American College of Radiology
ACR Appropriateness Criteria®

Abdominal Aortic Aneurysm or Dissection-Interventional Planning and Follow-up

Variant: 1 Adult. Known abdominal aortic aneurysm or dissection without repair. Without or with new symptoms. Follow-up imaging.

Procedure	Appropriateness Category	Relative Radiation Level
CTA abdomen and pelvis with IV contrast	Usually Appropriate	☢☢☢☢
CTA abdomen and pelvis without and with IV contrast	Usually Appropriate	☢☢☢☢
MRA abdomen and pelvis without and with IV contrast	Usually Appropriate	O
CT abdomen and pelvis without and with IV contrast	Usually Appropriate	☢☢☢☢
US duplex Doppler aorta abdomen	Usually Appropriate	O
CT abdomen and pelvis with IV contrast	May Be Appropriate	☢☢☢
CT abdomen and pelvis without IV contrast and US aorta abdomen with duplex Doppler	May Be Appropriate	☢☢☢☢
CT abdomen and pelvis without IV contrast	May Be Appropriate	☢☢☢
MRA abdomen and pelvis without IV contrast	May Be Appropriate	O
US abdomen and pelvis with IV contrast	May Be Appropriate	O
US aorta abdomen with IV contrast	May Be Appropriate	O
Aortography abdomen and pelvis	Usually Not Appropriate	☢☢☢☢
US abdomen and pelvis	Usually Not Appropriate	O
Aortography abdomen	Usually Not Appropriate	☢☢☢
Radiography abdomen and pelvis	Usually Not Appropriate	☢☢☢

Variant: 2 Adult. Endovascular aneurysm repair (EVAR) or open repair of abdominal aortic aneurysm or dissection. Preprocedure planning.

Procedure	Appropriateness Category	Relative Radiation Level
CTA abdomen and pelvis with IV contrast	Usually Appropriate	☢☢☢☢
CTA abdomen and pelvis without and with IV contrast	Usually Appropriate	☢☢☢☢
MRA abdomen and pelvis without and with IV contrast	Usually Appropriate	O
CT abdomen and pelvis without and with IV contrast	May Be Appropriate	☢☢☢☢
CT abdomen and pelvis with IV contrast	May Be Appropriate	☢☢☢
CT abdomen and pelvis without IV contrast and US aorta abdomen with duplex Doppler	May Be Appropriate	☢☢☢☢
MRA abdomen and pelvis without IV contrast	May Be Appropriate	O
Aortography abdomen and pelvis	Usually Not Appropriate	☢☢☢☢
CT abdomen and pelvis without IV contrast	Usually Not Appropriate	☢☢☢
US abdomen and pelvis	Usually Not Appropriate	O
US abdomen and pelvis with IV contrast	Usually Not Appropriate	O
US duplex Doppler aorta abdomen	Usually Not Appropriate	O
Aortography abdomen	Usually Not Appropriate	☢☢☢
Radiography abdomen and pelvis	Usually Not Appropriate	☢☢☢
US aorta abdomen with IV contrast	Usually Not Appropriate	O

Variant: 3 Adult. After endovascular aneurysm repair (EVAR) of abdominal aortic aneurysm or dissection. Follow-up imaging.

Procedure	Appropriateness Category	Relative Radiation Level
CTA abdomen and pelvis without and with IV contrast	Usually Appropriate	☢☢☢☢
CTA abdomen and pelvis with IV contrast	Usually Appropriate	☢☢☢☢
CT abdomen and pelvis without and with IV contrast	Usually Appropriate	☢☢☢☢
MRA abdomen and pelvis without and with IV contrast	Usually Appropriate	O
CT abdomen and pelvis with IV contrast	May Be Appropriate	☢☢☢
CT abdomen and pelvis without IV contrast	May Be Appropriate	☢☢☢
CT abdomen and pelvis without IV contrast and US aorta abdomen with duplex Doppler	May Be Appropriate	☢☢☢☢
MRA abdomen and pelvis without IV contrast	May Be Appropriate	O
US abdomen and pelvis with IV contrast	May Be Appropriate	O
US aorta abdomen with IV contrast	May Be Appropriate	O
US duplex Doppler aorta abdomen	May Be Appropriate	O
Aortography abdomen and pelvis	May Be Appropriate	☢☢☢☢
Aortography abdomen	Usually Not Appropriate	☢☢☢
Radiography abdomen and pelvis	Usually Not Appropriate	☢☢☢
US abdomen and pelvis	Usually Not Appropriate	O

Variant: 4 Adult. After open repair of abdominal aortic aneurysm or dissection. Follow-up imaging.

