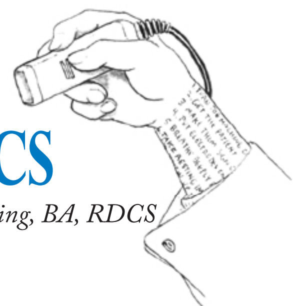
STRESS ECHOCARDIO-GRAPHY BASICS



Written & Illustrated by Andrew Horning, BA, RDCS

INTRODUCTION

Stress echocardiography (SE) combines and compares a baseline echocardiogram with a similar echocardiogram acquired during or immediately after some form of stress. Most commonly, SE uses two-dimensional imaging and some form of physiologic or pharmacologic stress to increase the heart's workload. Insufficient blood flow to a section of heart muscle causes a visible wall motion abnormality. Although diastolic changes actually occur earlier and persist longer, an abnormality is easiest to capture, display, and assess with ventricular systole. In the assessment of wall motion abnormalities, diastole is typically considered a nuisance. A computer compiles and displays the baseline and stress images as systolic side-by-side loops, and the diagnosis is made by visual assessment. SE computers produce digital loops that represent just the small span of time needed for systole.

SE started with the advent of fast, reliable computers and became commonplace when SE computers were integrated into echocardiography machines. Thus SE has established itself as a valuable noninvasive diagnostic test for detecting *coronary artery disease* (CAD) and assessing cardiac efficiency.

SE is considerably more sensitive and specific than treadmill testing alone and compares very favorably to radiographic tests such as stress thallium imaging. In addition, SE is:

- Fast
- Non-invasive
- Mobile
- Versatile
- Relatively cheap
- Suitable for serial analyses

SE is also useful for assessing disease states other than CAD as well as prosthetic valves. However, these subjects are beyond the scope of this article.

A STEP-BY-STEP GUIDE TO PERFORMING SE

Performing a SE test requires obtaining a patient history, obtaining informed consent, prepping the patient, obtaining a resting echo, applying stress, obtaining post-exercise imaging, and finally, choosing the best images.

1. Patient History

Obtain a complete patient history. An in-depth cardiac history is important. Remember, SE is often performed to rule out or follow up on some very serious conditions. A detailed history is not only useful to physicians reading the test, but is also beneficial to the sonographers and technicians actually performing it.

The following items should be included in the history:

- Presence of risk factors: Hypertension, stroke, hypercholesterolemia, smoking, diabetes, or family history.
- Previous tests or procedures: Has the patient had a treadmill ECG test, a nuclear study, a catheterization, or *percutaneous transluminal coronary angioplasty* (PCTA)? Were the results normal, non-diagnostic, or positive (if the latter, what vessels were involved)? When was the test or procedure performed?
- Previous coronary disease (include dates): Encourage the patient to be as specific as possible. Was their myocardial infarction subendocardial or transmural?
- Types of medications: This is very important, because certain medications may affect the performance and outcome of the test findings.
- Reason for the SE: Why is the patient in for SE today? Is the patient being tested for re-stenosis of PTCA, to find a cause of present symptoms, or for evaluation of overall cardiac performance?

2. Explain Procedure and Obtain Informed Consent

Fully inform the patient by explaining the procedure to be performed in detail. For treadmill echocardiography, emphasize the importance of returning to the bed in the proper position as quickly as possible. Let the patient know that you have only 1 minute after the treadmill

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stops to obtain the post-exercise images.

Patients that receive dobutamine may become light-headed or nauseous. They may get headaches or palpitations. The test will run smoother if you inform and reassure them of possible side effects.

Tell *all* patients to *keep you informed regarding how they feel* (eg, if the patient needs to stop, a few seconds warning gives you the opportunity to put gel on the transducer).

Explain the procedure again a second time. When the treadmill stops, patients often hang on to the rail and try to catch their breath, recover some lost dignity, and make a few comments. Tell them there is no time for these actions. A minute goes by very fast if the patient takes 50 seconds to lie down. Dry-runs are often beneficial.

Once the procedure has been described and any questions answered, ask the patient to sign a consent form.

