31 Endovascular Therapy for Thoracic Aortic Dissection and Intramural Hematoma

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Introduction

Depending on the duration of symptoms at the time of presentation, thoracic aortic dissection can be classified as an acute or chronic disease. Identifying a dissection within less than 15 days of symptom initiation is considered the acute phase; from 15 to 92 days, it is called the subacute phase; after 93 days, it is considered chronic [1]. This classification is based on the morbidity and mortality rates that occur in the different phases.

The anatomical classifications follow the Stanford or DeBakey systems [2]. The Stanford classification describes a dissection involving the ascending aorta as a type A aortic dissection, whereas if the entry tear occurs distal to the left subclavian artery (LSA), it is considered a type B aortic dissection. The DeBakey classification uses the site of entry tear location: type 1 originates in the ascending aorta and propagates to at least the aortic arch; type 2 originates in and is confined to the ascending aorta; and type 3 originates distal to the LSA. A type A dissection occurs twice as frequently as a type B dissection. If type B dissections are uncomplicated, medical management is focused mainly on pain relief, maintaining a low blood pressure, and controlling heart rate [3]. Surgical treatment is generally reserved for complicated dissections. Although surgical management can be handled with either open surgery or endovascular repair, it is clear that endovascular management is favored because of its improved outcomes [4]. This chapter focuses only on the endovascular treatment of aortic dissection.

An aortic intramural hematoma (IMH) is a hemorrhage within the media layer of the aortic wall without an intimal lesion [5]; it can be a precursor for aortic dissection. Data suggest that 8–16% will develop into a dissection [6]. The classification of an IMH is the same as for aortic dissection, with type A occurring in the ascending aorta and type B, in the descending aorta. Type B IMH occurs more often than type A. Medical therapy plays an important role in type B IMH and is the mainstay of therapy. The mortality is lower with medical therapy, with fewer cardiac complications; they less often develop into a type B aortic dissection [7, 8]. The 5-year survival rate is about 85% [9]. For patients with type A IMH, the medical treatment is more controversial, as 27–96% of patients treated medically had severe aortic events requiring aortic replacement during follow-up [7]. Others reported that one third of the medically treated type A IMH cases developed into an aortic dissection, ruptured, and/or eventually needed surgery [8, 10, 11]. If surgery is eventually necessary, patients with type A IMH receive open surgical repair, and patients with type B IMH can undergo thoracic endovascular aortic repair (TEVAR) [12]. Literature suggests medical treatment for uncomplicated type B IMH; the 3-year aortic event–related mortality was 5.4%, as opposed 23.2% with open surgery and 7.1% with endovascular therapy [13]. Patients treated for IMH have a higher risk of developing retrograde aortic dissection (RAD) after TEVAR [14], which should be taken into account when planning for endovascular therapy.

Preoperative and Postoperative Imaging

An aortic dissection can be diagnosed with multiple imaging modalities, most commonly CT angiography (CTA), transesophageal echocardiography (TEE), and in some cases, MR angiography (MRA). In the acute setting, time is of the essence. When the patient is hemodynamically stable, the most commonly used imaging modality remains CTA (63%), or less often TEE (32%) or MRA (4%) [15]. In the hemodynamically unstable patient, availability and local expertise determine the appropriateness of the modality, in most cases CTA [16].

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Imaging of IMH is the cornerstone for diagnosis. CTA has a negative predictive value of 100% [17]. The typical finding on CTA is a crescent-shaped area of uniform hyperattenuation with associated aortic wall thickening (Fig. 31.1). MRA is used less commonly because of slower scan times, but it is able to differentiate between acute and chronic hematomas. On T2-weighted images (in which blood appears white), acute IMHs (<7 days old) are hyperintense (bright white), and chronic IMHs (>7 days) are less intense (*see* Fig. 31.1). A recent study by Schwein et al. suggests MR imaging criteria to confirm IMH, as opposed to aortic dissection [18]. This pilot study confirms not only the pathology of the disease but also lesion volume decrease during follow-up, which should make this a more commonly used imaging modality.

Intraoperative Imaging

Two imaging modalities are most widely used in TEVAR, fluoroscopy and intravascular ultrasound (IVUS). Fluoroscopy is used to assess the anatomy and the placement and deployment of a stent graft. It is mainly used for the arteriography of the aorta and great vessels. It is now not uncommon also to use a combination of preoperative CTA (3D) and fusion with fluoroscopy (2D or 3D). By fusing the images, the surgeon benefits from a continuous visualization of the intraoperative landmarks for improved endograft navigation and placement [19].

IVUS provides real-time data during interventions and is mainly used for accurate graft sizing during the placement of endovascular stent grafts; some prefer it to CTA [20, 21]. It can provide imaging information that can reduce the contrast load in patients with renal dysfunction [22]. In aortic dissection, we believe it is essential to use IVUS to help define the entry and re-entry sites during treatment [23].

Unlike type B dissections, the difficulty with IMH is that there is no intimal disruption. Therefore, the extent of the required endograft coverage of the descending aorta is unclear.

