Stress echocardiography: personnel and technical equipment

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In recent years, stress echocardiography has gained broad acceptance as a non-invasive method for the diagnosis of coronary artery disease. Facing different protocols, dosages and instrumentation, official guidelines for the performance, standardization and quality control of stress echocardiograms are needed; however, so far they are not available. This paper recommends the type of personnel and technical equipment needed for stress echocardiography laboratories, based on experience gained during more than 2000 stress echocardiographic procedures.

To perform stress echocardiography, a cardiologist and a technical assistant — both well trained over a large number of tests — should be involved. The laboratory must have basic equipment such as a 12-lead ECG, blood pressure monitoring capacity, a treadmill or bicycle for ergometry, a precision intravenous delivery system for pharmacological stress testing as well as an adequate echo table; additionally, emergency equipment is mandatory.

The ultrasound machine should contain transducers with high 2-D resolution; most important is a digital image acquisition system which facilitates performance and interpretation through side-by-side display of synchronized rest and stress images. Finally, there is a need for proper patient preparation and the obtaining of informed consent.

Key Words: Stress echocardiography, technical equipment, digital imaging, exercise testing laboratory.

Introduction

Following a survey in 1995, it was found that more than 25 000 stress-echoes have been performed in Germany. Most of them (56%) were carried out with various types of dynamic stress, the remaining 44% either with dobutamine (36%) or dipyridamole (8%) (Haug, personal communication). The results often cannot be compared directly with sensitivity and specificity because of non-uniformity of test protocols, dosages, patient preparation and technical equipment. So far, there have been no guidelines from the official scientific societies on the performance of stress-echocardiography. This paper describes recommendations for standardization and quality control worked out in our laboratory. They take into account the guidelines of the American College of Cardiology/American Heart Association and the European Society of Cardiology with respect to exercise testing[1-4].

General considerations

As stress-echocardiography needs space and time to be performed, the laboratory should be large enough to accommodate all equipment and to allow comfortable freedom of movement for personnel and patients, especially in emergencies (Fig. 1). The environment — as regards the amount of light, the temperature and humidity — should be suitable for exercise testing: a temperature of 22 °C and a humidity of 50 to 60% are considered comfortable, as exercise performance decreases at higher figures[2].

Personnel requirements

Those most involved in stress echocardiography are usually physicians — cardiologists and echocardiographers in particular — echocardiography technicians, nurses and technical assistants. All staff should be trained in at least basic life support, and training in advanced cardiac life support is strongly recommended. In Germany, a specialist in cardiology or internal medicine with additional expertise in cardiology — will usually perform the stress echo exam and monitor the patient throughout exercise and recovery. The physician must be well trained in conventional 2-D echocardiography and have sound expertise in cardiology and cardiopulmonary resuscitation/emergency cardiac care, as outlined in the American College of

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Physicians/American College of Cardiology/American Heart Association statement on clinical competence. Based on a study of Picano et al. and following the criteria of appropriate expertise for healthcare professionals in Germany, the examiner must have performed 100 stress echocardiographies independently before qualification is granted. The performance of another 100 exams per year is recommended to maintain competence. In addition, every physician involved with stress echocardiography should be able to operate a computer, at least the employed software. Sporadic or even regular controls of inter-observer variability may be useful to improve accuracy.

Apart from the examiner, at least one assistant — an echocardiography technician, a technical assistant or a nurse — should be readily available. His or her task is to support the patient monitoring throughout the test and to operate the computer and other instrumentation. The physician's assistant should have basic knowledge of electrocardiography and basic life support.

**Technical equipment (Table 1)**

Stress echocardiography can be performed with dynamic or pharmacological stress. Although both kinds of stress aim at the induction of regional wall motion abnormalities that occur with myocardial ischaemia, the testing procedures differ with regard to patient preparation, protocols and technical equipment.