Procedure	Appropriateness Category	Relative Radiation Level
CTA abdomen and pelvis without and with IV contrast	Usually Appropriate	☢☢☢☢
CTA abdomen and pelvis with IV contrast	Usually Appropriate	☢☢☢☢
MRA abdomen and pelvis without and with IV contrast	Usually Appropriate	O
CT abdomen and pelvis with IV contrast	May Be Appropriate	☢☢☢
CT abdomen and pelvis without and with IV contrast	May Be Appropriate	☢☢☢☢
CT abdomen and pelvis without IV contrast	May Be Appropriate	☢☢☢
CT abdomen and pelvis without IV contrast and US aorta abdomen with duplex Doppler	May Be Appropriate	☢☢☢☢
MRA abdomen and pelvis without IV contrast	May Be Appropriate	O
US abdomen and pelvis with IV contrast	May Be Appropriate	O
US aorta abdomen with IV contrast	May Be Appropriate	O
US duplex Doppler aorta abdomen	May Be Appropriate	O
US abdomen and pelvis	Usually Not Appropriate	O
Aortography abdomen	Usually Not Appropriate	☢☢☢
Aortography abdomen and pelvis	Usually Not Appropriate	☢☢☢☢
Radiography abdomen and pelvis	Usually Not Appropriate	☢☢☢

Panel Members

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Summary of Literature Review

Introduction/Background

Guidelines for abdominal aortic aneurysm (AAA) screening have been established to assist medical decision making [1, 2]. These guidelines were developed based on a patient's health status and comorbidities, the aneurysm's maximum diameter (>5.5 cm) and rate of change (>1 cm/year), and other signs that indicated impending rupture [1, 3]. The arrival of the endovascular aneurysm repair (EVAR) technique introduced new variables to managing AAAs. Relatively recent developments of the fenestrated EVAR (FEVAR) and percutaneous EVAR have advanced therapeutic potential while maintaining low morbidity [4-6].

For patients who present de novo for treatment of AAA without any prior imaging available, the entire aorta (including the thoracic portion) should be assessed to fully characterize the aneurysm and exclude a concomitant thoracic aortic aneurysm. Preoperative imaging for open repair of AAA has one primary focus: to determine the need for surgery based on aneurysm size, extent, and rate of growth. Additional information regarding potential variant anatomy can also be helpful in guiding appropriate treatment and preventing unexpected complications at the time of repair.

EVAR requires accurate preoperative imaging evaluation for appropriate patient selection based on aneurysm morphology, access vessel size, and patency [7, 8]. Paramount considerations in evaluating an AAA for EVAR lie in the morphology of the proximal neck, which for an infrarenal AAA is defined as the segment of aorta between the most caudal renal artery and the proximal boundary of the aneurysm. Unfavorable neck anatomy, based on its diameter, length, angulation, morphology, and presence of calcification, is the most frequent cause of exclusion from EVAR [9-11]. Over 50% of patients have aneurysm morphology unsuitable for conventional EVAR [6]. In conventional EVAR, a neck size of >10 to 15 mm in length and <30 mm in diameter is required to provide an adequate proximal graft seal.

The advantages of EVAR come at a cost of lifelong imaging surveillance. This is due to a higher rate of complications that require reintervention when compared to open repair [12, 13]. Complications of EVAR include stent graft migration, kinking, infection, thrombosis, and renal dysfunction. The most important complication to detect is continued aneurysm expansion leading to eventual rupture, which can occur even after successful EVAR [14]. The most common complication of EVAR is endoleak formation, which may contribute to aneurysm sac enlargement and rupture [15]. Although EVAR is safe and has a low mortality rate [16], the possibility of complications and need for reintervention remains high [17-19], thereby requiring life-long monitoring.

The ultimate goal of endovascular therapy is to prevent aneurysm rupture. Follow-up imaging is the most useful tool for evaluating posttherapeutic outcomes and monitoring potential complications. Successful therapy results in an aneurysm that remains stable or decreases in size over serial follow-up imaging examinations, with decreasing size of the aneurysm sac believed to indicate a low risk of future rupture [20, 21].