3. Prepare the Patient

ECG lead placement in SE is different from traditional ECG lead placement. The standard Einthoven 12-lead ECG hookup will not permit adequate echocardiographic imaging. Tearing off ECG patches after exercise wastes time and may cause you to lose the ECG signal that is critical to loop capture. There are two basic schemes for lead modification; anterior lead placement or inferior lead placement (Figures 1 and 2). Choose one and stick to it for ECG interpretation and test-performance consistency. Both schemes use standard stress-ECG limb-lead placement.

- **Anterior lead placement** (Figure 1): This scheme is perhaps closer to an orthodox placement, so some cardiologists prefer it: V2 moves up to the first or second intercostal space on the left sternal border. V3 is on a line between V2 and V4. V4 through V6 are one to two inches above the nipple line.

- Inferior lead placement (Figure 2): This is often preferred for women and heavy patients. The electrodes are on leaner, more stable tissue. Since this is something of a gestalt placement (ie, put them where you can), here is a rough guideline: V2 may be placed in the same position as with the anterior placement scheme. V3 through V6 are dropped and form a line approximately along the sixth intercostal space). Many technicians place leads V2 through V6 in an arc at around the seventh intercostal space. If the cardiologist does not object to the resulting, slightly different ECG, this provides the largest window and often the best ECG.

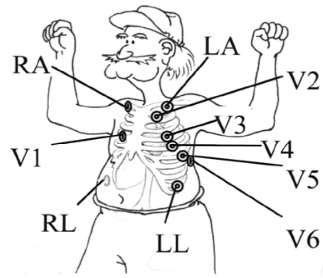

FIGURE 1. Anterior Lead Placement

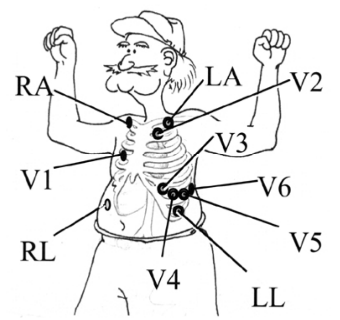

FIGURE 2. Inferior Lead Placement

4. Obtain a Resting Echocardiography (Baseline Study)

Protocols vary on this, but here is what I recommend for treadmill and most other forms of stress echocardiography:

Standard views obtained from the left lateral decubitus position (ie, patient laying on their left side). These images should be videotaped (for back-up and supplemental review), digitized, on-axis and as clear as possible. Views include: parasternal long axis (LAX), parasternal short axis at the papillary level (SAX), apical four-chamber (A4C) and apical two-chamber (A2C).

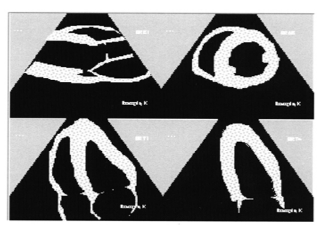

FIGURE 3. Baseline Images

Figure 3 shows how the baseline images should look. Make sure that you've properly labeled all views and that they're in the correct quadrant.

Two additional views not digitized, but recorded on videotape:

- Apical long axis (Ap Long) because you can't see the true apex from the parasternum.

- Apical 4C with inferior angulation ("angle down view") to assess the inferior basal wall.

Upright bicycle ergometry, or stress via an upright exercise bicycle, typically requires additional images. For these examinations, acquire the A4C and A2C again while the patient is upright and on the bicycle.

IMPORTANT IMAGING TIPS

- Adjust your gain/transmit settings before digitally acquiring any images. Choose your transducer, imaging frequency and settings for the best compromise between apical and parasternal views. Once selected, don't touch them again! Endocardial brightening is an important finding, and you will miss it if you fiddle with settings. Scan at 16- to 20-cm depths. Obtain the whole ventricle into the picture with a little margin top and bottom; obtain all your resting views at the same depth, and then *don't touch that dial*! Chamber size and shape changes are often subtle; playing with the depth can make interpretation difficult.
- Don't bother marking the imaging windows. First, they will move after exercise. Second, if you are looking at the marks, you are looking in the wrong place and wasting time. Watch the screen and get your pictures.
- Well-designed SE systems employ a region-of-interest (ROI) window or box. This ROI box is the "frame" for your picture (Figure 4). Make sure that all views fit into this frame! You may need to adjust depth a bit deeper than you would otherwise like, but *you must fit the picture into the ROI window!*

