Digital Subtraction Angiography Technical in Lower Limb Arteries

Subjects: Peripheral Vascular Disease

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Cardiovascular diseases represent one of the most frequent diseases worldwide; among these, lower limb ischemia is a threatening condition, which can lead to permanent disability if not promptly and correctly diagnosed and treated. A patient's clinical evaluation and diagnostic imaging (e.g., color-Doppler ultrasound, computed tomography angiography (CTA), and magnetic resonance imaging (MRI)) are mandatory to carefully assess arterial lesion extension and severity. Digital subtraction angiography (DSA) is a minimally invasive technique that represents the gold standard for percutaneous revascularization treatment of symptomatic patients who are refractory to medical management.

Keywords: digital subtraction angiography ; lower limb ; stenosis ; interventional radiology

1. Introduction

Lower limb peripheral artery disease represents a common pathology, affecting more than 200 million adults worldwide and leading to adverse clinical outcomes and physical impairments, such as pain, soft tissue ulceration, osteomyelitis, claudication, and eventually amputation [1].

Diagnostic catheter angiography (DCA) was once considered the gold standard for the diagnosis and assessment of peripheral arterial disease lower limb pathology; however, as noninvasive and panoramic techniques such as computed tomography angiography (CTA) and magnetic resonance angiography (MRA) became more and more available, giving lower risk of complications and similar diagnostic efficacy, DCA was progressively replaced [2][3]. Multidetector CTA is a validated diagnostic imaging method for the evaluation of patients with claudication and limb ischemia, to grade disease severity and plan treatment. CTA is currently considered as the most feasible, useful, reliable, and accurate diagnostic imaging technique in the assessment of lower limb artery disease, with an overall sensitivity of 92–99%, specificity of 93–98%, accuracy of 94–98%, positive predictive value of 97%, and negative predictive value of 99% [4][5][6]. CTA is noninvasive and has a low effective radiation dose; however, CTA usefulness can be limited in determining the degree of stenosis in the case of highly and extensively calcified lesions [7]. Contrast-enhanced MRA appears to be more specific than CTA in ruling out arterial stenosis greater than 50%, and more sensitive than duplex ultrasound (US) in ruling in arterial stenosis smaller than 50% [8]. CTA and MRA are characterized by low or absent use of ionizing radiation, three-dimensional volumetric display, direct plaque visualization, identification of abnormal nonvascular findings, as well as multiplanarity [2]. Nowadays, when it comes to endovascular treatment of arterial lower limb pathology, digital subtraction angiography (DSA) is the imaging method of choice [9].

2. Digital Subtraction Angiography Technique

Nowadays, the standard for contrast arteriography of the lower limb is intra-arterial DSA, which replaced the previously used conventional film-screen angiography (FSA) with cut-film radiographs and rapid film changers [10]. Conventional angiography is based on image acquisition after contrast medium injection: the obtained image is made up of blood vessels, bones, and other structures; this superimposition of nonvascular structures makes it difficult to accurately evaluate the blood vessels. Therefore, to obtain better visualization of vascular structures, a pre-contrast image (so-called "mask image") is firstly acquired and is digitally subtracted to the post-contrast images, granting the removal of distracting structures [11].

2.1. Pre-Procedural Evaluation

Before performing DSA, it is mandatory to collect data from patients affected by lower-limb pathology, regarding history and physical examination, laboratory study, as well as noninvasive imaging of lower limb arteries in order to determine the appropriateness of DSA and the most appropriate endovascular treatment. In particular, it is advised to elicit an accurate description of the patient's symptoms and the consequent impairment in daily activities. Symptoms that do not compromise common daily activities contraindicate an invasive procedure such as DSA. Physical examination and patient's history most of the time will identify nonvascular etiologies for a patient's symptoms (usually originating from musculoskeletal or neurologic diseases); in addition, a pre-procedural patient's evaluation allows the categorization of lower limb ischemia as acute versus chronic, and the assessment of the degree of ischemia severity [12]. Atopy or allergy history as well as any prior adverse reaction to iodinated contrast media must be known prior to DSA.

2.2. Angiography Technique

DSA is usually performed through an antegrade approach, puncturing the common femoral artery and placing a 5 French vascular sheath. Diagnostic angiography can be obtained by injecting iodinated contrast medium through the vascular sheath, or using a diagnostic straight catheter. Injection can be performed manually or with an automatic injector, which can provide a controlled flow rate and contrast medium dose. The injection volume and flow rate varies depending on the examined site and on the diagnostic catheter position. In the case of iliac artery disease, a retrograde approach is performed through the common femoral artery. When an ipsilateral common femoral artery approach is not feasible due to vessel occlusion or highly calcified plaques, the target limb can be reached using a contralateral retrograde common femoral artery access and using a "cross-over" technique, which consists of reaching the aortic lumen and then catheterizing the contralateral iliac artery using a pigtail diagnostic catheter.

