Introduction

The objectives of this chapter are to (1) summarize specific goals of distinct vascular laboratory arterial examinations, (2) describe protocols for duplex ultrasound arterial mapping (DUAM), (3) describe philosophies of implementation of a preoperative arterial ultrasound mapping program, and (4) summarize advantages of DUAM over X-ray, contrast arteriography (XRA), magnetic resonance angiography (MRA), and computed tomographic arteriography (CTA). The following sections represent the experience acquired with over 1000 arterial procedures performed in the lower extremity based on preoperative and perioperative ultrasound imaging.

The distinct goals of arterial examinations include (1) screening, (2) definitive diagnosis, (3) preoperative or preprocedural mapping, (4) intraoperative or perisurgical imaging, either during open or endovascular surgery, and (5) postoperative follow-up for procedure and/or patient evaluation. The protocols for arterial imaging can be complete and time consuming or short and very specific. High-level communication between sonographer and surgeon in charge of the patient is necessary to create imaging shortcuts.

The philosophies or steps of implementation of a peripheral arterial mapping program include (1) discussion of what is the primary objective to be accomplished by arterial mapping, (2) comparison of ultrasonographic and arteriographic findings for specific segments of the peripheral arterial tree, (3) evaluation of virtual decision making based on ultrasound examinations, (4) appraisal of real decision making, and (5) assessment of procedures based entirely on preoperative and perioperative ultrasound imaging.

Advantages of DUAM are primarily based on imaging of the arterial wall and hemodynamic data besides lower cost, portability, noninvasiveness, and freedom of malignancy risk. Concomitant mapping of veins to be used as arterial conduits is another advantage of the preoperative ultrasound assessment.

Arterial Examinations

This section summarizes details of specific arterial examinations according to their goals and objectives. It fulfills the first two objectives of this chapter.

Screening

Peripheral arterial screening is commonly based on the measurement of ankle pressures. Systolic ankle pressures are compared to brachial pressures and the ankle-brachial systolic blood pressure ratio, or ankle-brachial index (ABI), is calculated. An ABI below 1 is abnormal and warrants a medical investigation of the cardiovascular system. An ABI below 0.5 suggests severe peripheral arterial disease and evaluation by a vascular surgeon. Contrary to popular belief, the lowest ABI should be employed as a screening criterion. Relation of calf flow rate is stronger to the lowest than highest ABI.

The toe-brachial index could also be used as a screening method in patients with incompressible tibial arteries. Triphasic flow waveforms are normal. Monophasic waveforms suggest severe peripheral arterial occlusive disease. Detection and evaluation of tibial arteries waveforms are a first training step toward arterial mapping.

Definitive Diagnosis

Although pulse volume recording (PVR) and segmental pressure measurements have been used in the vascular
laboratory, a protocol based on ABI and flow waveforms obtained at the common femoral, mid superficial femoral, popliteal, and distal tibial arteries is recommended from the perspective of arterial mapping. With this protocol, an expert interpreter can predict the levels of significant arterial obstruction with an accuracy greater than 80% when compared to X-ray arteriography. Upper calf and thigh pressures may not present additional information once the ABI and waveforms are analyzed. From the arterial mapping learning point of view, the early experience can be acquired with a continuous-wave Doppler. The sooner the sonographer starts using a duplex scanner looking for the sites to collect the waveforms, the better. The next training step would be to scan the femoropopliteal arteries while looking for the sites to collect the waveforms. With this approach, the sonographer is acquainted with arterial mapping of the ankle and from below the knee to the groin. Proper imaging at the adductor canal level requires specific training. Additional experience is needed for upper calf and aortoiliac arterial mapping.

Preoperative Mapping

DUAM of the lower extremities requires information about the procedure being considered based on clinical findings and definitive diagnosis. Clinical findings may dictate if treatment is limited to the aortoiliac segment or the femoropopliteal segment or if a distal bypass is being considered. The aortoiliac or femoropopliteal treatment may be a bypass or an endovascular procedure. The protocols for arterial mapping described below are subdivided into three segments: (1) aortoiliac, (2) femoropopliteal, and (3) infrapopliteal. They are complemented by venous mapping if an autogenous conduit is considered.

Aortoiliac Segment

A long protocol demands an attempt at a complete aortoiliac mapping from the renal arteries down to the groin. Imaging of the aortoiliac segment may be suspended (1) if the primary objective is infrainguinal revascularization, (2) if the waveform of the common femoral artery is clearly triphasic, and (3) if intraoperative pressure measurements are scheduled following the infrainguinal procedure. The patients receive instructions to get ready for an abdominal ultrasound scan. They should not eat, chew gum, or smoke for about 10 h prior to the examination, usually scheduled in the morning. Antigas medication is recommended if not contraindicated.

A low-frequency abdominal transducer is commonly used to image the aorta and its bifurcation. Imaging is performed in transverse, longitudinal, and oblique planes, pending aortic elongation and tortuosities. Aortic flow waveforms are obtained above and below the level of the renal arteries and proximal to the aortic bifurcation. Occlusion, aneurysms, conditions of the arterial wall, and degree of stenosis are assessed based on B-mode, color flow, or power Doppler imaging. Local increase in velocity may be employed to grade severe stenosis. If dilatation of a stenosis is considered, the test may be repeated after treadmill exercise.

The iliac arteries are also commonly imaged with a low-frequency abdominal transducer. Patient size may allow the use of a linear transducer, particularly during imaging of the external iliac artery. Images are obtained in transverse, longitudinal, and several oblique positions. Patient and transducer positioning are constantly changed to obtain appropriate images. Forceful pressure to bring the transducer closer to the iliac artery segment under scrutiny is common. Flow waveforms are obtained at the proximal and distal common iliac arteries and at various segments of the external iliac artery. Occlusion, aneurysms, stenosis, and conditions of the arterial wall are observed with B-mode, color flow, and power Doppler imaging. Aliasing and increased velocities are scrutinized at stenotic sites. Usually, a local tripling in peak systolic velocity represents a hemodynamic significant stenosis corresponding to a 50% diameter reduction. A local tripling in peak systolic velocity corresponds to a severe stenosis greater than 75% diameter reduction. A significant stenosis should result in a monophasic flow waveform distal to the stenotic site. Plaques in large iliac arteries, however, may not alter the triphasic characteristic of the common femoral waveform. Examination after treadmill exercise is recommended to evaluate such cases.

Patency or obstruction of the iliac arteries and aorta are reevaluated during the treatment procedure. Intraarterial pressure measurements are performed from the groin and compared to brachial pressures. A decrease greater than 20 mmHg indicates the presence of a hemodynamically significant stenosis. Pressure measurements are more sensitive to detection of a stenosis once iliac flow is increased after an infrainguinal procedure. The drop in pressure across a stenosis is proportional to the flow rate through the lesion. Pending intraarterial pressure evaluation, dilatation and perhaps stenting of the iliac artery may be considered in addition to infrainguinal reconstruction.

In summary, the long protocol requires imaging from the perirenal aorta to the groin in both extremities. The short protocol does not include aortoiliac mapping if the common femoral waveforms are clearly triphasic and intraarterial pressures are going to be measured during the treatment procedure.

Femoropopliteal Segment

DUAM is commonly performed with a high-frequency linear transducer. Imaging of the adductor canal may have