ELSEVIER
SAUNDERS

Perioperative Nursing Clinics 1 (2006) 121–133

PERIOPERATIVE
NURSING
CLINICS

Vascular Diagnostic Testing: Imaging

Patricia C. Seifert, RN, MSN, CNOR, CRNFA, FAAN

Cardiovascular Operating Room, Inova Heart and Vascular Institute, 3300 Gallows Road, Falls Church, VA 22042-6502, USA

Arteriosclerosis and *thrombophlebitis* are two common sources of vascular problems [1]. Although these conditions tend to affect the lower extremities more frequently than the upper extremities or the central visceral organs, arteriosclerosis and thrombophlebitis produce considerable morbidity and morality throughout the body. Patients referred for consultation with a vascular surgeon can expect initially to undergo noninvasive diagnostic testing (such as ultrasonography) to confirm the clinical diagnosis and to measure the severity of the condition. When an operative or other invasive procedure is indicated, the patient may undergo invasive testing (such as arteriography) to provide detailed anatomic imaging to guide the interventional procedure [2]. Both noninvasive and invasive studies may be used to evaluate the efficacy of a procedure postoperatively.

Diagnostic imaging may be performed in the vascular laboratory, the radiology suite, or the cardiac catheterization laboratory. With the growth of endovascular procedures, imaging capabilities increasingly are being incorporated into surgical suites.

Noninvasive studies

Noninvasive diagnostic or therapeutic techniques do not require breaking the skin or entering the body. These tests are employed to provide preoperative diagnostic information, intraoperative confirmation of successful intervention, and postoperative follow-up for vascular patients.

Radiography

One of the earliest noninvasive tests—the plain film radiograph (X-ray film)—is not useful for imaging vascular disorders because vascular structures cannot be clearly differentiated. X-ray films can provide some information about pulmonary disease, and may be ordered during the vascular patient's preoperative assessment. Because radiographs are inexpensive and easily available, they are useful for postoperative evaluation of the metallic, radiopaque components of endovascular stent-grafts for stent fractures, migration, kinking, or other changes affecting the devices [3].

Ultrasound

Ultrasound is based on the generation and movement of sound waves (ie, *sonography*), and the "echos" that are bounced back when the sound waves contact tissue or body fluid. The human ear can detect sounds in the frequency range of 20 to 20,000 Hertz (Hz); *ultrasound* is defined as frequencies greater than 20,000 Hz [4]. Ultrasonography converts electrical energy into mechanical (sound) energy with a *transducer*, which converts electrical energy into sound energy when sending signals, and coverts sound signals into electrical energy when receiving the echos. The transducer is placed on the skin to direct sound waves percutaneously at different internal structures (with varying densities); the sound waves bounce back at different speeds and intensity, producing images of discrete structures. The echos are displayed as analog recordings on a strip chart recorder, or digital or video images on a monitor screen, or as audible signals. Because of its ability to distinguish between adjacent

E-mail address: patricia.seifert@inova.com

1556-7931/06/$ - see front matter
doi:10.1016/j.cpen.2006.02.010

structures, ultrasonography produces clarity or *resolution* between these structures [5,6].

Ultrasound can be displayed in different modes.

- A-mode (*amplitude*-mode): echoes are displayed as spikes on an oscilloscope; the higher the spike, the greater the intensity of the signal.
- B-mode (*brightness* mode): echoes are seen as dots; the brighter the dots, the more intense the echo signal. Both A-mode and B-mode are stationary formats that, without adjunctive technology, limit their usefulness to assess dynamic tissues, organs, and blood flow. However, by increasing the rate of changes in the reflected ultrasound (ie, greater than 15 frames per second), *real-time* B-mode imaging can be achieved [7].
- M-mode (*motion* mode): the dimension of *time* is added to B-mode echocardiography to produce M-mode echos. Tissues and organs are seen as a series of moving dots configured as spikes and waves in a linear tracing, but the shape and position of specific structures cannot be delineated. The intensity of the brightness represents the strength of the echo to demonstrate a narrow ''icepick,'' view of the tissue. This mode often is applied to cardiovascular structures [6].

Two-dimensional, that is, cross-sectional, ultrasonography can be achieved when a large section of tissue is viewed by sweeping the ultrasound beam rapidly across the heart or other structure with a biplane probe. The time delay and the direction of the reflected echoes are measured electronically in the ultrasound machine to produce a wide, fan-shaped, image. Multiplane probes can construct *three-dimensional* images [5].

Echocardiography is a form of ultrasonography, and uses sounds waves of 1.6 to7.5 million Hz. Echocardigraphy is commonly used to assess the heart in the preoperative, intraoperative, and postoperative periods. The *transthoracic* echocardiography (TTE) probe is positioned externally on the chest wall; interference from chest wall structures can limit the utility of TTE. *Transesophageal* echocardiography (TEE) is performed with a scope placed inside the esophagus and stomach where the probe transducer is adjacent to the posterior portion of mediastinal structures such as the heart. TEE images are not obstructed by chest bones, and provide an excellent view of the heart chambers, blood flow, and cardiac function. Because the probe is inserted into the esophagus, TEE may be considered a *semi-invasive* procedure. TEE is especially useful for assessing intraoperative myocardial function and cardiac valve repair in real time.

Doppler ultrasound imaging

The addition of *Doppler* technology to M-mode and two-dimensional ultrasonography provides qualitative and quantitative information about blood flow, hemodynamic variables, and cardiovascular function. The *Doppler effect* refers to the change in frequency (the Doppler *shift*) of sound waves as they move toward (increasing sound frequencies) or away (decreasing sound frequencies) from the transducer. (A hand-held *Doppler* probe is often used to test peripheral pulses after vascular surgery, and to test arterial flow in both the radial and ulnar arteries when contemplating the use of the radial artery as a coronary artery bypass graft. The *swishing* sound is a result of the Doppler effect.) Transcutaneous Doppler ultrasonography is especially useful for studying blood cell velocity, and is the most commonly used technique to examine the arterial vasculature [8].

Initially, Doppler instruments operated in a continuous-wave mode, making interpretation of the signals difficult. *Pulsed* Doppler ultrasound transducers emit a burst of signals, wait a specified period of time, and then receive reflected sounds and measure the frequency shifts from a specific site at a specific depth [9]. *Multigated* pulsed Doppler echos can provide information from several sites.

The addition of *color* to Doppler ultrasound provides visualization of the velocity and direction of blood flow (Fig. 1) Color is encoded by a computer algorithm into the ultrasound technology and superimposed on the gray-scale real-time image. Commonly, arterial flow or flow toward the transducer is seen as *red,* and venous flow or flow away from the transducer is seen as *blue*. Slow blood flow has a deeper hue of color; fast flow reflects a lighter hue. Turbulent flow is a mixture of green and yellow with red and blue. The addition of color enables the viewer to identify and trace specific blood vessels and detect flow abnormalities [8].

Duplex ultrasonography

The combination of two technologies (*duplex*) into the transducer—pulsed Doppler detection