The Role of Imaging in Peripheral Arterial Disease

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Abstract

Peripheral arterial disease, specifically lower limb peripheral arterial disease, can be defined as atheromatous narrowing or occlusion of an artery or arteries in the lower limb. This is becoming an ever more present disease affecting more and more people each year. Diagnosis and prompt treatment are key as the effects of untreated peripheral arterial disease can be dire. Symptoms can range from largely asymptomatic to severe pain, ulcerations, claudication, and rest pain. Treatment is dependent upon the degree of stenosis; this makes diagnosis and visualization of the affected area key. In the past, the cornerstones for diagnosis consisted of contrast, or conventional, angiography and duplex ultrasonography. Newer imaging modalities for diagnosis have since emerged, which consist of magnetic resonance angiography and, more recently, computed tomography angiography. No modality is without fault; therefore, it will be essential to consider side effects, potential risk, and specificity and sensitivity of results, all of which will be covered in this chapter.

Keywords: peripheral arterial disease (PAD), computed tomography angiography (CTA), magnetic resonance angiography (MRA), duplex ultrasonography, conventional angiography

1. Introduction

There are several instances in which non-invasive imaging can be used in patients with, or suspected of having, peripheral arterial disease (PAD). It is reasonable to consider ordering imaging for patients who are suspected to have PAD, based on risk factors, to aid in future management. Imaging can be done on a patient to confirm a diagnosis of PAD or in patients who have signs or symptoms of PAD. Most importantly, imaging will be useful in evaluating patients prior to a planned vascular intervention or to provide surveillance after a vascular intervention has been performed. This chapter will discuss the pertinent imaging modalities:

duplex ultrasonography, computed tomography angiography (CTA), magnetic resonance angiography (MRA), and the gold standard, conventional angiography. These imaging modalities will then be compared according to the latest studies.

2. Duplex ultrasonography

Duplex ultrasonography is a method that uses sound waves with frequencies above those heard by the human ear. When this ultrasound beam travels, it runs into various “targets,” such as soft tissue, bone, blood, fluid, etc., and is reflected back creating an image. The term duplex ultrasonography refers to the utilization of both B-mode and pulsed Doppler analysis of the velocity of blood flowing in the various arteries and veins. B-mode, “brightness-mode,” is a technology that provides real-time, gray scale images. For analyzing the presence or severity of PAD in the lower extremity, high frequency transducers are best, in that they provide excellent image resolution in superficial structures. The “Doppler shift” has been studied and described by Christian Doppler, who found that as an artery is narrowed, the blood velocity will be increased. This has served as the foundation for all vascular ultrasonography [1].

Arterial duplex ultrasonography allows direct visualization of the arteries of the lower extremities. Vessels are classified into 1 of 4 groups. The first being “normal,” which is considered 1–19% stenosis, followed by 20–49%, 50–99% stenosis, and full occlusion. Knowing where and how severe various lesions are allows for the clinician to determine the best therapy, whether that be nothing at all, medical therapy, or invasive therapy, such as percutaneous transluminal angioplasty, stent, or even surgery for bypass [1]. According to Whelan et al., Doppler ultrasonography demonstrated a sensitivity and specificity of 95 and 99%, respectively, for patency versus occlusive disease, and 92 and 97%, respectively, for hemodynamically significant lesions [2].

The following are a few of the accepted clinical applications for the use of duplex ultrasonography imaging: (1) the evaluation of symptomatic patients with abnormal ABIs (<0.9) to identify lesions amenable to endovascular intervention; (2) the occlusion of occult inflow aorto-iliac disease in patients that require a lower limb femoral-distal bypass graft; (3) the evaluation of hemodynamics in distal arterial segments in patients who have an ambiguous history and/or physical exam [3].