Special Imaging Considerations

The key component of diagnostic imaging of a known AAA or dissection is to understand changes in vascular anatomy, size, and perfusion. This can now be accomplished with a variety of techniques that allow both planar and cross-sectional evaluations across the gamut of diagnostic modalities.

CT is a cross-sectional imaging modality that offers excellent spatial resolution and fast image acquisition times. However, without contrast material administration, its ability to assess vascular structures is limited. Evaluation of the vessel lumen is accomplished through CT angiography (CTA), a technique that uses the administration of iodinated contrast material. The addition of 3-D volumetric postprocessing techniques allow the abdominal aorta and associated vasculature to be viewed in any obliquity and affords quantification of luminal diameter, cross-sectional area, and sac volume [22-24].

For the purposes of distinguishing between CT and CTA, ACR Appropriateness Criteria topics use the definition in the ACR–NASCI–SIR–SPR Practice Parameter for the Performance and Interpretation of Body Computed Tomography Angiography (CTA) [25]:

"CTA uses a thin-section CT acquisition that is timed to coincide with peak arterial and/or venous enhancement, depending on the vascular structures to be analyzed. The resultant volumetric data set is interpreted using primary transverse reconstructions as well as multiplanar reformations and 3-D renderings."

All elements are essential: 1) timing, 2) reconstructions/reformats, and 3) 3-D renderings. Standard CTs with contrast also include timing issues and reconstructions/reformats. Only in CTA; however, is 3-D rendering a required element. This corresponds to the definitions that the CMS has applied to the Current Procedural Terminology codes.

CTA imaging may be performed as a single arterial phase, biphasic study (noncontrast and arterial or arterial and delayed phases), or triphasic study (noncontrast, arterial, and delayed phases). Several authors have proposed eliminating either the arterial phase [26] or delayed phase [27, 28], although one author has suggested eliminating noncontrast scans from all surveillance examinations with the exception of an initial 1-month follow-up [29].

Several studies have reported significant dose reduction using dual-energy CT with acquisition of delayed-phase images only [30, 31]. Accompanying software allows for the isolation of iodine from a selected region and enables reconstruction of virtual noncontrast images. A colored overlay can be applied to voxels containing iodine, rendering detection of contrast material within the aneurysm sac external to the stent-graft more visible [30].

Determining the optimal dose-efficient CT technique is a work in progress that will continue to evolve with increased experience and technological advancement.

Aortography is an invasive imaging modality that can accurately assess aortic side branch patency, knowledge of which is crucial for deployment of conventional and fenestrated endografts with or without bridging stents. However, it fails to demonstrate mural thrombus, thereby limiting diameter measurements and landing zone assessment. Though less sensitive than CTA in detecting endoleaks, aortography is able to demonstrate the direction of blood flow in or out of the aneurysm sac, rendering it more accurate than CTA in classifying endoleaks [32]. Although traditional aortography relies on iodinated contrast material, recent studies suggest that carbon dioxide may be an acceptable alternative for evaluating endoleaks in patients at risk for contrast-related nephropathy [33, 34].

The major advantage of MR angiography (MRA) relative to CTA is improved soft tissue characterization. Disadvantages of MRA include relatively long scanning duration, patient claustrophobia, and decreased spatial resolution in patients with certain implantable devices. MRA is also limited in its ability to detect intimal calcification [22]. Additionally, susceptibility artifact from the metal interstices of the stent graft presents a diagnostic challenge for assessing device integrity and may mimic graft stenosis.

Superior soft tissue characterization inherent to MRA may assist clinicians in differentiating slow-growing aneurysms from fast-growing aneurysms. For example, Nguyen et al [35] demonstrated that AAAs containing intraluminal thrombus that have high T1-weighted signal intensity are associated with higher growth rates. Some studies have also suggested noncontrast MRI can be used to evaluate endoleak after EVAR.

Color duplex ultrasound (CDUS) is a noninvasive imaging modality that is portable and safe, sparing patients from nephrotoxic contrast material administration. CDUS is able to assess blood flow dynamics in real time and allows for quantification of luminal diameter and cross-sectional area. Image quality in CDUS depends on patient cooperation and patient body habitus [36, 37]. Although excellent correlation between AAA diameter measurements made by CT and CDUS is well documented, there is general agreement that conventional US techniques systematically underestimate aneurysm diameter by ~2 mm [24, 38-40].