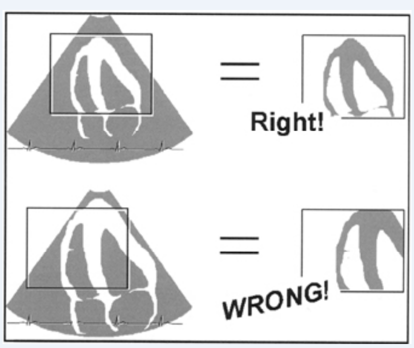

FIGURE 4. ROI Box Placement Examples

5. *Stress Testing*

Whether physiologic or pharmacologic, the stress modality can be stressful for everybody. Exercise patients have to work much harder than they want to. They may have many unfamiliar feelings or symptoms. Tell them what to expect.

Most SE systems have a timer. Turn on the stress duration or exercise timer when exercise begins. Try not to stop physiologic stress until the patient has maintained 90% of *age predicted maximum* (APM) for at least 1 minute. With pharmacologic stress, the patient should maintain 85% APM for at least a minute.

TARGETS FOR A GOOD STRESS TEST

Ninety percent of APM for ***at least 1 minute.*** APM heart rate is typically 220 minus age. Therefore:
220 – age x 0.90 = SE goal
(85% of APM for pharmacologic stress)

A Double Product (peak systolic blood pressure x peak heart rate) **than 25,000.**

There are several other endpoints that are of a more troublesome nature. This is the physician's call; every laboratory has its own rules and operating conditions, but in general *you should stop for:*

- Serious arrhythmias. You'll see more arrhythmias with pharmacologic stress.
- Extremely high blood pressure. Or with pharmacologic stress, low BP.
- With pharmacologic stress, you can see problems as they develop. If you see a new wall motion abnormality, show the physician and he or she will likely stop the test. Do not forget that pharmacologic agents have maximal doses for good reasons!
- Extreme or abnormal symptoms or when the patient firmly says "no more."

Whatever the endpoint, make sure that you tell the patient *one more time* what happens next! Your patient needs to aim for the bed (remind them to watch for the cable), and get into position as fast as possible.

6. *Post Exercise*

Start both the timer and videotape *as soon as the exercise stops.* Do not wait for the patient to reach the table or until you feel ready. The post-stress acquisition time is important diagnostic information.

- Ninety seconds is really too long. Your results will be much better if you obtain all of your images within *1 minute.* Your patient may say, "Just let me catch my breath!" Do not allow this! Breathing rate reflects physiologic load. Fast is good.
- Keep scanning and taping for at least 2 minutes after exercise. You may occasionally tape something interesting, for instance, *reperfusion abnormalities.* When your arm "falls asleep" and you shake it out and get a "pins and needles" sensation, you have had a small reperfusion abnormality. When a heart does this, ectopy and wall motion abnormalities result.

7. *Choosing the Best Images*

Narrow the loops down to the four best. The "prettiest" images are not always best. You should always try to obtain clear, on-axis images. However, you should also look for the most *representative and diagnostic images.*

- Make sure that your SE system has properly triggered ECG loops. Make sure you are looking at *systole*. If the image shows the mitral valve wide open for more than an instant, or an aortic valve that doesn't open, then you are *not viewing systole*! Also, avoid ectopic or aberrant systoles. (You may not always see the ECG with the images. And it's often hard to tell by the image alone.) If the loop looks weird and different from any other loop, don't pick it.
- Review the videotape whenever possible to help you gauge what's truly *representative wall motion.*
- Stay on axis. There is a big difference between an A2C and an Ap Long.
- If there is doubt, choose the earliest post-exercise image or the one with the highest heart rate.

When you're finished, the SE system should arrange a two-stage stress echocardiograph to look something like that of Figure 5.

