The future of cardiovascular imaging and non-invasive diagnosis†

A joint statement from the European Association of Echocardiography, the Working Groups on Cardiovascular Magnetic Resonance, Computers in Cardiology, and Nuclear Cardiology, of the European Society of Cardiology, the European Association of Nuclear Medicine, and the Association for European Paediatric Cardiology

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Received 21 March 2006; accepted 20 April 2006

KEYWORDS
Cardiovascular imaging; Clinical services; Training; Guidelines; Research

Advances in medical imaging now make it possible to investigate any patient with cardiovascular disease using multiple methods which vary widely in their technical requirements, benefits, limitations, and costs. The appropriate use of alternative tests requires their integration into joint clinical diagnostic services where experts in all methods collaborate. This statement summarizes the principles that should guide developments in cardiovascular diagnostic services.

Introduction

Continuing developments in medical technology and clinical research constantly expand the range of imaging tests and diagnostic measurements. Nowhere is this more true than in cardiology, where the choice of investigations includes different technologies with overlapping capabilities. How should clinicians, hospital managers, and funding bodies respond and adapt to these changes? How should the demands of different approaches be reconciled to the benefit of patients? What are the implications for the education and training of future cardiologists, cardiac surgeons, and other specialists in cardiovascular imaging?

Collaboration between imaging subspecialties

Important information for the diagnosis and management of patients with cardiovascular disease can be provided by ultrasound examination including echocardiography, by scintigraphy using single photon and positron emitting radiopharmaceuticals, by magnetic resonance with or without a paramagnetic imaging agent, and by X-ray computed tomography or cardiac catheterization and angiography with the injection of an iodinated contrast agent. These alternatives encompass a wide spectrum from non-invasive investigations with no associated risks, through non-invasive tests that require exposure to ionizing radiation, to invasive procedures with a small risk of major complications.

Diagnostic cardiac catheterization is increasingly conducted by cardiologists who also perform interventions, and this trend is likely to continue. The progression to therapy by percutaneous intervention makes coronary arteriography a unique imaging modality because of its direct and immediate link to treatment, but the limitations of arteriography, well demonstrated by intravascular ultrasound, mean that it may be appropriate in non-urgent cases to
reserve the invasive approach for patients in whom abnormal haemodynamic function or ischaemia has already been confirmed. Invasive tests of perfusion reserve can aid clinical decision-making during a coronary procedure, but with this exception, precise haemodynamic investigation of cardiovascular pathophysiology is now performed during cardiac catheterization less frequently than before.

The selection of which test to use to establish a diagnosis of abnormal function should be based on a broad perspective and expert knowledge of what each available technique can offer. This is possible only if colleagues experienced in each imaging modality collaborate fully, so that choices are not constrained by knowledge or practice limited to a single technology.

It follows that experts in different imaging subspecialties should produce joint recommendations and guidelines from which shared diagnostic protocols can be developed and promulgated. These may require the development of new criteria for summarizing the outcome of diagnostic studies, which vary from those now in common usage for the assessment of therapeutic studies. In addition when there is a diagnostic component of general clinical guidelines, then an expert in all the relevant imaging modalities should be included in the writing group.

Collaboration should of course also embrace non-invasive and invasive services because these approaches are complementary rather than competitive. This can be achieved when there are appropriate funding and resources for both. Colleagues who specialize in either approach should have some education and experience in all imaging modalities.

Evidence-based diagnostic practice

Best diagnostic practice should be based on impartial professional advice. Some investigations, such as the exercise ECG, were widely implemented before they had been adequately assessed, and some new technologies are evolving so fast that thorough assessment is very difficult. Nonetheless, investment in new imaging technologies for routine practice can only be justified when there is clear scientific evidence that the new modality is substantially better and preferably also more cost-effective than prior alternatives.

Talk of ‘winners’ and ‘losers’ and confrontational debates, are inappropriate. Advice should be based on clear data from well-conducted research establishing accuracy (preferably against an independent reference criterion), reproducibility, and safety. Most importantly, diagnostic tests should be evaluated and compared for their impact on clinical outcomes, not just on their attainment of more precise diagnoses or more impressive images. Relevant outcomes might include a reduction in complications or hospital admissions, or an improvement in quality-of-life, as well as survival.