TEE is another imaging modality that can be used intraoperatively. It is mainly employed to reduce the contrast load and radiation exposure, but when contrast TEE (cTEE) is used, it can have additional benefits, such as in the preoperative characterization phase of aortic pathology (identifying the number of entry tears), or intraprocedural or postprocedural identification of slow and/or remaining flow, persistent leaks, or retrograde dissection [24, 25].

Preoperative Planning

As mentioned earlier, two main imaging modalities are used for the planning of TEVAR. MR and CT are widely used to give a clear overview of the aortic side branches (i.e., supra aortic trunks, celiac trunk), the landing zone, the angle of the take-off branch vessels, and the entry- and re-entry tears

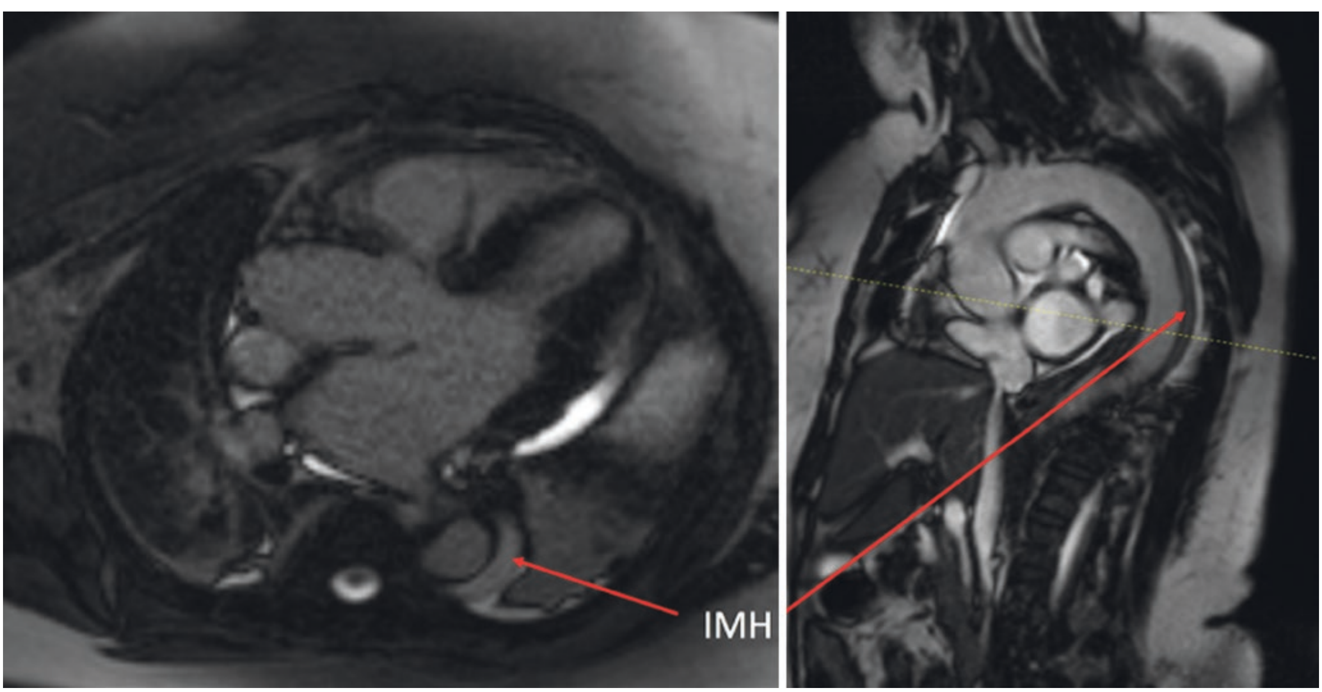

Fig. 31.1 Axial and sagittal MR images of 58-year-old female patient showing chronic type B intramural hematoma (IMH)

