A personal ultrasound imager (ultrasound stethoscope)  

A revolution in the physical cardiac diagnosis!

J. R. T. C. Roelandt

Department of Cardiology, Thoraxcentre, Erasmus University Medical Centre Rotterdam, Rotterdam, The Netherlands

Introduction

By providing an enormous amount of qualitative and quantitative information obtained in a short period of time and its high versatility in application, echocardiography has become the most widely used and cost-effective cardiac imaging method. It has contributed significantly to the reduction of cardiovascular misdiagnosis since 1971[1]. Since it is often the best or even the only applicable method, it has largely supplanted other imaging modalities in a wide variety of health care environments.

Miniaturization and digital techniques have resulted in the development of high resolution battery-powered personal and portable ultrasound imaging devices with excellent grey-scale and colour blood flow imaging capabilities. These personal imagers are appropriately named ‘ultrasound stethoscopes’ since they allow the chest to be examined (stehos=chest and skopein=see). They can be used anywhere, as part of the clinical examination, just like a conventional stethoscope.

In this short review, we outline the potential behind using a small ultrasound imager in different clinical scenarios and how ‘the echocardiograph in your pocket’ will change the practice of physical examination and diagnosis.

Personal ultrasound imagers

Recently, two small personal ultrasound imagers, based on miniaturized digital technology, have been introduced (SonoHeart®, SonoSite, Inc. Bothell, WA, U.S.A. and OptiGo®, Agilent Technologies, Andover, MA, U.S.A.). They make use of phased array transducers and provide high-resolution two-dimensional dynamic grey-scale images combined with colour Doppler flow imaging (directional for the SonoHeart®).

Both imagers operate on a rechargeable battery or AC current and have measurement packages including linear measurement callipers. The internal memory of the SonoHeart® stores 50 images which can be downloaded into a PC and there is a video output, which can be connected to a monitor or to a VCR for permanent recording. The OptiGo® archives images using a CompactFlash card for documentation.

Other companies are also developing miniaturized ultrasound imaging systems. The Terason® device (Teratech Corp., Burlington, MA, U.S.A.) has the ultrasound system incorporated in the transducer and connects to commercially available PC platforms.

These small personal ultrasound imagers should not be confused with the portable desktop systems which are full featured systems and include pulsed and continuous wave Doppler. The examination procedure with these devices is the same as with standard echocardiography and all precordial windows can be used for structure and blood flow imaging. Our 1 year experience with the SonoHeart® device indicates that morphological data, obtained in standard cardiac views and basic linear measurements of structures and cavities, adequately compare with those documented with standard equipment[2].

Clinical scenarios

Physical examination

The physical examination remains the cornerstone of the initial evaluation of a patient with suspected cardiovascular disease. However, notable shortcomings in
examination skills, and more particularly in auscultation, have been documented even after training with innovative instructional methods including patient simulators. In addition, over the years, echo/Doppler studies have revealed the limitations of the physical examination in many cardiac conditions, particularly in the early stages of disease.

It is now common experience that a limited echo/Doppler examination is able to provide more diagnostic accuracy, together with quantitative information, than the physical examination including inspection, palpation and auscultation. We have to accept the shortcomings of the physical examination and that seeing the heart provides additional information beyond what we can perceive with palpation and auscultation.

The ultrasound stethoscope extends the perception of our physical examination by direct ‘visualizing the invisible pathology’. Murmurs and abnormal movements can be directly related to cardiac structural, functional and flow abnormalities. The device allows rapid confirmation of a cardiac abnormality during a routine physical examination (valve disease, shunt, cavity dilatation, hypertrophy, pericardial effusion, wall motion abnormality) and often enables a specific diagnosis to be made in any clinical setting (Fig. 1). Incidental findings can be regularly recognised. The physical cardiac examination can be extended by imaging and by limited quantitative measurements of the inferior vena cava, liver, spleen and abdominal aorta. The major strength of a limited echo/Doppler examination is its specificity; a cardiac abnormality can be excluded with certainty after limited training.

**Goal-oriented echocardiography**

Standard echocardiography involves a comprehensive examination with complex equipment by an operator with considerable training and experience. However, the diagnosis and follow-up of many cardiac conditions requires only a fraction of the potential of these expensive facilities and a specific clinical question can often be answered in a short time and with few examination protocols. The ultrasound stethoscope is very suitable for such a limited ‘goal-oriented’ examination. The resolution of a pericardial effusion after a pericardiocentesis involves cardiac dimensions and left ventricular function, both of which are important parameters in the follow-up of many patients. These are rapidly assessed at the bedside (agreement for semi-quantitative left ventricular size assessment between standard echocardiography and SonoHeart in 111 consecutive patients was 99%; kappa value 0·970 and for ejection fraction 93%; kappa value 0·871). Patients with hypertension and left ventricular hypertrophy have an increased risk of a cardiovascular event and the success or failure of their antihypertensive treatment can be assessed by wall thickness measurements (Fig. 2). A limited ‘goal-oriented’ echocardiographic examination will undoubtedly be valuable in the future, on initial clinical screening by primary care physicians via telecommunication technology, to identify or exclude a cardiac condition in the future.