Besides being useful for diagnosis and planning interventions, duplex ultrasonography is also useful for after an intervention has taken place [1, 3]. If a patient has received a stent or bypass, he or she will likely be closely monitored by serial ultrasonography's to make sure that the stent or bypass stays patent. Some further benefits of duplex ultrasonography are that it is non-invasive, which means that there are usually no contraindications. As far as diagnostic accuracy, studies have shown duplex ultrasonography to be similar to contrast angiography, and superior to standard MRA [3].

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As was stated in the introduction, no modality is without fault, and duplex ultrasonography is no exception. First off, duplex ultrasonography requires contact with the skin. Some of the patients that need this testing done suffer from chronic leg wounds that can be severe. These wounds can preclude appropriate placement of the probe; therefore, a high-quality exam cannot be performed. Other factors that could make a high-quality exam difficult include contractures, largely edematous legs, and morbid obesity. Another thing to remember with duplex ultrasonography is that it is entirely operator dependent; it is important to have someone educated on proper technique when ordering this test. Lastly, duplex ultrasonography fails to categorize stenosis in the presence of calcified walls and/or plaques [3]. Whenever picking an imaging modality it is important to weigh the pros and cons and adjust accordingly for the specific patient.

3. Computed tomography angiography (CTA)

Another commonly utilized imaging modality is CTA. It is an attractive option for a few reasons, those being: it is non-invasive, there are shorter acquisition times, thinner slices, higher spatial resolution, and improvement of multidetector computed tomography (CT) scanners that enable scanning of the whole vascular tree in a limited period of time with a smaller (but still significant) amount of contrast medium. Some further benefits include CTA being more cost-effective than MRA, and there being less patient contraindications. Recent studies have reported a sensitivity and specificity of 98% for the diagnosis of PAD [4] (**Table 1**).

Imaging modality	Sensitivity	Specificity	Advantages	Disadvantages
Duplex ultrasonography	80–98% [2, 5]	89–99% [2, 5]	• Non-invasive • Helpful for monitoring after intervention has taken place • Low cost [3]	• Contraindications: edematous legs, morbid obesity, open sores, contractures • Operator dependent • Unable to classify calcified vessels or plaques [3]
Computed tomography angiography (CTA)	89–99% [5]	83–97% [5]	• Non-invasive • Short acquisition time • Techniques are being developed to utilize less contrast [4]	• Radiation • Iodinated contrast • Unable to classify calcified vessels [4]
Magnetic resonance angiography (MRA)	93–99.5% [5]	64–99% [5]	• Non-invasive • Iodinated contrast not needed • No radiation [5]	• Contraindications: pacemakers, other metallic implants; if patient is claustrophobic, may need sedation • Gadolinium administration and risk of nephrogenic systemic fibrosis [5]

Table 1. Summarized overview of the sensitivity, specificity, advantages, and disadvantages of the imaging modalities.

Disadvantages of CTA include exposure to radiation, which can accumulate with repeated studies and be potentially carcinogenic, along with the necessity of giving iodinated contrast, which can be problematic for those patients with kidney disease. Some patients also have allergies to iodine; a CTA can still be done, but the patient will need pre-medication with a combination of Benadryl, steroids, hydration, and possibly N-acetylcysteine, which is still under investigation. Another disadvantage includes the inability to accurately assess vessels that have been calcified [4].

4. Magnetic resonance angiography (MRA)

Gaining more popularity is the imaging modality called MRA. The most obvious benefit in using this modality to diagnose PAD is that intravenous contrast is not standardly needed, and it does not utilize ionizing radiation. Both phase-contrast (PC) and time-of-flight (TOF) MRA's are non-contrast techniques that detect blood by its movement compared with static surrounding tissue. MRA is also non-invasive, which gives it an edge over the gold standard, contrast angiography. For completeness sake, there is a form of contrast MRA that is called contrast enhanced MRA; this modality uses an intravenous contrast and relies on the T1 shortening effect of the contrast medium within the arterial system [5].