Different imaging technologies and tests may be appropriate for screening asymptomatic individuals or for identifying a disease and then monitoring its response to treatment. The utility of applying a test may vary between populations and within populations between individuals with different pre-test probabilities of disease. Some tests may be very effective in the controlled conditions of a clinical research study, but inefficient in routine clinical practice. Feasibility and costs can vary greatly between technologies that are capable of demonstrating the same diagnoses. When alternative tests are equally useful, their safety and convenience to the patient may differ. All these issues need to be assessed and acknowledged in recommendations. An organizational framework could usefully be established for the systematic evaluation and meta-analysis of diagnostic tests, analogous to the Cochrane collaborations that now overview therapeutic trials (www.cochrane.org).

Joint imaging strategies

The clinical use of diagnostic imaging technologies available in a cardiac unit and hospital should be coordinated through a joint service (Figure 1). This should be managed by a group of specialists including clinicians and radiologists and chaired by an expert in several cardiovascular imaging modalities. There is much more to ‘imaging’ than pictures—so colleagues with clinical and technical expertise together can exploit the potential of new techniques for studying both anatomy and pathophysiology. Rather than ‘imaging’, perhaps a new term will emerge as current subspecialties converge and a new type of multi-modality diagnostic specialist evolves.

It is established that echocardiography and coronary arteriography are performed within cardiology departments under the supervision of cardiologists. Nuclear cardiology is usually managed by a team of experts including physicists or nuclear medicine physicians and cardiologists. The integration of these technologies into daily practice has greatly enhanced their diagnostic impact and indirectly their therapeutic potential. The newer tomographic imaging techniques, such as magnetic resonance and X-ray computed tomography, have been developed by radiological and cardiological research groups, and it is appropriate and timely now to integrate them also into clinical practice. This process will be helped by a shift of diagnostic expertise, from specializing in a particular technique that is applied by cross-sectional imaging to multiple organs, to an organ- or system-based approach where the diagnostic expert is more concerned with function, the integration of results into clinical decision-making, and the impact of diagnostic imaging on clinical outcomes.

For logistic and physical reasons, it may not be feasible to locate tomographic imaging machines geographically within the cardiological departments of many hospitals. This need

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**Figure 1** Suggested organization of joint, multi-disciplinary diagnostic services; SCINT nuclear scintigraphy, PET positron emission tomography, CT X-ray computed tomography, and CMR cardiovascular magnetic resonance.
not allocate funds to joint cardiovascular research initiatives that encompass clinical research in diagnostic imaging in conjunction with research in mechanical and electronic engineering, informatics and biostatistics, and epidemiology. Medical equipment companies cannot be expected to fund such research; collaboration between universities and research engineers in industry is very important, but major clinical research should be conducted without specific company sponsorship.

The increasing precision of non-invasive diagnosis paradoxically makes it more difficult to determine whether or not a patient has subclinical disease because the influences or associations of risk factors and age on arterial and myocardial structure and function can now be identified. This makes it necessary to establish very large databases of normal subjects which are relevant to each country or major region. Population studies with precise phenotypic definition by new diagnostic techniques, undertaken in conjunction with genetic investigations, may yield important insights into the interaction of genetic and environmental influences and thereby offer directions for new epidemiological approaches to the prevention of common diseases. Such projects will need to be organized as multi-centre collaborations.

Academic cardiologists who organize large clinical trials of new drugs with support from pharmaceutical companies should take expert advice about recent diagnostic advances whenever they design a new study. This will avoid any time-lag between testing new drugs and implementing new tests for detecting changes with optimal sensitivity and accuracy.

Universities should recruit, encourage, and support academic cardiologists to develop and retain expertise in clinical physiology and diagnosis. These are necessary and legitimate interests for an academic department, which should be developed in conjunction with expertise in basic science and genetics.