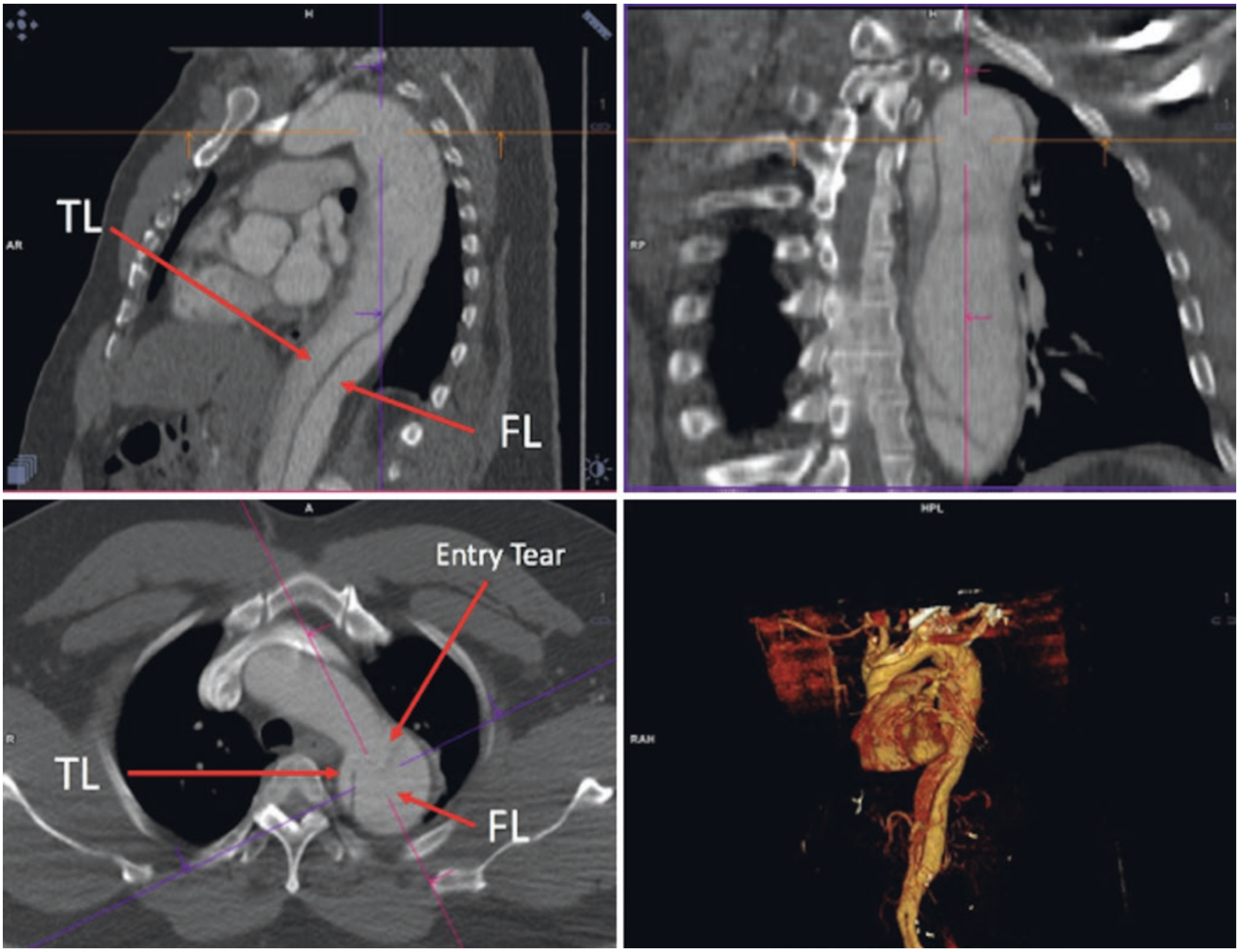

Fig. 31.2 Multiplanar reconstructions of CT angiography (CTA) with sagittal, coronal, and axial views and 3D reconstruction in a 49-year-old male patient, who presented with type B aortic dissection demonstrating the true lumen (TL) and false lumen (FL)

(Figs. 31.2 and 31.3). It is important to observe whether the flow goes retrograde or antegrade into the false lumen.

When planning TEVAR for a type A aortic dissection/IMH, it is critical to pay attention to the innominate artery, and in case of a type B aortic dissection/IMH, to the left subclavian artery (LSA). It is necessary to avoid covering these arteries with the TEVAR, and critical to understand the associated risks if they are covered. If there is a high risk of complications, other surgical options can be considered, such as debranching or some form of investigational device that allows for preservation of the supra-aortic branches.

To get a continuous visualization of the critical landmarks during surgery, fusion imaging is used. The use of this imaging ensures reductions in contrast media, radiation exposure, and procedure time [26, 27]. Fusion imaging uses the preoperative cross-sectional images (CTA and MRA scans) and marks the critical landmarks.

In a 3D-3D registration, the non–contrast-enhanced cone beam CT (nCBCT) is combined with the preoperative CTA to create a 3D model, which is based on normalized mutual information and aligns bony structures and vessel calcifications and vessels [28]. It is clear that the more points of co-registration, the more likely that there is a reliable fusion.

A 2D-3D registration lays the preoperative CTA scan over two projections of 2D fluoroscopic images (anteroposterior and lateral). Both 2D-3D and 3D-3D are good choices for co-registration during TEVAR (Figs. 31.4 and 31.5) [19].

Intravascular ultrasound (IVUS) is a critical part of a TEVAR in the setting of aortic dissection. The distal portion consists of a cylindrical ultrasound transducer and is highly accurate in measuring the luminal diameter or identifying the position of branch vessels, inspecting vessel wall morphology, evaluating the presence of plaques or thrombi, and selecting appropriate landing zones for endografts [29].