The basic technical equipment for exercise testing includes an electrocardiographic recording system, a blood pressure monitoring unit, a treadmill or bicycle for ergometry, and emergency equipment (see guidelines for clinical exercise testing laboratories from the Committee on Exercise and Cardiac Rehabilitation of the American Heart Association). In exercise electrocardiography, a 12-lead electrocardiogram is essential for continuous monitoring and recording of heart rhythm and ST-segment changes during exercise and recovery. In stress echocardiography, a 12-lead ECG registration is recommended at every exercise or dosage step to improve specificity and sensitivity of the test; however, its elimination from dobutamine stress echocardiography does not reduce the diagnostic value of the test. Some ECG
leads may be placed in a modified position to avoid interference with the echocardiographic window. Blood pressure measurement is necessary at each step and may be carried out by manual auscultation or automated blood pressure units.

Exercise echocardiography can be performed by treadmill exercise, upright or supine bicycle exercise. Echo images have to be obtained before, if possible at peak, and immediately after exercise. Usually, the patient is examined in the left lateral position. A treadmill should be electrically driven and allow variable speeds. For patient safety, front and/or side rails are recommended. This technique is less dependent on patient cooperation to maintain a specific workload than bicycle exercise; however, it bears certain difficulties in image acquisition. Although regional wall motion abnormalities seem to persist longer after treadmill than after bicycle exercise, the patient must first lie down in the left lateral decubitus position after termination of treadmill exercise while echo images must be acquired within the first 1 to 2 post-exercise minutes to guarantee high diagnostic accuracy.

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Echocardiographic monitoring throughout exercise and early recognition of new wall motion abnormalities is almost impossible. This is a disadvantage as cardiac imaging during peak exercise increases the sensitivity of the test.

During supine bicycle exercise, which is the least strenuous, peak-exercise images can be derived from all standard windows. However, as exercise-induced ischaemia is often of short duration, post-exercise images frequently fail to show wall motion abnormalities. With upright bicycle exercise, peak-exercise images are more difficult to obtain because patient movements are more extensive and because of respiratory interference; furthermore, sometimes only apical and subcostal images can be viewed by the sonographer. However, the patient is able to exercise longer, so that optimal post-exercise images often show ischaemic wall motion abnormalities. The bicycle should be mechanically or electronically braked and allow manual or automatic increments of workload. Several standardized ergometry protocols are in use, which include an initial warm-up at low workload, a stepwise workload increase and a recovery period. Most exercise testing laboratories use a kind of Bruce or Balke protocol.

For exercise echocardiography an echo table or bed adjacent to the bicycle is required. A specially constructed stress echo table with the possibility of left lateral and head-up tilting is a comfortable alternative to simple supine and upright bicycle exercise and allows optimal peak-exercise imaging from the standard acoustic windows (Fig. 2). An additional removable 'cut-out' may be useful in bringing the apex closer to the transducer and vice versa.

A precision intravenous delivery system is necessary to deliver dobutamine, and it is recommended for the infusion of dipyridamole. Arbutamine needs to be delivered only by the GenESA delivery system which includes an infusion pump. All common dosage tables should be available in the stress echo laboratory. In certain patients, atrial or transoesophageal pacing has also been used to induce ischaemia by increasing heart rate; thus, stimulation catheters and a TEE probe should eventually complete the stress echo equipment.

For echocardiographic equipment the following is necessary: the echo machine should provide high resolution two-dimensional and Doppler properties; a video recorder of high quality (e.g. SVHS) should be integrated to allow on- or off-line recordings of exams on a video tape. In addition, a single-lead electrocardiogram should be displayed on the screen to monitor the rhythm continuously.

Fundamental progress in stress echocardiography was achieved when digital image processing techniques were introduced into echocardiography. This 'digital echocardiography' technique allows the acquisition of analogue ultrasound images, their digitization, analysis and storage. Image processing was realized by a 'frame-grabber' within a digital computer which can be integrated within a digital ultrasound machine or free standing and connected to the echo system via cabling. Initially, digital imaging was performed 'off-line' by selecting a cardiac cycle from a videotape; nowadays 'on-line' digitization directly from the 'life' echocardiogram is the common method.

