Diagnostic and Interventional Imaging (2016) **97**, 296—305

PICTORIAL REVIEW / *Cardiovascular*

Three-dimensional MDCT angiography for the assessment of arteriovenous grafts and fistulas in hemodialysis access

S. Ahmed, S.P. Raman*, E.K. Fishman

Johns Hopkins University, Department of Radiology, JHOC 3251, 601 N. Caroline Street, 21287 Baltimore, United States

KEYWORDS
Dialysis fistula;
Dialysis graft;
Computed tomography;
MDCT-angiography;
Multidetector-row computed tomography

Abstract Arteriovenous grafts and fistulas are placed for long-term hemodialysis access, and their associated complications can lead to considerable morbidity. Multi-detector computed tomography (MDCT) images provide accurate delineation of hemodialysis access anatomy and show potential complications. This review makes the reader more familiar with vascular access anatomy and configurations, describes the appearance of access complications encountered on MDCT, and discusses endovascular and surgical treatment options for complications, which should aid in post-treatment evaluation.

A growing number of patients with end-stage renal disease (ESRD) are undergoing long-term hemodialysis. According to the latest statistics from the United States Renal Data System, more than 871,000 persons were being treated for ESRD in 2009, which represented an increase of nearly 600% between 1980 and 2009, and accounted for 6% of the 2009 Medicare budget ($29 billion) [1]. Complications of hemodialysis access account for a sizable proportion of these costs, and provide challenges for physicians involved in their management [1,2].

Tunneled and non-tunneled central venous catheters provide short-term (days to weeks) access when urgent or emergent hemodialysis is required. Alternatively, arteriovenous

* Corresponding author.
E-mail addresses: sahmed23@jhu.edu (S. Ahmed), srsraman3@gmail.com (S.P. Raman), efishman@jhmi.edu (E.K. Fishman).

http://dx.doi.org/10.1016/j.diii.2015.12.008
2211-5684/

(AV) fistulas and grafts are placed for long-term usage. Several studies have demonstrated longer patency and lower complication rates in patients with autogenous AV fistulas by comparison to AV grafts and catheters [3,4]. According to the Dialysis Outcomes Quality Initiative (DOQI) and Society of Vascular Surgery (SVS) guidelines, there are several basic principles with regards to dialysis access. In this regard, autogenous hemodialysis access is favored over prosthetics, distal extremity access sites should first be utilized in order to preserve more proximal options, and upper extremity access is preferred over the lower extremity.

Vascular access complications lead to substantial morbidity and high rates of hospitalization in these patients [5]. The most common complications include infection, stenosis, thrombosis, arterial steal syndrome, aneurysms, and pseudoaneurysms. DOQI emphasizes the importance of monitoring programs to detect vascular access at risk [5]. Diagnostic imaging plays a critical role in the management of hemodialysis access, and promotes early management of complications. Conventional angiography and duplex Doppler ultrasonography have established roles in delineating access anatomy and complications [6,7]. However, magnetic resonance angiography (MRA) and multi-detector computed tomography (MDCT) with three-dimensional reconstructions are being employed for this indication with increasing frequency [7].

Rapid advancements in MDCT have led to short acquisition times and unsurpassed spatial and temporal resolution for the accurate assessment of the peripheral vasculature [8]. Unlike older generation technology, studies can now be reliably acquired at peak arterial enhancement, allowing exquisite imaging of the peripheral vasculature on a consistent basis. However, a limited number of studies have investigated the utility of evaluating hemodialysis access with MDCT, and the growing use of MDCT for this indication has been a relatively recent phenomenon. In order to appropriately interpret these often complex studies, the radiologist must be familiar with vascular access anatomy and configuration, as well as the appearance of a number of common access complications encountered on MDCT angiography. In addition, an understanding of endovascular and surgical treatment options for complications is critical to allow the radiologist to help appropriately guide treatment and properly conduct post-treatment radiographic evaluation. The goal of this review was to make the reader more familiar with vascular access anatomy and configurations, describe the appearance of access complications encountered on MDCT, as well as discuss endovascular and surgical treatment options for complications.

Vascular access anatomy and configuration

A general understanding of the vascular anatomy utilized to create vascular access for hemodialysis, as well as knowledge of both autogenous and synthetic access configurations, are critical for properly diagnosing complications on MDCT angiography. The superficial venous system of the upper extremity is considered the most important for dialysis access creation. Alternatively, while the deep veins are not ideal, they may be utilized as options become limited, a not uncommon situation in an aging population [2,4].

The cephalic vein is the preferred and most commonly utilized superficial vein of the upper extremity. It travels along the radial aspect of the forearm, communicates with the basilic vein via the median cubital vein at the elbow, and traverses in the superficial fascia along the anterolateral surface of the biceps brachii muscle. A radiocephalic AV fistula at the wrist, created by anastamosing the forearm segment of the cephalic vein and radial artery, is generally regarded as the first choice for hemodialysis access [5]. The preferred alternative is to connect the cephalic vein to the posterior radial carpal artery, which lies beneath the extensor tendons of the thumb (''snuffbox'' AV fistula).

A brachiocephalic fistula at the elbow (Fig. 1), utilizing the proximal segment of the cephalic vein and brachial artery, is generally the second choice site [5]. The proximal cephalic vein can also be anastomosed to the proximal radial artery, which is generally considered inferior to the brachiocephalic option. In cases where the cephalic vein does not reach the forearm brachial artery, it can be transposed to the upper arm brachial artery. The basilic vein on the ulnar aspect of the forearm and the median cubital vein near the elbow are sometimes used for dialysis access. The median cubital vein is typically anastomosed with the proximal radial artery.

If choices for vascular access are limited in the forearm, upper arm options may alternatively be utilized. The most commonly used deep vein is the basilic vein in the medial aspect of the upper arm, which is mobilized and transposed superficially through the deep fascia for fistula creation (Fig. 2). Alternatively, the transposed brachial vein can be anastomosed to the brachial artery in situations where the cephalic and basilic veins are not suitable options. Saphenous and femoral vein fistulas are exceedingly rare, and are usually not favored over prosthetic upper arm access.

AV grafts are created by anastomosing a straight or looped synthetic conduit between an artery and vein. The two primary options in the forearm are a straight graft connecting the radial artery to the cephalic vein, or alternatively, a looped graft between brachial artery and cephalic vein. In the upper arm, a graft connecting the brachial artery and axillary vein can be created.

Lower extremity access is typically constructed in situations where all upper extremity options have been exhausted. Given their higher rates of infection and steal, as well as their poorer overall patency, the lower extremities are generally considered less desirable for hemodialysis access. The great saphenous vein, which travels along the medial leg, can be anastomosed to the superficial femoral artery in the groin. An autogenous fistula can also be constructed between the femoral artery and vein, which run alongside each other within the femoral sheath in the upper medial leg, adjacent to the femur. The third autogenous option is mobilizing the distal end of the great saphenous vein to connect to the posterior tibial artery, which travels dorsal to the tibia in the posterior compartment of the lower leg. The primary prosthetic access in the lower extremity is a looped graft between the femoral artery and vein (Fig. 3).