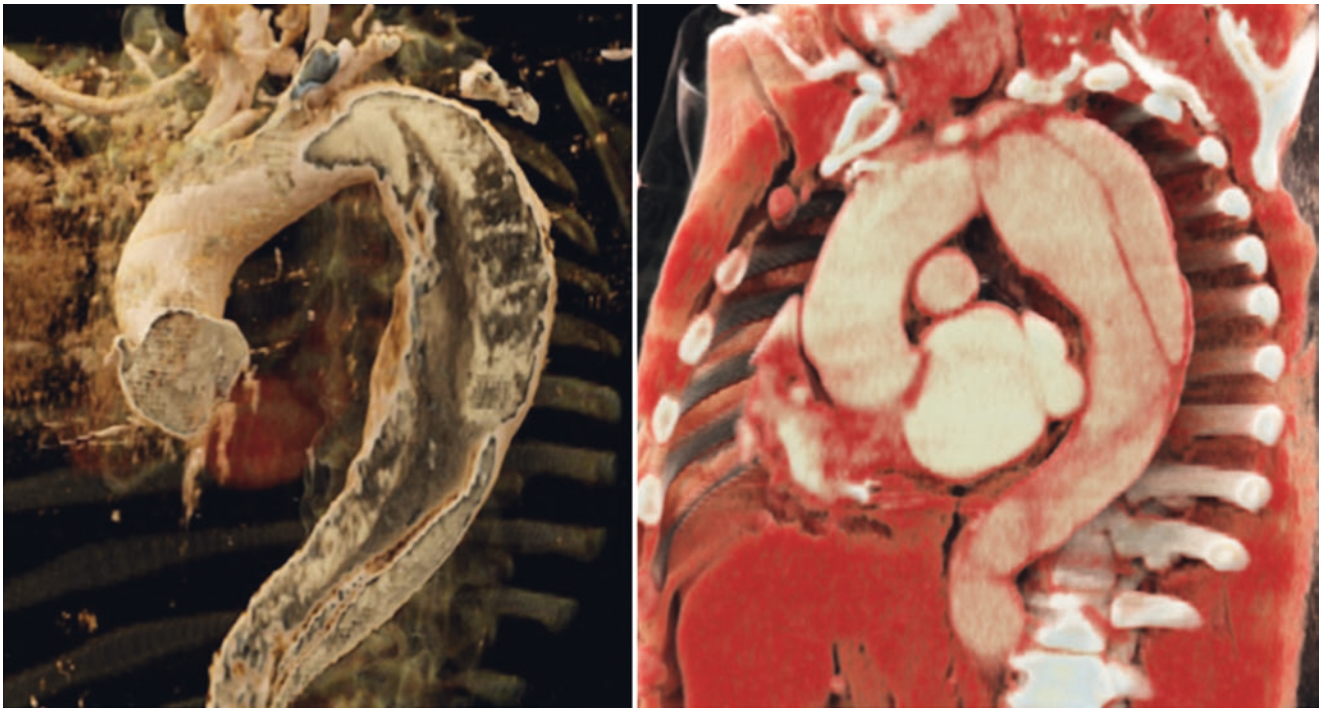

Fig. 31.3 Advanced cinematic rendering of CT images showing type B aortic dissection

