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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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Abstract 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 summarises the principles that should guide developments in cardiovascular diagnostic services. © 2006 The European Society of Cardiology. Published by Elsevier Ltd. All rights reserved.

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 catheterisation 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 ionising radiation, to invasive procedures with a small risk of major complications.

Diagnostic cardiac catheterisation 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 catheterisation 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 summarising the outcome of diagnostic studies that vary from those now in common usage for the assessment of therapeutic studies.¹ 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 since these approaches are complementary rather than competitive. This can be achieved when there are appropriate funding and resources for both. Colleagues who specialise 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 organisational framework could usefully be established for

the systematic evaluation and meta-analysis of diagnostic tests, analogous to the Cochrane collaborations that now overview therapeutic trials² (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 (Fig. 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

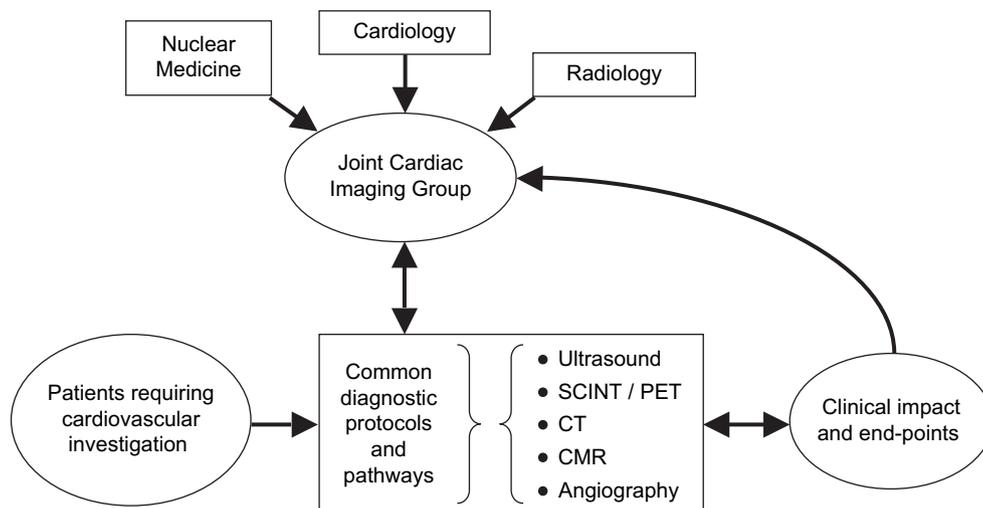


Figure 1 Suggested organisation of joint, multidisciplinary diagnostic services. SCINT, nuclear scintigraphy; PET, positron emission tomography; CT, X-ray computed tomography; CMR, cardiovascular magnetic resonance.

into clinical practice. This process will be helped by a shift of diagnostic expertise, from specialising 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 not prevent planning for such an arrangement in future, when resources and local circumstances or new buildings allow it. What is much more important than the location of equipment or the background and specialty of the staff who perform examinations, however, is that all disciplines work together and that services are coordinated. A joint department is not necessary, but a joint service where patients follow agreed common clinical investigative pathways, should become the norm. These pathways should be reviewed regularly and modified in response to feedback from their impact on outcomes (see Fig. 1), and also to take account of the preferences of patients.

A common channel for processing requests for sophisticated diagnostic tests is preferred, since it allows recommendation or selection by experts of the most appropriate test in any specific circumstance. It is important to avoid duplication of tests and to prioritise locally according to available facilities and expertise. Selection of a single test in a patient, when it has been shown to have clinical value, is preferred to a succession of tests based on different technologies, used in turn after each previous test has given ambiguous or uncertain results.

Ideally, algorithms for the investigation of cardiac patients by tomographic imaging should be established jointly by cardiologists and radiologists. If new methods are to be properly evaluated and implemented, then access should be unhindered. The cardiological indications for best use and cost-effectiveness of magnetic resonance and X-ray computed tomographic imaging need to be established by clinical research in departments where there are no major financial barriers to their use, and where equivalent expertise is available for all modalities that are compared.

When direct access to diagnostic services is offered to non-cardiovascular specialists or to primary care physicians, then patients should

be referred to a joint diagnostic team; the investigation will then be performed either by a cardiologist or by a cardiovascular radiologist as part of the combined service. Ideally, reports should be issued jointly by cardiologists and radiologists, but in principle a study can be performed and interpreted by any appropriately trained specialist.

Priorities for research

The prevailing trend is to emphasise the importance of basic biomedical, molecular and genetic research³ and to allocate the largest share of resources to these fields of enquiry. These programmes have significantly advanced our understanding of the mechanisms of disease, but in order to translate developments into any major clinical impact on the prevalence, morbidity or mortality of common cardiovascular diseases such as atherosclerosis, hypertension, diabetes and heart failure, it is necessary also to develop more sophisticated tests for the precise measurement of vascular and cardiac function and the effects of new treatments. Clinical diagnostic expertise with sensitive and accurate characterisation of early disease and its progression is required to assist further progress, and cardiovascular imaging has a key role to play in meeting this challenge. The best basic science needs to be combined with the best imaging methods.

Governmental and European Union grant-funding bodies should 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 organised as multicentre collaborations.

Academic cardiologists who organise 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 that 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, between 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 timetabled and protected. For prospective general cardiologists, this experience is perhaps more important than time allocated for training in diagnostic cardiac catheterisation, since 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, optimise 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 organising, 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 subspecialties⁴; 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, since they need to understand the potential and limitations of any technique that is used to establish a preoperative diagnosis. They should also be familiar with techniques that are used to assess the outcome of surgery, such as intraoperative transesophageal 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 between the medical professional societies in Europe that are concerned with diagnostic imaging in cardiovascular disease.

Acknowledgement

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