The prerequisite for an appropriate digital recording is an electrocardiogram with direct connection to the echo image to trigger the start of the image acquisition. Generally, the ECG trigger is set on the R-wave of the ECG either from the ultrasound monitor.
Image acquisition

(a) Image acquisition

Trigger level

R wave

(b) Image acquisition

Interim delay

Figure 3 Image acquisition. (a) The ECG trigger is set on the R-wave to start with systole. (b) The computer captures eight consecutive frames, each 50 ms apart.

or taken from an external signal (e.g. 12-lead ECG) which is less frequently subject to artifacts (Fig. 3(a)). As systole is the most interesting part of the cardiac cycle in stress echocardiography, the computer is commonly programmed to capture eight frames with an interim delay of usually 40 to 50 ms, resulting in a sequence of 280–350 ms (Fig. 3(b)). This series of eight images can then be played in an endless 'cineloop'. When all cineloops are digitized they can be displayed in a single-, dual- or quad-screen and repeated in real time, slow motion or frame by frame. Each stress echo computer contains several flexible study protocols which either consist of quad screens for each exercise stage or allow free a combination of cineloops. This allows the analogous and synchronized display of rest and stress images side-by-side which facilitates the comparison of identical wall segments (Fig. 4). Moreover, subsequent studies in the same patient e.g. before and after cardiac interventions, can also be displayed side-by-side in dual- or quad-screen format and enable the analysis of changes at follow-up. Digital imaging is time-saving because only a single cardiac cycle of each view is needed for recording. Besides, as the cycle can be chosen, respiratory or other interferences are minimized.

Several centres report storing echocardiographic images on-line from each level of stress on videotape as a back-up procedure if digitization fails. Software programmes for wall motion analysis, quantification and report generation enhance the efficiency of the stress echo computer. It should contain a data archive with patient and exam directories to recall stored stress studies easily. To facilitate interpretation of stress echocardiograms the computer is commonly equipped with a qualitative/semiquantitative wall motion scoring index which should follow the recommendations of the American Society of Echocardiography for a 16-segment-model (Fig. 5)\[16\]. Rest and stress wall motion of each segment are characterized as normal (score = 1), hypokinetic (=2), akinetic (=3), or dyskinetic (=4). Most of the computer systems offer several approaches to a quantitative analysis of regional and global LV function. A clear-cut delineation of the endocardial
Figure 5 The 16-segment model following the American Society of Echocardiography. The following scoring index is used for qualitative analysis of segmental wall motion: 1, normal; 2, hypokinetic; 3, akinetic; 4, dyskinetic; ■ = left anterior descending coronary artery; E3 = proximal left anterior descending coronary artery; D = left circumflex artery; D = proximal descending right coronary artery; ANT = anterior; SEPT = septal; INF = inferior; LAT = lateral.

border is necessary for any measurement. Assessment of ejection fraction and end systolic volume is recommended, but not compulsory. This holds also for the additional use of the centreline or radial wall motion method, which is time consuming and not generally superior to visual wall motion analysis. Digital data need a tremendous amount of computer memory, so an exchangeable hard disk, an optical disk or a rewriteable computer disk should be installed for storage. A fast processor facilitates handling and saves time.

At present there are new technologies for evaluation: automatic border detection by acoustic quantitation, intravenous contrast agent application and tissue Doppler imaging; from these techniques further enhancement in sensitivity and specificity can be expected in the near future.

<table>
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<tr>
<th>Table 2 Emergency equipment</th>
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<tr>
<td>Portable defibrillator</td>
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<tr>
<td>Oxygen, O₂ mask</td>
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<tr>
<td>Airways (oral), nasal cannula</td>
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<tr>
<td>Bag-valve-mask, hand respirator (Ambu bag)</td>
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<tr>
<td>Laryngoscope, intubation equipment</td>
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<td>Suction apparatus</td>
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<td>Syringes, needles, intravenous tubing; adhesive tape</td>
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citation. Emergency equipment includes a defibrillator and intubation equipment (Table 2), the required drugs are listed in Table 3.

Patient preparation

Although stress echocardiography is considered a safe method, serious cardiac complications (ventricular tachycardia/fibrillation, asystole, myocardial infarction, death) requiring emergency treatment may occur; their incidence is reported in around 1% of patients. To secure appropriate emergency cardiac care, all personnel should be sufficiently trained in cardiopulmonary resus-
should be avoided during the last 12 h before administration of dipyridamole. Contraindications must be considered.

**References**