Contrast-enhanced US (CEUS) uses the infusion of gas-filled microbubbles to visualize the vessel lumen. Unlike iodinated contrast materials used in CTA, this gas is not nephrotoxic and is safely eliminated via the respiratory system. The advent of 3-D CEUS uses positional information for magnetic field emitters to assemble collected US reflections into a high-resolution 3-D image, which results in improved image quality relative to CDUS [41]. Three-dimensional CEUS is reported to be more accurate than 2-D methods in quantifying maximum vessel diameter, as the former allows measurements to be made orthogonal to vessel centerline [38].

Discussion of Procedures by Variant

Variant 1:Adult. Known abdominal aortic aneurysm or dissection without repair. Without or with new symptoms. Follow-up imaging.

Any known AAA or dissection that presents with new symptoms warrants prompt clinical and diagnostic evaluation. This is most commonly achieved with contrast-enhanced CT imaging, particularly CTA, due to its widespread availability and accuracy.

The goals of imaging for this variant are to detect anatomical changes and possible complications of AAA without repair. With the information from imaging, the expected patient benefits include making the best treatment plan based on the morphology of the aneurysm/dissection.

Variant 1:Adult. Known abdominal aortic aneurysm or dissection without repair. Without or with new symptoms. Follow-up imaging.
A. Aortography abdomen

There is no relevant literature supporting the use of conventional angiography in the surveillance of AAA. Noninvasive techniques to monitor aneurysm characteristics make this invasive option less reasonable.

Variant 1:Adult. Known abdominal aortic aneurysm or dissection without repair. Without or with new symptoms. Follow-up imaging.
B. Aortography abdomen and pelvis

There is no relevant literature supporting the use of conventional angiography in the surveillance of AAA. Noninvasive techniques to monitor aneurysm characteristics make this invasive option less reasonable.

Variant 1:Adult. Known abdominal aortic aneurysm or dissection without repair. Without or with new symptoms. Follow-up imaging.
C. CT abdomen and pelvis with IV contrast

The majority of evidence regarding AAA surveillance using CT is based on CTA data and is primarily related to contrast bolus timing. Contrast-enhanced CT is well established in the literature and is capable of identifying aortic aneurysms [12, 18, 45, 47-50].

Variant 1:Adult. Known abdominal aortic aneurysm or dissection without repair. Without or with new symptoms. Follow-up imaging.
D. CT abdomen and pelvis without and with IV contrast

The majority of evidence regarding AAA surveillance using CT is based on CTA data and is primarily related to contrast bolus timing. Contrast-enhanced CT is well established in the literature and is capable of identifying aortic aneurysms [12, 18, 45, 47-50]. There is no specific role for multiphase CT imaging in evaluation of an unrepaired AAA or dissection.

Variant 1:Adult. Known abdominal aortic aneurysm or dissection without repair. Without or with new symptoms. Follow-up imaging.
E. CT abdomen and pelvis without IV contrast

The majority of evidence regarding AAA surveillance using CT is based on CTA data and is primarily related to contrast bolus timing. Contrast-enhanced CT is well established in the literature and is capable of identifying aortic aneurysms [12, 18, 45].

There is no specific literature regarding the use of noncontrast CT in the surveillance of AAA. However, the spatial accuracy of low-dose noncontrast CT imaging has recently been validated in a small retrospective series evaluating aortic size [55]. A "near-zero contrast" approach has also shown to be feasible in EVAR for patients with simple aortoiliac anatomy [56]. Noncontrast imaging can be employed in CTA protocols to evaluate for calcification, with spectral CT scanners offering virtual noncontrast reconstructions as an alternative.

Variant 1:Adult. Known abdominal aortic aneurysm or dissection without repair. Without or

with new symptoms. Follow-up imaging.
F. CT abdomen and pelvis without IV contrast and US aorta abdomen with duplex Doppler

There may be some benefit in combining the cross-sectional ability of CT with that of a duplex Doppler to assess flow.