Although MRA is considered a non-invasive, cost effective, time efficient way to assess and diagnose lower extremity PAD, there are some downfalls. For example, if a patient has a pacemaker that is not compatible with magnetic resonance imaging (MRI), if he or she is claustrophobic, or have other metallic implants, MRI might be contraindicated. There is also the risk of nephrogenic systemic fibrosis with the administration of gadolinium [5].

5. Conventional angiography

Conventional angiography is the gold standard for diagnosis in PAD. This modality involves the intravascular injection of a contrast agent during planar radiographic imaging. The base images are then enhanced by background subtraction of a precontrast frame using a digital technique, such as digital subtraction angiography (DSA), which allows only the opacified arterial system to be seen on the final image. DSA is able to provide superior contrast resolution with lower doses of intravenous contrast, while also having the ability to magnify images and image vessels in real-time, which provides the option for simultaneous intervention [5].

Like the other modalities that have been discussed, conventional angiography has some downsides. In contrast to the other modalities discussed in this chapter, conventional angiography is invasive, and there can be issues with arterial punctures, such as uncontrollable bleeding or hematoma formation. It also involves higher levels of radiation, along with a strong potential for nephrotoxicity and allergic reactions to the contrast agent [5].

6. Comparing the different imaging modalities

As reported above, duplex ultrasonography has a high sensitivity and specificity; however this goes down when multivessel disease is present. Normally, when compared to the "gold standard" of conventional angiography the diagnostic accuracy of duplex ultrasonography is >80% for the detection of a >50% diameter stenosis or occlusion. This diagnostic accuracy can reach up to >90% without the presence of multivessel disease. But overall, in 50% of patients with symptomatic PAD, duplex ultrasonography can detect disease amenable to endovascular therapy. Two prospective studies were done in 1990 and 2003, comparing duplex ultrasonography and conventional angiography in planning for infrainguinal bypass procedures; patient outcomes, which included limb salvage and graft patency, were similar. This indicates that, "the clinical accuracy of duplex ultrasonography to select appropriate inflow-outflow anastomotic sites for lower limb arterial bypass was equivalent to angiography" [3].

According to a systemic review that included over 100 studies that compared MRA, CTA, and duplex ultrasonography for the evaluation of lower extremity PAD, the following findings were found: contrast enhanced MRA had the highest diagnostic accuracy, with sensitivities ranging from 93 to 99.5% and specificities from 64 to 99% for the detection of whole leg arterial stenosis >50%. Two dimensional TOF MRA had sensitivities ranging from 79 to 94% and specificities from 74 to 92%. CTA appeared to be slightly inferior when compared to contrast enhanced MRA, but better than duplex ultrasonography, with sensitivities of 89–99% and specificities of 83–97%. Similar to what was stated earlier, duplex ultrasonography has sensitivities of 80–98% and specificities of 89–99%. Contrast enhanced MRA and duplex ultrasonography appeared to be more accurate for detecting proximal lesions and occlusions above the knee when compared to lesions below the knee or in the pedal artery. When comparing adverse events, MRA had the highest overall incidence of adverse events, however contrast angiography was associated with more severe adverse events. For evaluation of the whole extremity, duplex ultrasonography was the most cost-effective option when compared to CTA and MRA; however when the assessment was limited to a specific section, above or below the knee, two dimensional TOF MRA was more cost effective. Finally, when evaluating patient's attitudes and comfort levels associated with MRA, CTA, and conventional angiography it was found that, not surprisingly, conventional angiography was the most uncomfortable, followed by contrast enhanced MRA, with CTA being the most comfortable [5].

7. Conclusion

When it comes to choosing an appropriate imaging modality for a patient, it is important to consider the symptoms the patient is dealing with, whether an intervention is anticipated, and what their current situation is. PAD is a very complex disease with many available tools, imaging being one of them. Armed with the right information, a thorough history and physical exam, and an appropriate imaging modality, the patient will be on the right track to getting the help and care he or she needs.

Conflict of interest

There are no conflicts of interest.

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