a girl aged 16 years with an eating disorder and tachycardia. After spending 25 min performing a careful, complete echo on this patient with excellent echo windows, the sonographer came to me and said the entire study was normal except for a large VSD. Since our sonographers are so good, I hesitated to point out the obvious, that it is highly unlikely that this girl would have a previously undetected large VSD. I looked at the images, and indeed saw what appeared to be a large inlet or posterior muscular VSD, both by imaging and colour Doppler. I went into the room to examine the patient and repeat the imaging of the ventricular septum myself. During my brief physical examination, I found she was not clubbed, had no evidence of heart failure and had a normal second heart sound with no murmur, clinically ruling out a VSD. However, to explain the echo findings, I spent several more minutes obtaining sufficient imaging and colour Doppler to definitively prove that the apparent 'defect' was the result of false dropout and the colour Doppler signal was due to diastolic tricuspid valve inflow, confused by the sonographer in the setting of tachycardia. A 'rooky' mistake indeed, but what is significant is the fact that it was made by a highly skilled sonographer, working in a busy echo lab for the past 6 years. The total time it took to perform, review and repeat portions of this echo was 30 min, compared with the 30 s it took to definitively rule out the false-positive echo finding by physical examination.

At the other end of the spectrum, earlier this past month, we sent for surgery a child aged 13 months with a large VSD, who had both prenatal and postnatal echocardiograms interpreted as normal by an outside hospital. Fortunately for the patient, the paediatrician eventually decided to refer the child to us despite these two normal studies due to the presence of a pathologic murmur. Our echo showed a large VSD and pulmonary hypertension and the patient was immediately referred for surgery.

These two recent anecdotes highlight both the potential pitfalls of imaging and the ability of auscultation in the appropriate setting to confirm cardiac health or detect the presence of serious heart disease. In both cases, the physical examination allowed for greater understanding and more accurate interpretation of the results of imaging. Using technology we are now poised to improve auscultation skills, set standards for proficiency and develop automated pathologic heart sound detection algorithms to assist the busy clinician or the underserved area without access to trained healthcare workers or advanced technology. The future of auscultation, like its past, is starting to sound glorious.

Competing interests None declared.

Provenance and peer review Commissioned; externally peer reviewed.

REFERENCES

1 Tavel ME. Cardiac auscultation: a glorious past—but does it have a future? *Circulation* 1996;93:1250–3.
2 Tavel ME. Cardiac auscultation. *Circulation* 2006;113:1255–9.
3 Mangione S, Nieman LZ. Cardiac auscultatory skills of internal medicine and family practice trainees. A comparison of diagnostic proficiency. *J Am Med Assoc* 1997;278:717–22.
4 Mehta M, Jacobson T, Peters D, *et al*. Handheld ultrasound versus physical examination in patients referred for transthoracic echocardiography for a suspected cardiac condition. *JACC Cardiovasc Imaging* 2014;7:983–90.
5 Geva T, Hegesh J, Frand M. Reappraisal of the approach to the child with heart murmurs: is echocardiography mandatory? *Int J Cardiol* 1988;19:107–13.
6 Smythe JF, Teixeira OHP, Vlad P, *et al*. Initial evaluation of heart murmurs: are laboratory tests necessary? *Pediatrics* 1990;86:497–500.
7 McCrindle BW, Shaffer KM, Kan JS, *et al*. Cardinal clinical signs in the differentiation of heart murmurs in children. *Arch Pediatr Adolesc Med* 1996;150:169–74.
8 Jost CH, Turina J, Mayer K, *et al*. Echocardiography in the evaluation of systolic murmurs of unknown cause. *Am J Med* 2000;108:614–20.
9 Fuster V. The stethoscope's prognosis: very much alive and very necessary. *J Am Coll Cardiol* 2016;67:1118–19.
10 Williams KA. *The stethoscope lives*. American College of Cardiology, In Touch Blog, 18 January 2016.
11 Laennec, RTH, *De l'Auscultation Médiate ou Traité du Diagnostic des Maladies des Poumons et du Coeur*. Paris: Brosson & Chaudé, 1819.
12 Mulvagh SL, Bhagra A, Nelson BP, *et al*. Handheld ultrasound devices and the training conundrum: how to get to "seeing is believing". *J Am Soc Echocardiogr* 2014;27:310–13.
13 Spencer KT, Kimura BJ, Korcarz CE, *et al*. Focused cardiac ultrasound: recommendations from the American Society of Echocardiography. *J Am Soc Echocardiogr* 2013;26:567–81.
14 Beaton A, Okello E, Lwabi P, *et al*. Echocardiography screening for rheumatic heart disease in Ugandan school children. *Circulation* 2012;125:3127–32.
15 Douglas PS, Garcia, MJ, Haines DE, *et al*. ACCF/ASE/AHA/ASNC/HFSA/HRS/SCAI/SCCM/SCCT/SCMR 2011 Appropriate Use Criteria for Echocardiography. *J Am Soc Echocardiogr* 2011;24:229–67.

16 Campbell RM, Douglas PS, Eidem BW. *et al*. 2014 ACC/AAP/AHA/ASE/HRS/SCAI/SCCT/SCMR/SOPE Appropriate Use Criteria for Initial Transthoracic Echocardiography in Outpatient Pediatric Cardiology. *J Am Coll Cardiol* 2014;64:2039–60.
17 Finley JP, *Teaching heart auscultation to health professionals*. Canadian Pediatric Cardiology Association, 2011.
18 Kumar K, Thompson WR. Evaluation of cardiac auscultation skills in pediatric patients. *Clin Pediatr* 2013;52:66–73.
19 De Meo R, Matusz PJ, Knebel JF, *et al*. What makes medical students better listeners? *Curr Biol* 2016;26:R519–20.
20 Thompson WR, Hayek CS, Tuchinda C, *et al*. Automated cardiac auscultation for detection of pathologic heart murmurs. *Pediatr Cardiol* 2001;22:373–9.
21 DeGroff CG, Bhatikar S, Hertzberg J, *et al*. Artificial neural network-based method of screening heart murmurs in children. *Circulation* 2001;103:2711–16.
22 Watrous RL, Thompson WR, Ackerman SJ. The impact of computer-assisted auscultation on physician referrals of asymptomatic patients with heart murmurs. *Clin Cardiol* 2008;31:79–83.
23 Lai LS, Redington AN, Reinisch AJ, *et al*. Computerized automatic diagnosis of innocent and pathologic murmurs in pediatrics: a pilot study. *Congenit Heart Dis* 2016;11:386–95.