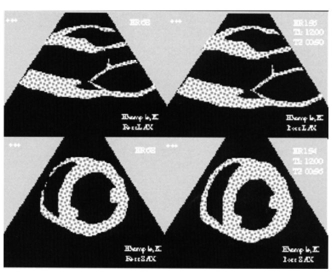

FIGURE 5. Example of Images from a Two-Stage Echo

You will have at least two "pages" of images. The resting stage is on the left of each page. The post-exercise stage is on the right half. Page 1 typically shows the parasternal views, and page 2 shows apical views (both before and after exercise).

INTERPRETATION

A normal response to exercise is the best outcome for the patient. This is indicated when:

- All walls become *hyperdynamic* (increased motion), and the ejection fraction increases. Baseline wall motion abnormalities often improve with exercise.
- Wall thickening increases.
- Left ventricular end-systolic volume *decreases.* This is best evaluated in the SAX view.
- An abnormal response to exercise constitutes a "positive" test result. Any of these findings indicate cardiac disease:
    - ♦ New wall motion abnormalities. These may be regional (segments of muscle affected) or global (the whole ventricle). Abnormalities are classified by degree:
        - * **Hyperdynamic** (or hyperkinetic): Supernormal or overly vigorous contraction. This isn't actually abnormal, but may be an adaptive accompaniment to an abnormality.
        - * **Tardokinetic:** The contraction starts late. Although end-systole may look OK, the slow start *can be* a subtle sign of trouble.
        - * **Hypokinetic:** Reduced or sluggish motion.
        - * **Akinetic:** No intrinsic motion, but may be "pulled" by other segments.
        - * **Dyskinetic:** Motion going the wrong way represents sick tissue. Dyskinesis is an ominous finding.
        - * **Aneurysmal:** Grab a partially-filled balloon so that only a little portion sticks out of your fist. Now squeeze. That's aneurysmal. Like a balloon, an aneurysm can pop. Aneurysms are not so much a motion type as a muscle condition. You would describe the motion as extremely dyskinetic.
    - ♦ Wall thickening decreases
    - ♦ Decrease in ejection fraction
    - ♦ Increase in left and/or right ventricular end-systolic volume
    - ♦ Increase in right ventricular size. This is not CAD-specific but is certainly an abnormal finding.

Absence of positive findings doesn't necessarily mean that the patient is free of disease. Another possible outcome is a false-negative test result. There are a number of reasons for this finding:

- Post-exercise imaging too slow. Reperfusion/recovery occurs rapidly. Again, you have only 60 seconds after exercise stops.

- Didn't achieve 90% age-predicted maximum heart rate. To obtain a valid test, you must work the patient's cardiovascular system. The patient should be breathing hard before you quit.
- Didn't achieve a double product greater than 25,000. Again, this is a cardiovascular workload examination. Push the patient if you have to.
- CAD of less than 75% area reduction or less than 50% diameter reduction. You can't do anything about this one. Smaller lesions may not be visible.
- *Collateral* circulation. Collaterals are "detours" that develop in a patient who has had CAD for a while. Some patients develop collateral arteries very quickly. But generally, it takes years for these structures to become significant. Although very good for the patient, collateral arteries make reperfusion occur much faster. This is bad for the sonographer. A patient with a high-grade lesion and little collateral help may show a wall motion abnormality for 2 minutes after exercise. A similar lesion in a patient with extensive collateral circulation may *look normal in 30 seconds.*
- Poor imaging and poor interpretation. This shouldn't occur, but it does more often than we think. A badly "sliced" image, especially if the picture quality is suboptimal, can look hyperdynamic just because the heart is swinging in and out of the plane obliquely. The diameter/thickening changes are false findings. Artifacts and improperly triggered or poorly chosen images are also problems. An experienced physician should catch these problems, but SE is such a challenging technique that mistakes will occur.

False-positive test results can also occur. These can result from the following:

- Left bundle branch block with abnormal septal motion. In these cases, the *left anterior descending* (LAD) distribution should be interpreted in the anterior wall of the two-chamber view.
- Artificial pacemakers may cause abnormal apical motion in both ventricles.
- Severe hypertension may cause significant wall motion abnormalities that mimic ischemia.
- Poor imaging and/or interpretation, as with false-negative findings.