Variant 1:Adult. Known abdominal aortic aneurysm or dissection without repair. Without or with new symptoms. Follow-up imaging.
G. CTA abdomen and pelvis with IV contrast

CTA of the abdomen and pelvis presents many benefits over the other modalities. Relative to US, CTA is considered slightly more accurate at determining aneurysm diameter [8, 25, 42-44].

The majority of evidence regarding AAA surveillance using CT is based on CTA data and is primarily related to contrast bolus timing. Contrast-enhanced CT is well established in the literature and is capable of identifying aortic aneurysms [12, 18, 45]. Noncontrast imaging can be employed in CTA protocols to evaluate for calcification, with spectral CT scanners offering virtual noncontrast reconstructions as an alternative.

Variant 1:Adult. Known abdominal aortic aneurysm or dissection without repair. Without or with new symptoms. Follow-up imaging.
H. CTA abdomen and pelvis without and with IV contrast

CTA of the abdomen and pelvis presents many benefits over the other modalities. Relative to US, CTA is considered slightly more accurate at determining aneurysm diameter [8, 25, 42-44].

The majority of evidence regarding AAA surveillance using CT is based on CTA data and is primarily related to contrast bolus timing. Incidental diagnosis of AAA on contrast-enhanced CT is well described in the literature [8, 25, 42-44]. Multiphasic CTA can accurately diagnose aortic dissection [43]. Noncontrast imaging can be employed in CTA protocols to evaluate for calcification with spectral CT scanners offering virtual noncontrast reconstructions as an alternative.

Although multiphasic CTA can detect both aortic dissection and endoleak [43], there is no specific role regarding aneurysm follow-up. Multiphase imaging is commonly performed after endovascular repair.

Variant 1:Adult. Known abdominal aortic aneurysm or dissection without repair. Without or with new symptoms. Follow-up imaging.
I. MRA abdomen and pelvis without and with IV contrast

There are benefits of MRA that make it worth considering in the surveillance of AAA. MRA can be obtained without the use of intravenous (IV) contrast. A prospective evaluation of nonenhanced MRA compared with contrast-enhanced CTA demonstrated equivalent accuracy of measurements for preoperative planning of EVAR suggesting adequacy for surveillance imaging [25]. MR elastography-derived AAA stiffness and stiffness ratio are associated with aneurysmal events (subsequent repair, rupture, or diameter >5.0 cm) [46].

Variant 1:Adult. Known abdominal aortic aneurysm or dissection without repair. Without or with new symptoms. Follow-up imaging.
J. MRA abdomen and pelvis without IV contrast

There are benefits of MRA that make it worth considering in the surveillance of AAA. MRA can be obtained without the use of IV contrast. A prospective evaluation of nonenhanced MRA compared with contrast-enhanced CTA demonstrated equivalent accuracy of measurements for preoperative planning of EVAR suggesting adequacy for surveillance imaging [25]. MR elastography-derived AAA stiffness and stiffness ratio are associated with aneurysmal events (subsequent repair, rupture, or diameter >5.0 cm) [46].

Variant 1:Adult. Known abdominal aortic aneurysm or dissection without repair. Without or with new symptoms. Follow-up imaging.
K. Radiography abdomen and pelvis

There is no relevant literature supporting the use of radiography in the surveillance of AAA. Calcified aneurysms may be identifiable by radiography.

Variant 1:Adult. Known abdominal aortic aneurysm or dissection without repair. Without or with new symptoms. Follow-up imaging.
L. US abdomen and pelvis

When appropriate windows are available, US can be used to measure reproducible AAA diameters [57, 58].

Variant 1:Adult. Known abdominal aortic aneurysm or dissection without repair. Without or with new symptoms. Follow-up imaging.
M. US abdomen and pelvis with IV contrast

When appropriate windows are available, US can be used to measure reproducible AAA diameters [57, 58]. In addition, the use of microbubble US contrast agents can increase the ability to visualize flow [54].

Variant 1:Adult. Known abdominal aortic aneurysm or dissection without repair. Without or with new symptoms. Follow-up imaging.
N. US aorta abdomen with IV contrast

When appropriate windows are available, US can be used to measure reproducible AAA diameters [57, 58]. In addition, the use of microbubble US contrast agents can increase the ability to visualize flow [54].