Implications for training

There should be joint educational programmes that rotate fellows who are training in cardiovascular medicine, among echocardiography, cardiovascular magnetic resonance, nuclear cardiology, and X-ray computed tomography, with optional experience for example in positron emission tomography or vascular ultrasound if it is available. Training time should be time-tabled and protected. For prospective general cardiologists, this experience is perhaps more important than time allocated for training in diagnostic cardiac catheterization because the non-invasive diagnostic department is now the place where fellows observe and learn in detail about cardiovascular function, myocardial perfusion, and pathophysiology. Such experience provides a sound understanding of mechanisms of disease, which forms the essential foundation for logical clinical practice.

Cardiovascular radiologists have their own training programme, which includes particular experience of radiation safety, medical physics, and technological factors required to perform, optimize, and interpret tomographic imaging. Expertise in these aspects is important for the safe and appropriate clinical implementation of advanced diagnostic imaging techniques, and therefore, radiologists and physicists have a particular contribution to make to joint
diagnostic services. At the same time, radiologists who wish to become more closely involved in a clinical service should obtain some experience during their training within that clinical specialty, both of mechanisms of disease and of the clinical utility of the diagnostic tests.

Acquiring theoretical and practical expertise in several diagnostic techniques presents major challenges, but there is a need for imaging specialists who have multiple skills. The goal of joint educational programmes should be to train cardiologists or cardiovascular radiologists who have the knowledge, skills, and experience to assume clinical responsibility for organizing, supervising, and reporting diagnostic tests in at least two different modalities (and ideally in all current modalities). Physicians who have clinical responsibility for non-invasive diagnostic imaging should have obtained national or European accreditation in their chosen subspecialties; cardiologists in this role should have completed a special fellowship in advanced diagnostic methods in addition to general cardiological training. Accreditation should be maintained through participation in continuing medical education, which should be supported financially by employers.

Cardiac departments need at least as many non-invasive experts as colleagues who perform coronary interventions, if advances in diagnosis and monitoring of disease are to be implemented fully for the benefit of patients. Doctors in training who want to choose non-invasive cardiology as their special interest should be rewarded similarly to those working in other subspecialties. Recruitment should be based on interest and not skewed by disincentives caused by extraneous non-clinical factors.

Clinical cardiologists should not personally perform or report investigations such as echocardiography or scintigraphy unless they keep up-to-date, for example by participating in hospital reporting sessions and case-review conferences and by attending national or international courses and conferences. Cardiac surgeons in training should undertake specific education in non-invasive cardiovascular imaging as well as in the interpretation of arteriography, as they need to understand the potential and limitations of any technique that is used to establish a pre-operative diagnosis. They should also be familiar with techniques that are used to assess the outcome of surgery, such as intra-operative transoesophageal echocardiography. A component of continuing medical education for all cardiologists and cardiac surgeons should relate to advances in diagnostic imaging and their clinical implementation and value.

Practitioners who undertake limited diagnostic imaging, for example with hand-held echocardiographic machines, should also complete approved training and participate in appropriate continuing medical education.

Conclusions

- Experts in different imaging modalities should collaborate not compete.
- Joint clinical services and common diagnostic pathways should be developed.
- Future diagnostic specialists should be trained in several imaging modalities.
- Diagnostic tests should be evaluated by their impact on clinical outcomes.
- Diagnostic guidelines should compare all methods that can be applied to a particular clinical question.
- New criteria should be developed for judging the quality of diagnostic research.
- Expertise in imaging should be encouraged and funded as an integral component of basic, epidemiological, and clinical collaborative research networks.

Our professional groups will now pursue these objectives jointly, both within the European Society of Cardiology and also through collaborations among the medical professional societies in Europe that are concerned with diagnostic imaging in cardiovascular disease.

Acknowledgements

This document has been reviewed and endorsed by the members of the Board of the European Association of Echocardiography, by the members of the Nuclei of the Working Groups on Cardiovascular Magnetic Resonance, Computers in Cardiology, and Nuclear Cardiology of the European Society of Cardiology, and by members of the Cardiovascular Committee of the European Association of Nuclear Medicine. We thank all our colleagues for their helpful comments. We also thank Professor Matthijs Oudkerk, President of the European Society of Cardiac Radiology, for his helpful advice.

Conflicts of interest: none declared.

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