Stress echocardiography in clinical practice: a United Kingdom National Health Service Survey on behalf of the British Society of Echocardiography

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Aims
Stress echocardiography (SE) is one of the leading modalities for the assessment of coronary artery disease and dynamic valvular heart disease. A wide range of different techniques have been established. There are no data which identify how current techniques have been integrated into clinical practice.

Methods and results
An electronic questionnaire was devised to identify SE practice in five core areas: service demographics, indications, methods, reporting, and adverse events. The questionnaire was sent to 198 National Health Service hospitals. Eighty-five (71%) out of the 120 departments who perform SE responded. Each unit performed a median of 400 SE (inter-quartile range 175 – 600). Thirty-two (37.6%) operators performed 100 SE per year. Exercise, dobutamine, dipyridamole, adenosine, and pacing SE were available in 57 (67.1%), 85 (100%), 6 (7.1%), 11 (12.9%), and 34 (40%) units, respectively. Eighty-one (95.3%) units performed SE for the evaluation of low-flow, low-gradient aortic stenosis. Thirty-four (40%) and 32 (37.6%) performed SE for the evaluation of asymptomatic severe aortic stenosis and symptomatic moderate mitral regurgitation, respectively. Eighty-three (97.6%) administered contrast agents during SE. Additional analysis of perfusion and strain was performed in 9 (10.5%) and 13 (15.3%) units, respectively.

Conclusion
SE has been incorporated into the majority of UK hospitals. A substantial proportion of operators perform less than the recommended number of procedures per year. The use of exercise SE, vasodilator SE, and SE for the evaluation of VHD are under-utilized. Penetration of new techniques is variable, contrast for left ventricular opacification has been almost universally adopted, while myocardial perfusion and mechanics are used much less.

Keywords
Stress echocardiography • Coronary artery disease • Valvular heart disease

Background
Over the past three decades stress echocardiography (SE) has emerged as one of the leading modalities for the evaluation of coronary artery disease. Clinical applications within this setting include detection of ischaemia, assessment of myocardial viability prior to revascularization, and prognostic evaluation and risk stratification in pre-operative assessment.¹⁻⁴ The utility of SE has expanded further to include the assessment of valvular heart disease, in particular, low-gradient, low-flow aortic stenosis and dynamic mitral regurgitation and stenosis.⁵⁻⁷

A range of methods, including exercise, inotropic, and vasodilator stress, have been developed with a high sensitivity and specificity for detection of coronary artery disease.⁸ Newer techniques including contrast for left ventricular optimization and perfusion, strain imaging, and 3D echocardiography are being applied to SE.⁹⁻¹¹

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Stress echocardiography in clinical practice

Significant experience and expertise is required for performing SE safely as the technique and protocol used for a particular patient is individualized.

The European Society of Cardiovascular Imaging (EACVI) and the American Society of Echocardiography (ASE) guidelines provide expert advice on the optimal way to conduct and interpretation of SE for each indication with the lowest risk of adverse events.8,12 There are no data which identify how these guidelines and the latest evidence base are incorporated into daily clinical practice. We, therefore, sought to investigate the current practice of SE by conducting a national evaluation of SE within the United Kingdom National Health Service (NHS).

Methods

Identification echocardiography departments

A list of all NHS hospitals was obtained from the NHS website list (www.nhs.uk). Each hospital was contacted by telephone to determine whether they had an echocardiography department. Each echocardiography departments was then contacted to identify whether they perform SE. The contact details of the clinical or technical head of echocardiography were obtained.

Questionnaire design

An electronic questionnaire was designed to identify the current clinical practice of SE within each unit during the preceding year. A total of 27 questions in 5 areas were formulated. The questionnaire was loaded onto a commercially available electronic template. The questionnaire was e-mailed to the clinical or technical head of echocardiography at each echocardiography unit in November 2012. Data represented the preceding 12 months. Reminder e-mails were sent at weekly intervals to those who had not completed the questionnaire.

Data acquired from questionnaire

Stress echo service demographics:

(1) The number of SE performed over the past year including the number performed with contrast.
(2) The number and grade (seniority) of SE operators.
(3) Other imaging modalities available to referrers within the institution.

Stress echo indications:

(1) The modalities of SE available within the unit (exercise, bicycle, dobutamine, dipyridamole, adenosine, and pacing).
(2) The range of indications for which SE is performed (coronary artery disease, valvular heart disease, hypertrophic cardiomyopathy, and congenital heart disease).
(3) The range of indications for which SE is performed in valvular heart disease.

Technical details:

(1) The stages at which images are acquired for exercise and dobutamine SE (ischaemia and viability).
(2) The maximum dose of dobutamine used for dobutamine SE (ischaemia and viability).
(3) Identification of whether atropine is used (and the maximal dose) for heart rate augmentation.
(4) Identification of whether isometric exercise is used for heart rate augmentation.

(5) Identification of the number of SE contrast is administered and the method of administration (bolus or infusion).

Reporting:

(1) The grade of the person reporting the SE.
(2) The method of the analysis of SE (wall motion analysis, perfusion assessment, strain measurement).
(3) The ability to view rest and stress images simultaneously.