Variant 1:Adult. Known abdominal aortic aneurysm or dissection without repair. Without or with new symptoms. Follow-up imaging.
O. US duplex Doppler aorta abdomen

US is the most widely studied and used imaging tool for evaluating AAA, both for screening and surveillance. US has been verified as having consistent measurement accuracy, which can approximate the accuracy demonstrated by CT, MRI, and MRA [8, 9, 14, 15]. Studies have reported that US may underestimate the maximum AAA diameter by 4 mm on average and the interobserver measurement difference can range from 2 to 10 mm with US compared with <2 mm using CT [15, 16, 20, 21, 51]. Evidence is still lacking as to whether these differences are clinically impactful. Variation in accuracy is believed to be related to differences in measurement technique. For example, there is debate as to whether to place the measurement calipers on the outer or inner edge of the vessel; there is no clear consensus on the best measurement method [21]. Finally, no significant difference in rate of growth measurements between US and CT has been found [9, 52]. US is also less capable of identifying specific aneurysm features beyond diameter, such as intraluminal thrombus or adjacent inflammation, both of which are more easily identified on CT [22, 23, 53]. However, the use of CEUS is growing to evaluate intraluminal pathology [54].

Variant 2:Adult. Endovascular aneurysm repair (EVAR) or open repair of abdominal aortic aneurysm or dissection. Preprocedure planning.

The goal of imaging for this variant is to detect anatomical changes or complicating features before repair. With the information from imaging, the expected patient benefits include making the best treatment plan based on the morphology of the aneurysm/dissection.

Variant 2:Adult. Endovascular aneurysm repair (EVAR) or open repair of abdominal aortic aneurysm or dissection. Preprocedure planning.
A. Aortography abdomen

As aortography and radiography are unable to accurately provide aneurysm sac diameter measurements and assessment of landing zones, these imaging modalities are inadequate for pre-EVAR or open repair evaluation. However, aortography may be of value in assessing branch vessel patency and is usually part of branch vessel occlusion procedures before aneurysm repair.

Variant 2:Adult. Endovascular aneurysm repair (EVAR) or open repair of abdominal aortic aneurysm or dissection. Preprocedure planning.
B. Aortography abdomen and pelvis

As aortography and radiography are unable to accurately provide aneurysm sac diameter measurements and assessment of landing zones, these imaging modalities are inadequate for pre-EVAR or open repair evaluation. However, aortography may be of value in assessing branch vessel patency and is usually part of branch vessel occlusion procedures before aneurysm repair.

Variant 2:Adult. Endovascular aneurysm repair (EVAR) or open repair of abdominal aortic aneurysm or dissection. Preprocedure planning.
C. CT abdomen and pelvis with IV contrast

The majority of evidence regarding AAA surveillance using CT is based on CTA data and is primarily related to contrast bolus timing. Contrast-enhanced CT is well established in the literature and is capable of identifying aortic aneurysms [12, 18, 45, 47-50]. However, in preoperative planning, an angiographic phase CT provides more usefulness.

Variant 2:Adult. Endovascular aneurysm repair (EVAR) or open repair of abdominal aortic aneurysm or dissection. Preprocedure planning.
D. CT abdomen and pelvis without and with IV contrast

The majority of evidence regarding AAA surveillance using CT is based on CTA data and is primarily related to contrast bolus timing. Contrast-enhanced CT is well established in the literature and is capable of identifying aortic aneurysms [12, 18, 45, 47-50]. However, in preoperative planning, an angiographic phase CT provides more usefulness.

Variant 2:Adult. Endovascular aneurysm repair (EVAR) or open repair of abdominal aortic aneurysm or dissection. Preprocedure planning.
E. CT abdomen and pelvis without IV contrast

The majority of evidence regarding AAA surveillance using CT is based on CTA data and is primarily related to contrast bolus timing. The absence of IV contrast makes appropriate preoperative planning a challenge.

Variant 2:Adult. Endovascular aneurysm repair (EVAR) or open repair of abdominal aortic aneurysm or dissection. Preprocedure planning.
F. CT abdomen and pelvis without IV contrast and US aorta abdomen with duplex Doppler

Noncontrast CT abdomen and pelvis does not allow for vessel interrogation and image manipulation to enhance preprocedure planning. It can readily identify severely calcified vasculature but again is unable to clearly delineate fibrofatty atherosclerosis. No evidence is present within the medical literature to support the use of either CDUS or CEUS in the formal preoperative evaluation of AAA, although CEUS have shown to detect abdominal aneurysm and aortic dissection [54].