**Critical care environment**

The ultrasound stethoscope can effectively assist in the initial evaluation and rapid diagnosis of potentially life threatening conditions or in situations where quick decision-making is essential. In many such situations standard echocardiography is not rapidly available. The ultrasound stethoscope, carried by the attending cardiologist, provides data inaccessible by clinical examination and enables an immediate diagnosis to be made, or an emergency tamponade (Fig. 3), a dilated heart or valvular pathology (e.g. calcific aortic stenosis in low output state) to be ruled out. Immediate echocardiographic assessment in the emergency room has been reported to considerably shorten the time to diagnosis of penetrating cardiac injury and to improve the chances of survival. Right ventricular involvement in acute myocardial infarction and the mechanical complications of a myocardial infarction are readily diagnosed in the
intensive care unit. Pericardiocentesis can be guided and the effects of acute interventions (e.g. fluid challenge in hemodynamically compromised patients, inotropic drugs) monitored through estimation of cavity dimensions, ejection fraction and wall dynamics.

Regional wall function abnormalities can be reliably detected (90% agreement in 204 segments of 34 patients), a potential which can be utilized in chest pain clinics. Here rapid screening would provide the context of acute chest pain and provide a non-diagnostic electrocardiogram.  

**Screening**

The ultrasound stethoscope could be used for screening and identifying unexpected cardiac disorders with a low prevalence in a specific population. However, the sensitivity of these devices for identifying certain conditions is still to be defined and the competence of the examiner is another important aspect to consider.

The ultrasound stethoscope allows rapid screening of occult aortic abdominal aneurysms in ‘at risk’ patient groups (patients with coronary artery disease, hypertension, the elderly). Physical examination is notably insensitive in moderately enlarged aneurysms and obese patients. Aortic diameter measurements compared well to those obtained with standard equipment (agreement 97% in 100 consecutive patients; kappa value 0.810) and are obtained in a few minutes during a routine physical examination (Fig. 4).

In patients with arterial hypertension, left ventricular hypertrophy is not always apparent from the electrocardiogram. Limited echocardiography allows left ventricular hypertrophy to be screened (agreement with standard echocardiography in 100 consecutive patients 92%; kappa value 0.730) and the effect of treatment in office practice to be followed.

Mitr valve prolapse is often suspected in otherwise asymptomatic individuals. This disorder can be excluded or confirmed in a limited number of standard views. Screening of athletes may become an important application of a personal ultrasound imager since potentially dangerous conditions can be identified at low cost. Hypertrophic cardiomyopathy, a dilated aorta (Marfan) and valvular abnormalities (bicuspid valve, mitral valve prolapse) are the most common disorders and are reliably detected. However, screening for cardiac disorders in young athletes and asymptomatic individuals involves a high risk of a false positive diagnosis and should be performed by well trained and experienced clinicians.

**Discussion**

Fluoroscopic visualization of the heart was introduced soon after the discovery of X-rays by W. C. Rontgen in 1896. In 1904, W. Rollins described the ‘Seehear’, a device combining a fluoroscope with a standard stethoscope. This illustrates the eagerness of clinicians to actually see cardiac pathology during the physical examination and to extend their clinical perception of auscultation with ‘seeing’. Clearly, ultrasound offers obvious advantages over X-rays, both in the construction of the device and in the practical use of a small personal imager.

We had already developed and were using a miniature ultrasound imager as early as 1978. However, limited imaging performance and reimbursement issues dampened the enthusiasm of cardiologists who were confronted in those days with the rapidly expanding...
capabilities and applications of high-end ultrasound systems. Now, technology has furthered the construction of personal imaging systems with excellent structure and blood flow imaging. Expanding our routine physical examination with a small personal imager will significantly strengthen our diagnostic accuracy. On the basis of normal structure and functional findings in the absence of blood flow turbulence, all of which can be tested in a limited number of imaging views, a cardiac disorder can be excluded with a high degree of certainty. This high negative predictive value is ideal for rapid screening, to avoid referral of normals, and to make more cost-effective use of our expensive diagnostic imaging facilities with quantitative Doppler functions.

Personal imagers will therefore have an impact not only on the physical examination but also on the use of echocardiography and other imaging modalities by targeted referral. A major application will be its use in a critical care environment. Direct diagnosis, or exclusion, of some life threatening conditions will shorten delays in therapy and lead to important cost-savings. These devices are extremely suited to limited ‘focussed’ ultrasound examination, to follow the course of a disease, or to test the effect of therapy in the outpatient clinic in office practice.

Obviously, a small ultrasound imager cannot substitute for the high-end ultrasound systems. Therefore, its use involves compromises some of which are still
unknown and will be learned when applications are expanded. Training of non-echocardiographers may become an important issue and should focus on criteria of normalcy and identifying both major and acute cardiac disorders. In fact, the device should be used in a way comparable to auscultation; whenever there is doubt, further echo/Doppler examination is indicated. Training programmes and continuing medical education including performance testing, can be organised with modern electronic means. In the future, advances in communications and software will allow for diagnostic support from experienced laboratories or intensive care units.

Many small devices, even of pocket size, are now being developed with increasing capabilities and offer ease of use similar to the standard stethoscope (the echocardiograph in your pocket!). These devices will undoubtedly revolutionize our physical cardiac examination. However, it should be remembered that the real value of any imaging technology is intimately dependent on our intellectual contribution: how, when and in what clinical scenario will it have its optimal clinical impact?

References