THE IMAGES

Obtaining reproducible, accurate image planes (very quickly) is the most basic and crucial element of your job. Following is a synopsis of the views that should be obtained.

LAX: The left ventricular walls should be parallel, and you should *not* see the apex. If you see an apex, your view is almost certainly fore-shortened (Figure 6).

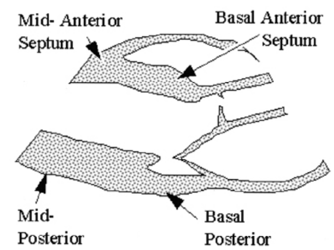

FIGURE 6. LAX View

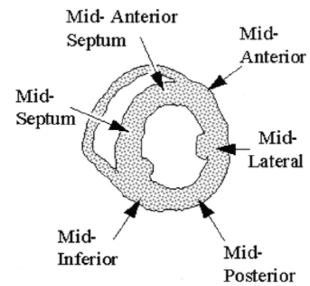

FIGURE 7. SAX View

SAX: While you should *videotape* the whole top-to-bottom length of the ventricle, your digital SAX loops should be acquired at the mid-papillary muscle level. You don't want to see valve leaflets here, nor do you want to look too far toward the apex (Figure 7).

For both parasternal views, you'll probably need to "notch into" or press in toward the sternum. The patient may find this uncomfortable.

A4C: A few physicians still like to see the apex down and/or with the left ventricle on the picture's left side. But the standard view is as shown in Figure 8, with the apex up and the left ventricle on the image's right side.

The important thing is that you cut cleanly through the apex and visualize four (not five, not three) distinct chambers. Position your ROI capture window to acquire both ventricles in their entirety. After all, *the right ventricle is also diagnostic* (Figure 8).

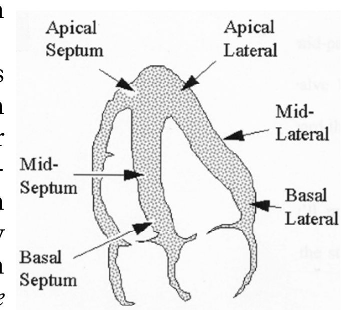

FIGURE 8. A4C View

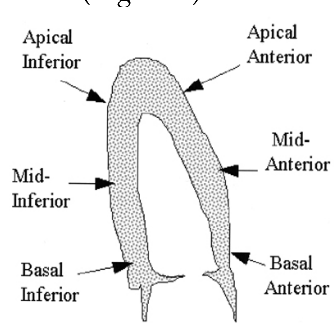

FIGURE 9. A2C View

A2C: A true apical two chamber is often difficult to get. Don't confuse this with the apical long-axis or apical angle-down view.

You should see only two chambers, and only *one* valve (ie, the mitral valve) (Figure 9).

The "angle-down" view is not universally recognized as an orthodox aging plane.

Some technologists acquire this image accidentally by foreshortening the four-chamber view. Some think that this view is unnecessary or even misleading. However, this view is arguably the best way to get additional information on the inferior base, which is an area that's difficult to assess.

You need to obtain a good apical four-chamber view before you point the transducer inferiorly.

The overlaid SAX shows the approximate cut-plane (Figure 10).

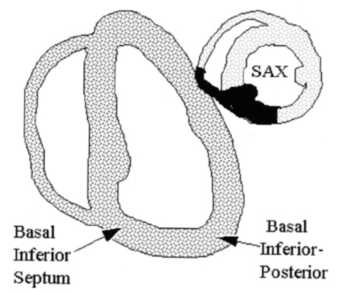

FIGURE 10. Angle-Down View with Overlaid SAX

Coronary Arteries

Some knowledge of coronary artery distribution is extremely helpful in any echocardiographic discipline. But stress echocardiography demands that you really know this material if you want to be more than a "paint by numbers" technologist. There are dozens of books that thoroughly explain coronary anatomy. You should read them all twice.

Failing that, here is a quick and overly simplified overview of the most important issues. Figure 11 illustrates the coronary artery distribution in the four main views. It is important to note that this only represents a typical, that is, right dominate, distribution. There is a wide range of individual variation in coronary artery distribution.