Variant 2:Adult. Endovascular aneurysm repair (EVAR) or open repair of abdominal aortic aneurysm or dissection. Preprocedure planning.
G. CTA abdomen and pelvis with IV contrast

Due to its superior spatial resolution and rapid image acquisition, CTA with 3-D volumetric reconstruction and vessel analysis has gained wide acceptance as the reference standard for pre-EVAR evaluation. The usefulness of 3-D reconstruction software has become paramount in EVAR planning, as it diminishes the impact of vessel tortuosity on diameter and length measurements, in addition to reducing intraobserver variability [59]. One author found that routine 3-D analysis of pre-EVAR images led to a significant reduction in Type I endoleaks [60]. Reformatted CTA images in the coronal and sagittal planes should be used for increased diagnostic accuracy. In most cases, a CTA of the abdomen and pelvis is appropriate to ensure coverage of the entire aneurysm and vascular access. The CTA should include the chest in patients with thoracoabdominal AAA (TAAA).

Variant 2:Adult. Endovascular aneurysm repair (EVAR) or open repair of abdominal aortic aneurysm or dissection. Preprocedure planning.
H. CTA abdomen and pelvis without and with IV contrast

Due to its superior spatial resolution and rapid image acquisition, CTA with 3-D volumetric reconstruction and vessel analysis has gained wide acceptance as the reference standard for pre-EVAR evaluation. The usefulness of 3-D reconstruction software has become paramount in EVAR planning, as it diminishes the impact of vessel tortuosity on diameter and length measurements,[59]. One author found that routine 3-D analysis of pre-EVAR images led to a significant reduction in Type I endoleaks [60]. Reformatted CTA images in the coronal and sagittal planes should be used for increased diagnostic accuracy. In most cases, a CTA of the abdomen and pelvis is appropriate to ensure coverage of the entire aneurysm and vascular access. The CTA should include the chest in patients with TAAA. Multiphasic CTA can detect both aortic dissection and endoleak [43].

Variant 2:Adult. Endovascular aneurysm repair (EVAR) or open repair of abdominal aortic aneurysm or dissection. Preprocedure planning.
I. MRA abdomen and pelvis without and with IV contrast

For the purpose of pre-EVAR planning, T1-weighted spin-echo images and flow-based methods such as time of flight or phase contrast provide adequate details regarding aneurysm morphology and relevant vascular anatomy. However, these techniques are limited by low spatial resolution and signal-to-noise ratio and are therefore suboptimal for evaluating small-vessel lesions or diminutive side branches [22]. Furthermore, flow-based sequences are susceptible to flow artifacts that may overestimate the degree of stenosis or falsely demonstrate an occlusion [61]. To overcome these limitations, contrast-enhanced MRA (CE-MRA) should be added to conventional T1- and T2-weighted spin-echo sequences. CE-MRA is much less susceptible to flow and susceptibility artifacts and has a high signal-to-noise ratio for evaluating small vessels and fine structural details. The effectiveness of CE-MRA has been found to be comparable to that of CTA in assessing the suitability of aneurysms for EVAR [62]. In most cases, an MRA of the abdomen and pelvis is appropriate to ensure coverage of the entire aneurysm and vascular access. The MRA should include the chest in patients with TAAA. AAA stiffness and stiffness ratio measured with use of MR elastography is associated with aneurysmal events (subsequent repair, rupture) at a 15-month follow-up [46].

One study found that AAA measurements obtained by noncontrast MRA were not significantly different from those measured by CTA [49].

Variant 2:Adult. Endovascular aneurysm repair (EVAR) or open repair of abdominal aortic aneurysm or dissection. Preprocedure planning.
J. MRA abdomen and pelvis without IV contrast

For the purpose of pre-EVAR planning, T1-weighted spin-echo images and flow-based methods such as time of flight or phase contrast provide adequate details regarding aneurysm morphology and relevant vascular anatomy. However, these techniques are limited by low spatial resolution and signal-to-noise ratio and are therefore suboptimal for evaluating small-vessel lesions or diminutive side branches [22]. Furthermore, flow-based sequences are susceptible to flow artifacts that may overestimate the degree of stenosis or falsely demonstrate an occlusion [61]. To overcome these limitations, CE-MRA should be added to conventional T1- and T2-weighted spin-echo sequences. CE-MRA is much less susceptible to flow and susceptibility artifacts and has a high signal-to-noise ratio for evaluating small vessels and fine structural details. The effectiveness of CE-MRA has been found to be comparable to that of CTA in assessing the suitability of aneurysms for EVAR [62]. In most cases, an MRA of the abdomen and pelvis is appropriate to ensure coverage of the entire aneurysm and vascular access. The MRA should include the chest in patients with TAAA.