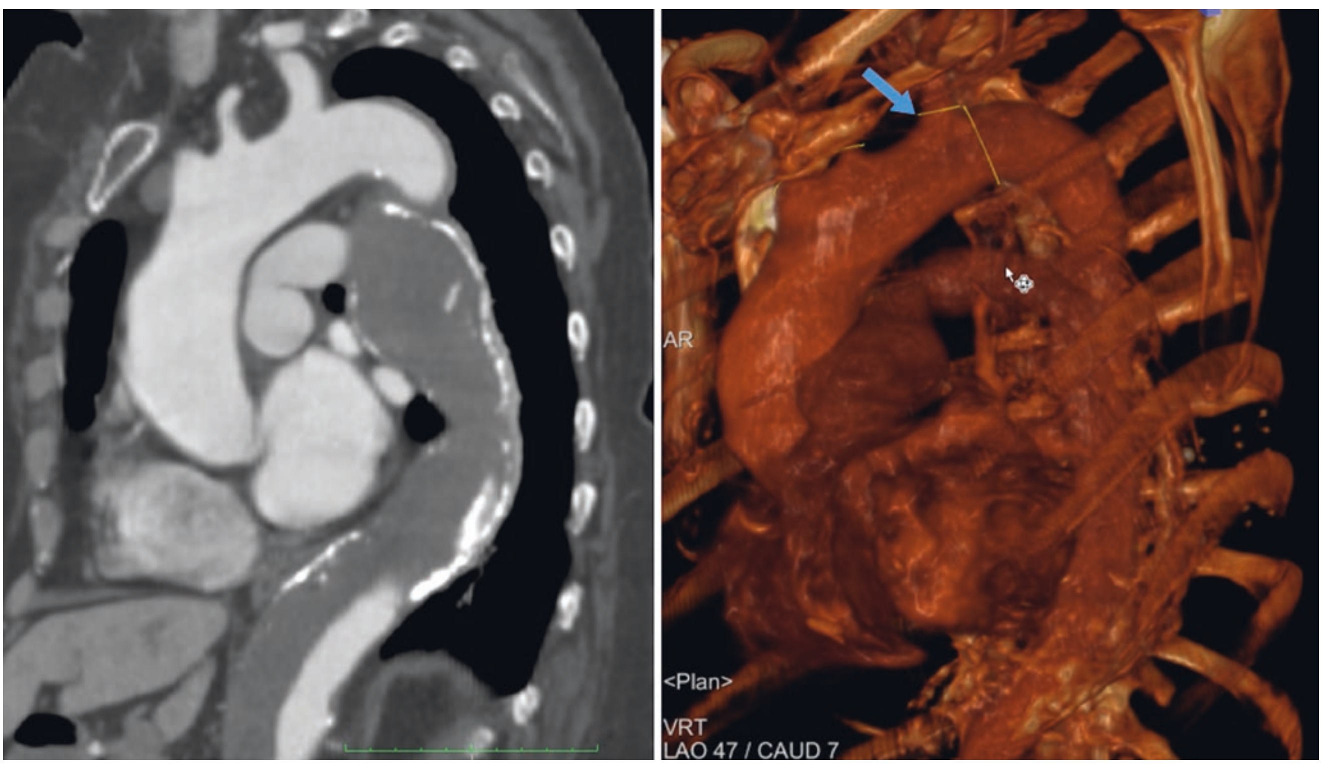

Fig. 31.4 Sagittal (**a**) and volume-rendered (**b**) CTA images demonstrating 3D planning for thoracic endovascular aortic repair (TEVAR) procedure. Origins of left carotid and left subclavian arteries, including the aortic landing zone for TEVAR, were electronically marked in the planning CTA images (*blue arrow*)

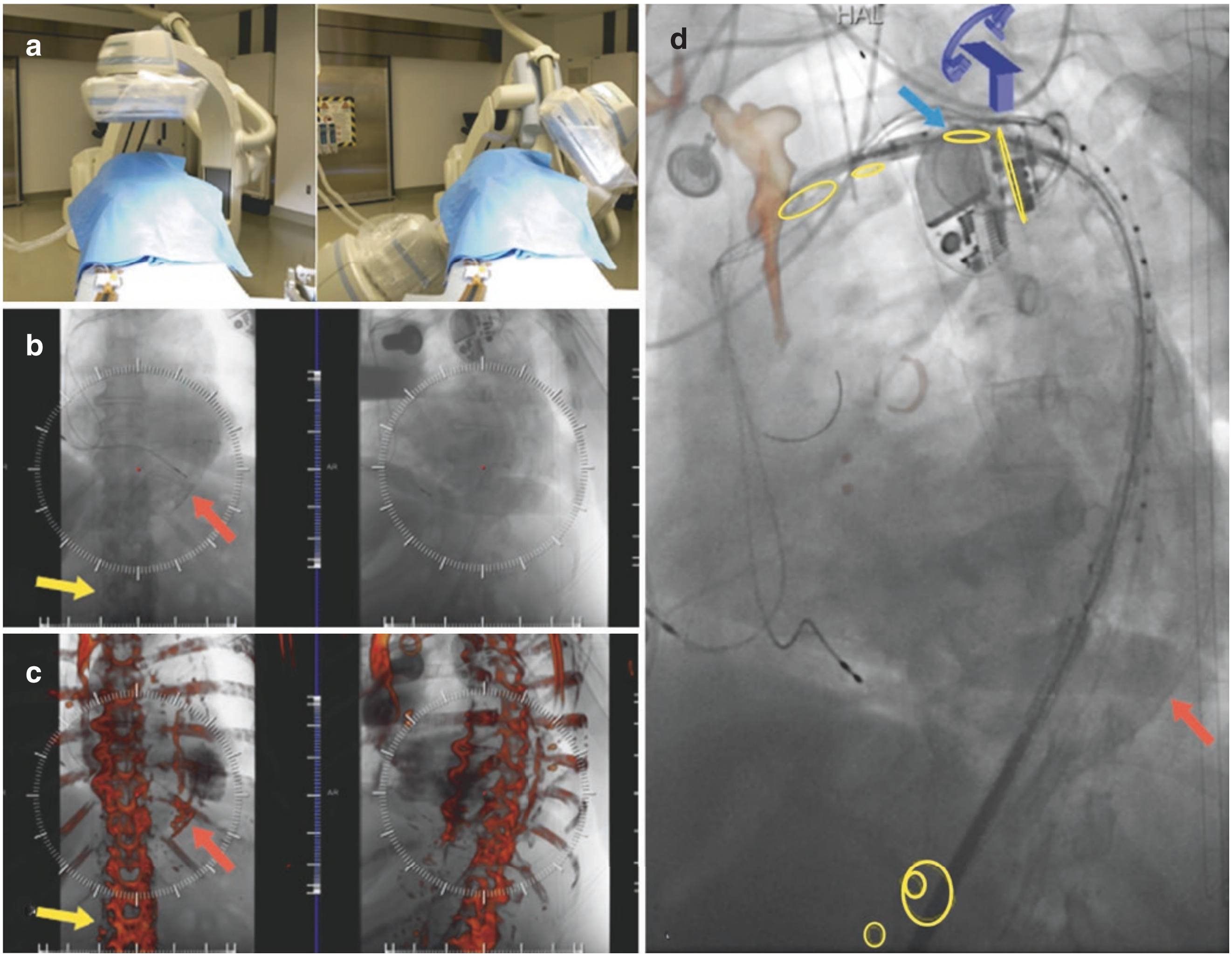

Fig. 31.5 CTA-fluoroscopy 2D-3D image fusion workflow. (**a**, **b**) A robotic C-arm angiography system was used to acquire two fluoroscopic images in anteroposterior (AP) and left anterior oblique (LAO 45) views. (**c**) 3D CT images are overlaid on 2D fluoroscopic images, demonstrating 2D-3D fusion using the spine (*yellow arrow*) and aortic wall calcifications (*red arrow*) as landmarks. (**d**) Overlay of vessel landmarks (*yellow circles*) from CTA on 2D fluoroscopy during stent graft deployment, at the planned landing zone (*blue arrow*)