Diagnosing trouble with the distribution of blood is the purpose of SE. In a complex organ made up of millions of individual cells, trouble comes in a practically infinite spectrum of possibilities. Keep in mind that every patient's vessel architecture is unique. Figures 11 and 12 show only what's considered average.

The diagram below shows *configuration changes* or transitory shape alteration that you may see due to insufficient blood flow (ie, *ischemia*). The muscle doesn't get what it needs to work or even hold the pressure generated by the working muscle segments. So the ischemic segments can bulge and thin out. If you see these changes after exercise, *this is a positive test finding!*

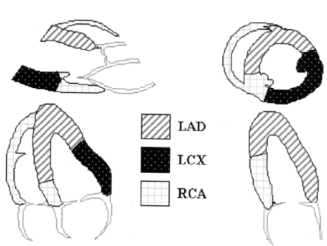

FIGURE 11. Left Dominate Coronary Artery Distribution in the Four Main Views

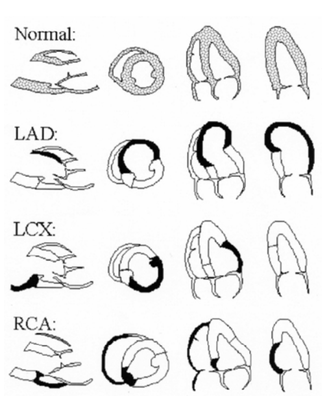

FIGURE 12. Configuration Changes

The uppermost drawings in the diagram show a normal configuration, while the lower drawings show artery block-age at or near the artery's origin in the aortic bulb. Generally, the farther downstream the blockage, the smaller the area affected. This is analogous to clogging a single faucet instead of the house's main water line.

Segmental Wall Motion Scoring

Although SE analysis is done mostly by visual assessment, many laboratory technicians quantify the results for serial analysis and some degree of reproducibility. Certainly, ejection fraction and fractional shortening have been used frequently, but these calculations don't take into account the complex interplay of specific hyperdynamic/hypodynamic segments. There have been many attempts to analyze segmental contribution to these measures with centerline analysis or even 3-D reconstruction, but so far these are computationally and/or operationally too complex for routine clinical use.

Presently, the most common method for segmental analysis and quantitation is *wall motion scoring.* This method is a standardized means of applying numbers to the visual assessment of segmental wall motion.

To merely summarize this technique, the left ventricle (the American Society of Echocardiography Standard models only the left ventricle) is divided into 16 segments. These segments can be graphically portrayed analogous to the standard echocardiographic views or in a cath lab-like "bulls-eye" presentation.

Each segment is visually assessed and given a numerical score based on 6 to 10 findings (institutions vary in their implementation of the standards). The finding scores increase with severity and include some combinations of the following progressions:

- Non-diagnostic (always a score of 0)
- Hyperkinetic (not always used but nevertheless useful)
- Normal
- Hypokinetic
- Akinetic
- Dyskinetic
- Aneurysmal
- Akinetic with scar
- Dyskinetic with scar

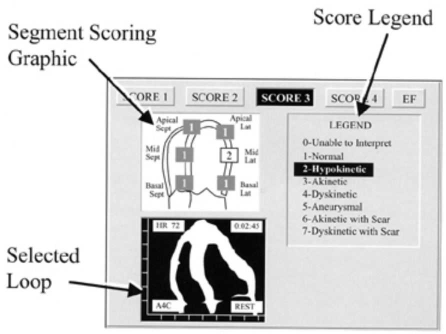

FIGURE 13. Segmental Scoring Package as Found in Biosound Esaote (Indianapolis, IN) Portable Machines

DIGITAL IMAGE BASICS

All moving pictures are composed of still pictures. In movies, videotapes, or ultrasound machines, the control of frame (the still pictures that make up a moving picture) rate, *resolution,* and *order of play* are set by design or nature.