Apart from procedural steps, it is essential to know that new angiography machines have automated sequences, which set the frame speed and exposure values according to different segments studied, such as the abdomen, brain, and lower extremities. Advanced computer processing power has made the vastly used techniques such as subtraction, pixel shifting, re-masking, or view tracing simple and feasible. The operator at the angiographic table can easily perform road mapping (superimposition of the fluoroscopic image on a DSA image) and un-subtracted image referencing (fluoro save mode). Collimation, magnification, edge filters, table positioning, and the gantry angle can be changed by the operator in order to optimize visualization of the arteries. An important technical improvement has been the introduction of high resolution flat panel image intensifiers, which provide great image quality minimizing parallax distortion. New flat panels have a large field of view (FOV) that can cover large body segments, bringing lower contrast medium usage and the reduction in radiation exposure both for the patient and the operator. DSA imaging evaluation can be performed on adequate portable C-arm machines, in the case of patients requiring endovascular treatment in the operating room, or on ceiling-fixed angiography machines in the angiographic suite.

To optimize and improve arterial vessel visualization in the lower limb, endovascular administration of vasodilator drugs can be performed, the most used being nitroglycerin and papaverine [13][14][15].

Optimal visualization of the arterial vessel is mandatory to evaluate the pathologic segment and to guide the endovascular guidewire and catheters. Therefore, the use of oblique projections of the C-arm or of the angiography machine is essential: while the superficial femoral artery and popliteal artery can be investigated using a frontal projection, below the knee arteries are evaluated with a slight anterior oblique projection, usually no more than 10 degrees, in which the proximal tibio-peroneal joint is clearly seen. Distal tibial arteries, the pedidial artery, and plantar arch can be evaluated using a pure frontal and, especially, a lateral projection. In the case of common and external iliac arteries, oblique projections help to identify the origin of the internal iliac (or hypogastric) artery, which is mandatory in the case of iliac stenting; identification of the hypogastric artery is performed in the same way as in the case of uterine fibroid embolization, and consists of a 20 degree ipsilateral anterior oblique projection [16].

3. Angiographic Findings

3.1. Stenosis and Occlusion

Arterial stenosis is characterized by a narrowing of the arterial lumen, which reduces the blood flow to the lower extremity; stenosis can be focal, short, or long. On the other hand, occlusion is characterized by a blockage of the artery, which stops the blood flow to the limb extremity. Occlusion can be focal, short, or long, as well as acute or chronic; in the case of chronic occlusion, collateral circulation usually provides inflow to the distal artery. Causes of stenosis and occlusion can be various, ranging from thrombus to atherosclerotic or calcified plaque [17]. The Transatlantic Inter-Society Consensus for the management of peripheral artery disease classified femoropopliteal stenoses and obstructions based on their number and length [18].

Acute occlusion is represented by a sudden blood flow blockage of one or more vessels, and can be due to an anomalous coagulation of blood after injury of the vessel's intima layer, after catheter or guidewire passage, or after angioplasty balloon inflation. As the guidewire or diagnostic catheter or angioplasty balloon hits a thrombus or a mural plaque, or when a clot forms attached to the catheter and is afterwards dislodged, the consequences can be acute embolization and ischemia.

3.2. Dissection

Arterial dissection happens when an intimal tear allows blood to enter the media layer, leading to a second channel filled with blood within the wall. The so-called "true lumen" is the one lined by the intima, while the "false lumen" is the channel filled with blood in the media. The pressure in the false lumen is higher compared to the true lumen because the blood has poor outflow. This leads to the compression of the true lumen and causes an impairment of the arterial flow in the artery in the limb extremity (flow-limiting dissection). Iatrogenic arterial dissection can be caused by passage of the guidewire (as the tip of the guidewire can advance in the subintimal space with very little resistance), or as a result of angioplasty balloon inflation.

3.3. Arteriovenous Fistula

The arteriovenous fistula is an anomalous communication between an artery and a vein, with consequent blood flow from the structure at a higher pressure (artery) to a structure at a lower pressure (vein). It can be iatrogenic, occurring after guidewire passage through a damaged vessel wall, or after angioplasty of calcified plaques. Arteriovenous fistula is identified after contrast medium injection as an early opacification of a vessel that is not referable to an artery, with a blood flow going in the opposite direction with respect to the arterial flow. A prompt identification of an arteriovenous fistula is mandatory, particularly to exclude a blood theft from the distal artery, which could cause or worsen the acute limb ischemia.

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