Adverse incidents and audit:

(1) Major adverse events within the past year during SE including death, myocardial infarction, and sustained arrhythmia.
(2) The presence of a system of clinical audit of the SE service including accuracy compared with coronary angiography, outcome, and safety.

Statistics

Descriptive statistic data are reported as median and inter-quartile range or number and percentage.

Results

One hundred and ninety-eight echocardiography departments were identified. One hundred and twenty (60.6%) echocardiography departments performed SE. Of these, 85 (71%) responded and completed the survey. Thirty-one (36.5%) were tertiary referrals centres, and 54 (63.5%) were district general hospitals. Of the 78 hospitals that did not perform SE, 68 were district general hospitals, and 10 were specialist hospitals (i.e. specialist oncology, women, or paediatric hospitals).

Service demographics

A total of 40 876 SE studies were performed. The median number of SE performed was 400 (inter-quartile range 175–600). Nine (10.6%) units performed < 100 SE per year. The majority of 61.2% performed between 100 and 500 SE per year (Figure 1). Nine (10.6%) units performed > 1000 SE per year. A median of three (inter-quartile range 2–4) operators per unit performed SE. Thirty-two (37.6%) operators performed < 100 SE per year (Figure 2). The majority of operators (40%) performed 100–200 SE per years. Ten (11.7%) operators performed over 300 SE per year. Other imaging modalities were available in 72 (84.7%) hospitals: 42 (49.4%) performed cardiac magnetic resonance, 49 (57.6%) performed nuclear scintigraphy, 51 (60%) performed cardiac computed tomography, and 6 performed positron emission tomography. The majority of SE units had between 1 and 3 alternative imaging modalities available in their hospital (Table 1).

Modalities and indications

The modalities of SE available in each unit are listed in Table 2. All units were performed dobutamine SE. Treadmill exercise SE was performed in 57 (67.1%) units. Only 6 (7.1%) and 11 (12.9%) performed SE using dipyridamole or adenosine. Seventeen (20%), 31 (36.5%), 24 (28.2%), 9 (10.6%), 2 (2.4%), and 2 (2.4%) SE units performed 1, 2, 3, 4, 5, and 6 modalities of SE, respectively.

All units perform SE for investigation of coronary artery disease, 81 (98.8%) for the evaluation of valvular heart disease, 51 (60%) for the evaluation of hypertrophic cardiomyopathy, and 10 (11.8%) for the evaluation of adult congenital heart disease. The majority
81 (95.3%) units performed SE for the evaluation of low-flow, low-gradient aortic stenosis. However, only 34 (40%) performed SE for the evaluation of severe, asymptomatic aortic stenosis, and 32 (37.6%) and 24 (28.2%) performed SE to evaluate symptomatic mild or moderate mitral regurgitation and stenosis, respectively (Table 3).

**Techniques**

For exercise SE, all units acquired baseline and peak images. Forty-seven (82.5%) acquired recovery images. For dobutamine SE (where LV function and no regional wall motion was found at baseline), all units acquired baseline and peak images. Forty-seven (55.3%) also acquired intermediate dose images.

**Dose and target heart rate**

The maximum dose of dobutamine infused for ischaemia assessment was 30 μg/kg/min in 6 units (7.1%), 40 μg/kg/min in 70 (82.4%) units, and 50 μg/kg/min in 9 (10.6%) units. When assessing viability, 7 (8.2%), 22 (25.9%), 5 (5.9%), 37 (43.5%), and 14 (16.5%) used 5, 10, 15, 20, and 30 μg/kg/min as the maximum dose, respectively.
Contrast

Of the 85 units, 83 (97.6%) used ultrasound contrast agents for a proportion of their SE. Overall, 28,279 (69.2%) SE studies out of the 40,876 SE studies were undertaken with the use of contrast. Sixty (72.3%) units used a bolus method and 23 (27.7%) units used an i.v. infusion for the administration of the contrast agent.

Image analysis

Eighty-four (98.8%) of SE units were able to view resting and peak stress images side by side on their reporting system. One unit was unable to do this. All SE were analysed for wall motion analysis. Nine (10.5%) SE units also analysed perfusion in addition to wall motion analysis. Thirteen (15.3%) SE units analysed strain during SE in addition to wall motion changes. Final reporting of SE was performed by consultants in 84 (98.8%) units. Co-reporting with sonographers or cardiology fellows occurred in 11 (13.1%) and 29 (34.5%) of these units, respectively. In one unit (1.2%), a sonographer reported SE independently.

Adverse events and audit

No major adverse events during the last year were reported by 68 (80%) of units. Of the remaining 17 units, 8 (9.4%) units reported, at least, one myocardial infarction during SE in the previous year and 8 (9.4%) reported an episode of sustained ventricular tachycardia during SE. One unit (1.1%) reported a death during SE. Adverse events were reported in 7 out of the 24 (29.2%) departments performing >500 SE per year, 10 out of the 52 (19.2%) departments performing between 101 and 500 SE per year, and none of the 9 (0%) departments performing 100 or less SE per year. Forty-three (50.6%) units performed an audit of the SE service every year. Nineteen (22.4%) units perform no audit of the SE service.