Equipment for Thoracic Endovascular Aortic Repair

As an interventionalist, it is important to have expertise with the various tools that are commonly used in endovascular practice. TEVAR is no different in this respect, involving not only devices but also occlusion balloons, sheaths, guidewires, and catheters. The tools required for a TEVAR in the context of an aortic dissection or IMH are not very different from those used for a standard TEVAR, although there are some important nuances.

Sheaths are widely used to gain safe access to the vascular system when performing an endovascular procedure. In TEVAR, the devices are generally larger, and this becomes even more of an issue for newer, advanced devices with side branches or other variations. The benefit of sheaths is that they minimize localized-access vessel trauma from the guidewire or catheter repeatedly entering the vessel [30], and more importantly, they provide a safe port of access for tool delivery. Sheaths are made of Teflon (tetrafluoroethylene), an inflexible material that has a low friction coefficient and is very torquable (turning the ex vivo portion results in rotation of the vivo portion). Torquability can vary by sheath, however, and particularly by its apposition to the vessel wall. Therefore, if a sheath fits in a vessel with great difficulty due to size or occlusive disease, torqueing the sheath is not advisable, as the vessel may be injured. Sheaths are sized by their inner diameter, which should be taken into account when estimating the largest-size device that can be inserted through them [29]. To determine the maximum sheath size tolerated by a vessel, one would need to multiply the vessel's actual inner diameter by a factor of 3. Additionally, it is important to assess vessel occlusive disease to further evaluate risk of rupture.

Guidewires help the surgeon navigate through the vascular system without damaging the vessel. The stiff inner wire is tapered and does not extend to the end of the guidewire, so the tip is more flexible and atraumatic to the vessel walls. The different types of wire tip configurations include J-curved, angled, straight, or those that can be formed into the shape preferred by the surgeon, called the “floppy” tip. Of equal importance is the core of the wire, which is generally either Nitinol or stainless steel. A safe standard J-tip or Starter wire (Bentson) is generally used for initial access, although many use a soft Glidewire®. These are generally used to gain access to the ascending aorta in a TEVAR case. These wires usually are exchanged later to stainless steel stiff wires over a support catheter of choice. The wires usually all have a form of antifriction coating, and some even an antithrombogenic coating. For access to a specific vessel or catheterization, the standard length of the guidewire is between 145 and 180 cm. When the guidewire is needed to exchange catheters and devices during an endovascular procedure, the length is usually between 260 to 300 cm [29]; this is always the case in TEVAR. As a rule of thumb, in order to appropriately gauge the length of wire needed, you simply double the shaft length of your catheter or device to calculate the minimum wire length needed. (For example, a device with shaft length of 120 cm needs a wire of at least 240 cm.)

This section is not intended to be an exhaustive discussion of all catheters; it will discuss only those used for the purpose of performing a TEVAR. Catheters serve essentially three primary purposes: (1) an infusion flush catheter, (2) a support catheter, and (3) a directional (selective) catheter. They are essential to performing the intervention safely. A variety of materials are used to make catheters (polyurethane, polyethylene, nylon, and Teflon), each with different characteristics—flexibility (the ability to track the guidewire to the intended position), the coefficient of friction, and the capacity for torqueing—which help in choosing the correct catheter [29].

Many different devices can be used in the treatment of aortic diseases. We recommend referring to the instructions for use (IFU) for each device. As different devices are approved in each country, this chapter simply refers to the device in a general sense, and not to a vendor-specific tool. Selection of device is most commonly based on availability and physician preference.

Thoracic Endovascular Aortic Repair: Step-by-Step Procedure

Accessing the Femoral Artery

The first step is access to the vascular system. This can be done either through a percutaneous access or an open exposure of the access vessel. This choice depends mostly on surgeon preference, unless a conduit is needed. Anecdotally, we prefer an open femoral exposure in cases of aortic dissection, as it is our experience that even the femoral artery can sometimes be a fragile vessel, so we favor a direct arterial repair rather than a percutaneous one. In the case of an aortic dissection, it is crucial to identify the extent of the dissection into the iliac or femoral vessels before accessing the femoral artery. Accessing the false lumen could have undesirable implications for the procedure. When puncturing the femoral artery, it is critical to use ultrasound as guidance, particularly if the femoral artery is dissected. Depending on the device and procedure, groin access may be bilateral or unilateral. We prefer to use a micropuncture set when accessing the vessels.