Along with *reproduction fidelity* (infinitely reproducible authenticity to the original) and speed, digital technology offers a bit more image capture control as well. Newer technology uses *compression* to store large amounts of data. To make the best use of this technology, you must understand these parameters:

Compression is a somewhat recent and very important consideration. Uncompressed digital movies as created by most ultrasound machines take up a lot of space. A 1-second full-color digital movie can be 7 megabytes or more. This can get expensive (much more expensive than videotape) unless you somehow compress the images down to a more manageable size. Compression is comprised of two subsets: *lossless and lossy.*

Lossless compression, like it sounds, loses nothing in quality or formatting and rarely squeezes image files by more than half. In stress echo, the most common, oldest compression tactic is to delete all color information (the images are black and white anyway) and store movies that represent just a little more than a third of a second. There are also mathematical compression schemes, or algorithms, that temporarily compress even color images without loss of information.

With lossy compression, on the other hand, you sacrifice something; typically both native ultrasound image format (eg, giving up calibration and processing functions) for a convenient compressed standard (like motion JPEG or MPEG), as well as some loss of image quality. These factors seem like a lot to give up. However, particularly with MPEG (the best of current compression schemes), you can compress images up to approximately 50:1 and still retain diagnostic image quality. This saves a lot of space and money.

Frames (or *cells*) are the still pictures that make up a loop. This is analogous to the length of tape or film and is limited only by the memory and software capability of your SE system. Some SE systems capture eight frames per loop, whereas other systems capture a variable number of frames tied to heart rate and ultrasound frame rate. Please note that the frame rate of a loop will probably *not be related to the ultrasound frame rate!* Multiply frames by the *interim delay* (defined below) and you get the *capture length* (or total duration) of digital video. Multiply frames by resolution and you get the storage space needed for the loop.

Interim delay determines acquisition frame rate. A small interim delay increases the frequency of still images for smoother motion tracking, or better *temporal resolution* (ability to resolve smaller time "slices"). A large interim delay decreases frequency (frame rate), and the loop may show a "strobe" effect. The *usual* is 50 msec for normal heart rates, 66 msec for low rates, and 33 msec for high heart rates. These odd numbers are chosen because they are multiples of the typical (American analog video output) interim delay of ~17 msec.

In this context, *image resolution* (as opposed to temporal resolution) refers not to ultrasound contrast resolution, but to digital spacial resolution (ie, the number of *pixels* that make up each still picture). A pixel, or *picture element,* is like one of the "dots" that make up a newspaper photo. More pixels (ie, higher resolution) create a smoother, finer picture. High image resolution also requires more digital processing power and storage space. Lower resolution pictures may look "grainy" or "pixeley." On the other hand, if an image to be digitized is grainy to begin with, higher resolution will not improve it.

Resolution is not the same as *fidelity.* Once an image is digitized (or digitally produced), however, fidelity is absolute (copies are the same as the original). However, that is not the case with analogue video. Figures 14 and 15 present examples of digital image resolution. Figure 14 displays higher resolution than Figure 15.

FIGURE 14. Display with Higher Level of Resolution

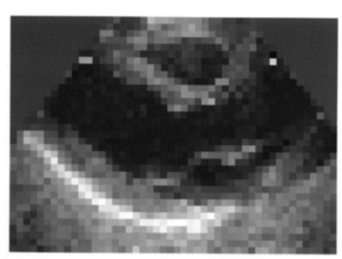

FIGURE 15. Larger Pixels Result in a Display with Lower Resolution

CONCLUSION

Performing adequate SE requires the technologist to understand many aspects of both medicine and technology. A grasp of basic cardiac anatomy, cross-sectional image appreciation, technical know-how and appropriate bedside manner must all come together to provide high-quality examinations that offer the best possible diagnostic information.

STRESS ECHOCARDIOGRAPHY BASICS POST TEST

Expires: July 15, 2009 Approved for 1 ARRT Category A Credit.