Discussion

This is the first study to identify how SE is incorporated into clinical practice within a national health system. It encompasses SE facilities, indications, maintenance of operator/reporter competency, SE techniques and equipment, adverse events, and audit.

The ASE and EACVI guidelines suggest operators must perform a minimum of 100 SE per year in order to maintain competency.8,12 In this study, 37.6% of operators performed less than these requirements. Operators (28.2%) performed large volume of procedures (>500). Interpretation of SE in clinical practice remains a qualitative technique relying on visual interpretation of wall motion abnormality. Intuitively, a high-volume operator would gain more experience of SE, however, no data are available to confirm or refute whether performing a low volume of studies leads to the reduced accuracy of SE. A possible explanation for low-volume centres/operators may be the local availability of other imaging modalities such as CMR, nuclear, and CT. In the era of limited funds and ionizing radiation issues, the most cost-effective and safe technique should be employed. SE certainly qualifies as a cost-effective and safe technique, free of non-ionizing radiation.13,14

All units were able to perform dobutamine SE, while only 67% perform exercise SE. Very few units performed vasodilator stress echo. Twenty per cent of SE units could only perform one modality of SE. The choice of SE technique is individualized according to the clinical scenario and patient. The accuracy of exercise, dobutamine, and dipyridamole are broadly similar,6 although exercise SE has a higher sensitivity for detection of coronary artery disease than

<table>
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<tr>
<th>Table 1 Alternative imaging modalities</th>
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<tr>
<td>Number of alternative imaging modalities available per hospital with stress echo unit</td>
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<tr>
<td>0</td>
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<td>1</td>
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<tr>
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<tr>
<th>Table 2 Modalities and indications for SE</th>
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<td>Modalities available for stress echocardiography within each echocardiography department</td>
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<tr>
<td>Exercise treadmill</td>
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<td>Exercise bicycle</td>
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<td>Dobutamine</td>
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<td>Dipyridamole</td>
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<td>Adenosine</td>
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<tr>
<td>Pacing (permanent pacemaker)</td>
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<tr>
<td>Indications for stress echocardiography</td>
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<tr>
<td>Ischaemic heart disease</td>
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<tr>
<td>Valvular heart disease</td>
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<td>Hypertrophic cardiomyopathy</td>
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<td>Congenital heart disease</td>
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<th>Table 3 Indications for SE in valvular heart disease</th>
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<tr>
<td>Units which perform stress echo for assessment of valvular heart disease</td>
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<tr>
<td>Low-flow, low-gradient aortic stenosis</td>
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<td>Asymptomatic severe aortic stenosis</td>
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<td>Asymptomatic severe mitral regurgitation</td>
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<td>Asymptomatic severe mitral stenosis</td>
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<td>Symptomatic mild/moderate mitral regurgitation</td>
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<td>Asymptomatic severe aortic regurgitation</td>
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achieve target heart rate.29 This and other studies suggest that the higher dose of dobutamine, 45% of this group had a maximal dose. The EAE guidelines suggest a maximum 1 mg atropine is used in contrast to the ASE guidelines, which allows up to 2 mg/kg/min. The availability and utility of SE for the evaluation of valvular heart disease is disappointing. Although the majority of units could evaluate low-flow, low-gradient aortic stenosis less than half routinely evaluated other forms of valve disease. There is emerging evidence that SE can predict or assess heart rate despite 40 mg/kg/min dobutamine. The patients received 50 µg/kg/min dobutamine (mainly due to contra-indications to atropine). With the higher dose of dobutamine, 45% of this group had a maximal dose. The EAE guidelines suggest a maximum 1 mg atropine is used in contrast to the ASE guidelines, which allows up to 2000 µg as the maximum dose. Doses of up to 2000 µg titrated up in 500 µg aliquots have been used in some protocols with no apparent adverse effects, although studies specificallydetailing the safety of high doses of atropine are lacking.

More than 80% of SE units reported no major adverse incidents during SE. Of SE units, 18.8% reported either a sustained arrhythmia or myocardial infarction. One unit reported a death. A recent analysis of the safety of SE in 55 071 studies reported a major complication rate of 1 in every 475 patients. Therefore, low-volume units performing significantly less than this may not witness an adverse event every year.

The limitation of this study is not all SE units in the UK participated leading to potential selection bias. However, >71% did so this effect is likely to be minimal. Second, we only included NHS hospitals as there are no databases of private SE providers in the UK. However, NHS hospitals provide the vast majority of healthcare in the UK. No external validation of the data provided by each unit was undertaken.

**Conclusion**

SE is available in >60% of UK hospitals. The majority of units are able to perform dobutamine SE. The full range of stress modalities/techniques is, however, not available in many units. The use of exercise SE, vasodilator, and SE for the evaluation of valvular heart disease are under-utilized. Penetration of new techniques is variable, contrast for LV opacification has been almost universally adopted, while myocardial perfusion and mechanics are used much less. Strategies to ensure sufficient numbers to maintain operator competency levels require further evaluation as do measures to systematically audit outcome and safety.

**Conflict of interest:** none declared.

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**References**