Insertion of 0.035 Guidewire, Sheath, and Support Catheter

When the access has been created, a guidewire is inserted, followed by a 9 Fr sheath. The 9 Fr sheath is essential in order to be able to perform IVUS. It is better to perform the IVUS over stiff wire, as the anatomy could be altered with a stiff wire, in comparison to a softer wire. With the appropriate support catheter, the guidewire is advanced to the aortic valve. Commonly used guidewires for this purpose are the Bentson wire 260 cm (Cook Medical, Bloomington, IN) or a hydrophilic wire, 260 cm.

Exchange to Stiff Wire

To get the eventual device in the correct position, a stiff guidewire is used. A catheter is therefore initially placed over the floppy guidewire, and the floppy guidewire is removed and exchanged for a stiff guidewire. We prefer a Lunderquist® 300 cm stiff wire (Cook Medical, Bloomington, IN), but a number of other wires with adequate support also can be used.

Intravascular Ultrasound

After placing the stiff wire in position, an IVUS catheter is used to confirm that the wire is in the true lumen throughout the aorta. It is important to understand that the true lumen is generally the smaller of the two lumens and usually appears as a half-moon (Fig. 31.6). Another reason for IVUS is to check for side branches, their locations, and entry and re-entry tears.

Place Device into Position

When IVUS has confirmed the position of the wire in the true lumen, the device is advanced into position over the stiff guidewire.

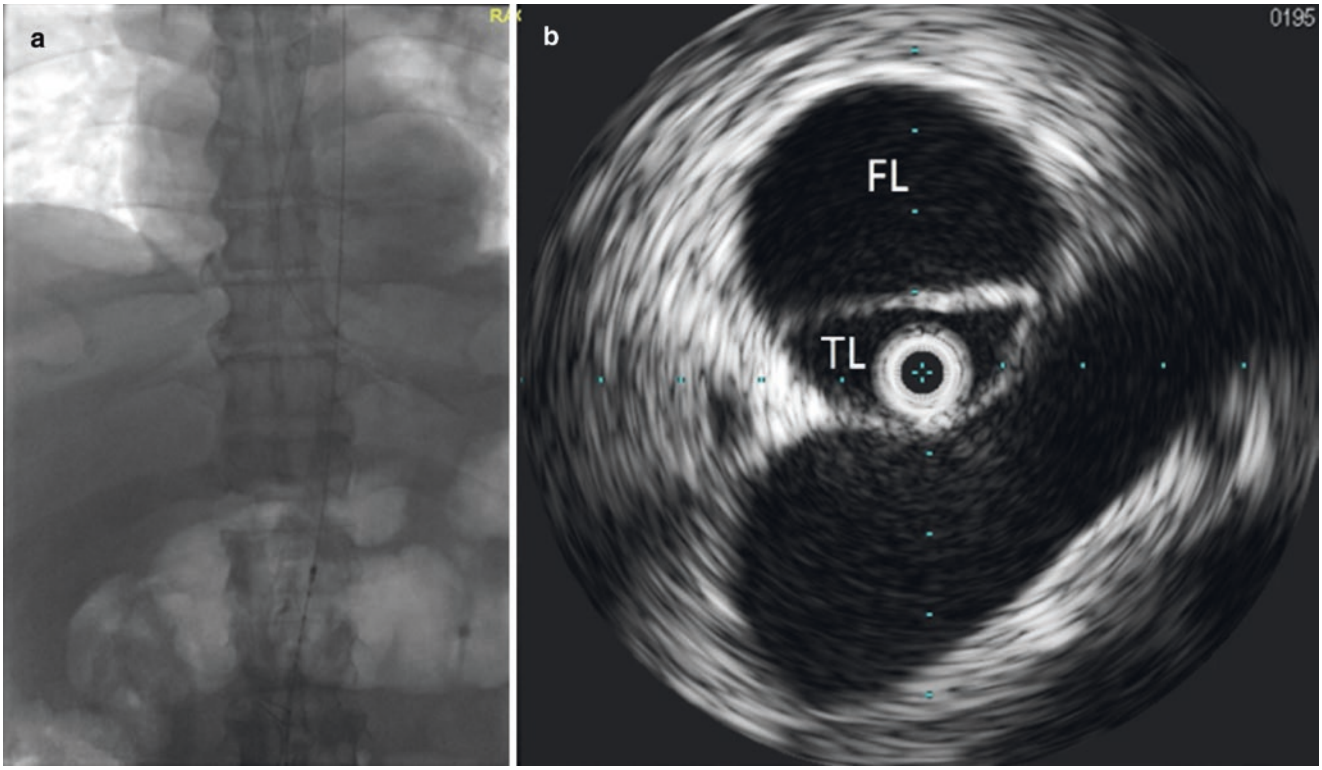

Fig. 31.6 Intravascular ultrasound (IVUS) of patient with type B aortic dissection. (**a**) IVUS catheter pull-back was performed under fluoroscopy. (**b**) IVUS image demonstrating visualization of the true lumen (TL) and false lumen (FL)

Aortogram

The aortogram confirms the device position and is the last step prior to deployment. For a type B dissection, it is important for the aortogram to include the arch; that will not only allow you to see the branch vessels but also will allow you to see the baseline aortic appearance so that you can ensure that there is no retrograde dissection on your completion films. The aortogram is generally done either by getting a second wire through your existing sheath and bringing a pigtail into position or via a second femoral puncture on the contralateral side. It is imperative to perform an arch aortogram in a left anterior oblique (LAO) projection (40–60 degrees). The actual angle can be estimated from the preoperative CTA.