1. **SE combines and compares a baseline echocardiogram with**
   a. electron-beam CT images.
   b. results from a cardiac catherization.
   c. perfusion MRI.
   d. an echocardiogram acquired during or immediately after some form of stress.
2. **Most SE systems capture only systole because**
   a. it's much easier to capture, display, and assess than diastole.
   b. it's diagnostically more sensitive and specific than diastole.
   c. that's where the QRS triggering occurs.
   d. it's much shorter than diastole.
3. **Diastolic wall motion is**
   a. nondiagnostic and is therefore eliminated as confusing.
   b. diagnostic, but it's technologically tricky to capture.
   c. simulated by the way systolic loops are played.
   d. exactly the reverse of systolic wall motion.
4. **It's important to talk with the patient before and during the examination because**
   a. this assures the patient of your professionalism.
   b. it helps you gauge the patient's compliance.
   c. it improves the likelihood of obtaining good examination results.
   d. this is only polite.
5. **Before you capture the baseline or resting examination,**
   a. adjust your gain/transmit and transducer settings.
   b. you must "dry run," or practice, the post-stress imaging.
   c. adjust the digital imaging parameters for higher resolution.
   d. mark the imaging windows.
6. **Inferior lead placement**
   a. requires the leads to be placed on fatty tissue.
   b. is often preferred for women and heavy patients.
   c. is the same as the standard Einthoven 12-lead ECG hookup.
   d. requires the placement of leads in very exact positions.
7. **SE is intended to**
   a. directly assess coronary artery distribution.
   b. compete with radiographic examinations.
   c. indirectly assess aerobic capacity.
   d. show the visible results of ischemia.
8. **As soon as the treadmill stops,**
   a. remove the electrodes closest to the patient's imaging windows.
   b. determine the patient's risk factors (eg, hypertension or smoking).
   c. start recording on videotape.
   d. select the best views for side-by-side comparison.
9. **Post-exercise imaging**
   a. must take exactly 1 minute.
   b. can reveal hibernating myocardium.
   c. should be done at a more proximal depth setting.
   d. should take 1 minute or less.
10. **If your SE system uses a region-of-interest capture window,**
    a. you can use it to cut out the distraction of the right ventricle.
    b. you must completely "frame" the image you want to capture.
    c. the system will put more pixels into that area for a better image.
    d. you may need to change imaging depth for post-exercise images.
11. **As soon as the exercise ends,**
    a. let the patient catch his or her breath to avoid dizziness and nausea.
    b. move the ROI window to capture the entire left ventricle.
    c. start recording on videotape and activate the post-exercise timer.
    d. put gel on the transducer and get ready to scan.
12. **It's always an exercise endpoint when**
    a. the patient complains of discomfort.
    b. 90% of the patient's age-predicted maximum has been reached.
    c. the patient has frequent premature ventricular contractions.
    d. the patient insists on stopping.
13. **Age-predicted maximum heart rate is typically calculated using what formula?**
    a. 220 – age
    b. 220 + age
    c. 110 x double product
    d. peak systolic blood pressure x peak heart rate
14. **When selecting images for side-by-side comparison,**
    a. always select the best-looking image.
    b. choose only the most representative and diagnostic images.
    c. ignore the ECG and focus on segmental wall motion.
    d. pick the images captured with the lowest post-exercise time.
15. **When selecting images for side-by-side comparison,**
    a. look at the valves to ensure that you've selected systoles.
    b. count the loop's still frames to ensure complete capture.

c. calculate the proper interim delay for the patient's heart rate.
d. choose one that looks different from all the others.

16. The apical two-chamber view
a. shows all four chambers of the heart.
b. is sometimes difficult to obtain.
c. is synonymous to the apical long-axis view.
d. is synonymous to the angle-down view.

17. SE can indicate problems in specific coronary arteries
a. by highlighting coronary artery distribution in each image segment.
b. by revealing wall motion problems in segments supplied by specific arteries.
c. only if you can visualize the arteries.
d. by comparison with catheterization laboratory results.

18. Which of the following is a normal response to exercise?
a. Left ventricular and end systolic volume decreases
b. Wall thickening decreases
c. Decrease in ejection fraction
d. Increase in right ventricular size

19. Segmental wall motion scoring
a. is an attempt to quantify visual assessment.
b. calculates the ratio of acquisition time divided by the number of wall segments.
c. is more accurate than centerline analysis.
d. correlates well with the radiology-like "bull's eye" ventricle.

20. Which of the following determines acquisition frame rate?
a. Pixel size
b. Fidelity
c. Interim delay
d. Compression type

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