Deploy Stent Graft

When everything is in the correct position, the stent graft will be deployed. Depending on the stent graft, it might be possible to adjust the device a little more before full deployment.

Aortogram to Confirm

After full deployment of the stent graft, an angiogram is performed to confirm the position of the stent graft and to check whether there is flow in the branch vessels and whether there is any evidence of retrograde aortic dissection (Fig. 31.7). If there is any doubt about a retrograde arch dissection, TEE is a useful imaging modality, as is your IVUS.

Extended TEVAR

When the disease involves the ascending aorta and/or the aortic arch, there are different treatment options. Generally, open surgery is the standard for type A dissections and can consist of hemiarch repair or a total arch repair [31, 32].

Debranching the supra-aortic trunks affords options for extending endovascular options. There are three types of aortic debranching, but the most commonly used types are type I and type II. In a type I aortic debranching, the supra-aortic trunks are inserted in the ascending aorta to obtain a Z0 landing zone for TEVAR. Type II aortic debranching consists of reconstruction of the ascending aorta to create a proximal Z0 landing zone [33].

A total arch repair (often in combination with a frozen elephant trunk procedure) is done when the disease extends mainly in the aortic arch. The proximal portion is non-stented and consists of a Dacron sleeve for a conventional surgical approach. The distal part consists of a stent graft [34, 35]. A stent graft currently used for the frozen elephant trunk technique is the E-vita open plus graft (Jotec; Hechingen, Germany).

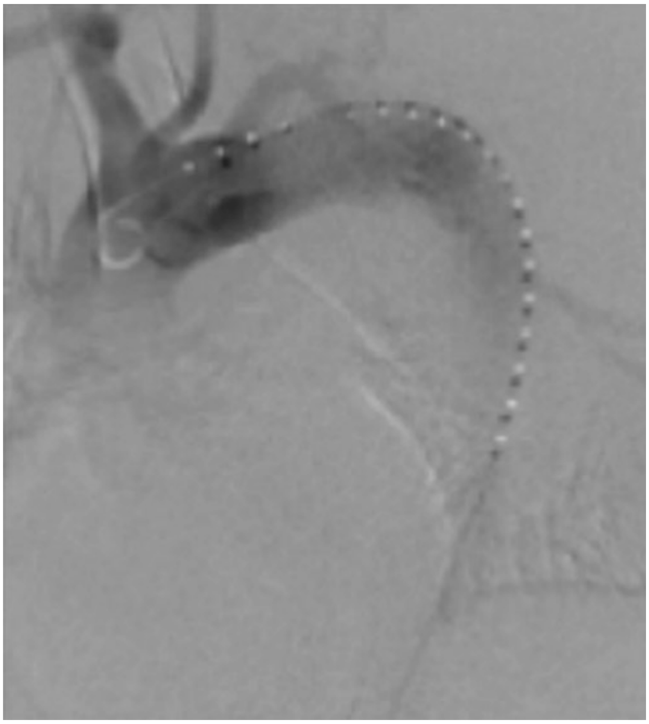

Fig. 31.7 Aortogram after stent graft implantation, with no signs of endoleaks or retrograde dissection, with flow in the branch vessels

Totally endovascular solutions are currently being used, as seen in anecdotal reports, and purpose-built devices are in trials. The overall techniques are essentially no different from that for type B dissection TEVAR, but the precautions differ, based on landmarks such as the coronary arteries and Innominate artery. Additionally, it is important to have experience in crossing the aortic valve with a guidewire, to understand rapid ventricular pacing, and to have TEE surveillance during the procedure. Because of the investigational status of this procedure in the ascending aorta and arch, this chapter will not go into any further details.

Pearls of TEVAR for Aortic Dissection

- Three phases of onset: acute (<15 days), subacute (15–92 days), and chronic (>92 days).
- Medical management for uncomplicated type B aortic dissection, with focus on pain relief, blood pressure and heart rate reduction, and close follow-up.
- Endovascular repair favorable over open surgery.
- Imaging is critical. CTA is most commonly used preoperatively in aortic dissection, to give a clear overview of the aortic side branches, landing zones, angles, and entry and re-entry tears. Intraoperative fluoroscopy and IVUS are essential for consistent and optimal results.
- Steps of TEVAR:
  - Accessing the femoral Artery.
  - Insertion of 0.035 guidewire, sheath, and support catheter.
  - Exchange to stiff wire.
  - IVUS.
  - Place device into position.
  - Aortogram.
  - Deploy stent graft.
  - Aortogram to confirm.

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