One study found that AAA measurements obtained by noncontrast MRA were not significantly different from those measured by CTA [49].

Variant 2:Adult. Endovascular aneurysm repair (EVAR) or open repair of abdominal aortic aneurysm or dissection. Preprocedure planning.
K. Radiography abdomen and pelvis

Radiographs are unable to adequately visualize the abdominal aorta, thereby prohibiting proximal landing zone assessment and luminal diameter quantification. As such, there is no role for radiography in the preoperative evaluation of AAA. However, given the high spatial resolution of radiography, this modality affords optimal visualization of stent graft geometry. When using consistent centering protocols, this allows for reliable detection of kinks and stent graft migration to within 2 mm [64] in the postoperative setting.

Variant 2:Adult. Endovascular aneurysm repair (EVAR) or open repair of abdominal aortic aneurysm or dissection. Preprocedure planning.
L. US abdomen and pelvis

Although the United States Preventative Services Task Force currently recommends one-time US screening for AAA in men 65 to 75 years of age who have ever smoked [63], no evidence is present within the medical literature to support the use of either CDUS or CEUS in the formal preoperative evaluation of AAA or dissection.

Variant 2:Adult. Endovascular aneurysm repair (EVAR) or open repair of abdominal aortic aneurysm or dissection. Preprocedure planning.
M. US abdomen and pelvis with IV contrast

Although the United States Preventative Services Task Force currently recommends one-time US screening for AAA in men 65 to 75 years of age who have ever smoked [63], no evidence is present within the medical literature to support the use of either CDUS or CEUS in the formal preoperative evaluation of AAA or dissection.

Variant 2:Adult. Endovascular aneurysm repair (EVAR) or open repair of abdominal aortic aneurysm or dissection. Preprocedure planning.
N. US aorta abdomen with IV contrast

Although the United States Preventative Services Task Force currently recommends one-time US screening for AAA in men 65 to 75 years of age who have ever smoked [63], no evidence is present within the medical literature to support the use of either CDUS or CEUS in the formal preoperative evaluation of AAA or dissection.

Variant 2:Adult. Endovascular aneurysm repair (EVAR) or open repair of abdominal aortic aneurysm or dissection. Preprocedure planning.
O. US duplex Doppler aorta abdomen

Although the United States Preventative Services Task Force currently recommends one-time US screening for AAA in men 65 to 75 years of age who have ever smoked [63], no evidence is present within the medical literature to support the use of either CDUS or CEUS in the formal preoperative evaluation of AAA, although CEUS have shown to detect abdominal aneurysm and aortic dissection [54].

Variant 3:Adult. After endovascular aneurysm repair (EVAR) of abdominal aortic aneurysm or dissection. Follow-up imaging.

The goal of imaging for this variant is to detect anatomical changes in known aortic aneurysm or dissection and provide understanding of stable and complicating features after repair. With the information from imaging, the expected patient benefits include making the best treatment plan based on the morphology of the treated aneurysm/dissection for the patient.

Variant 3:Adult. After endovascular aneurysm repair (EVAR) of abdominal aortic aneurysm or dissection. Follow-up imaging.
A. Aortography abdomen

Due to the relatively invasive nature of aortography, it is not practical for routine post-EVAR surveillance. However, in the setting of a known endoleak, aortography may be more accurate than CTA in classifying endoleaks. One study revealed only 86% agreement in endoleak classification between aortography and CTA, in which subsequent correct classification by aortography significantly improved patient management [32]. It therefore stands to reason that aortography may be best used as a second-line imaging modality in post-EVAR patients, playing a vital role in endoleak classification and reintervention [24].

Variant 3:Adult. After endovascular aneurysm repair (EVAR) of abdominal aortic aneurysm or dissection. Follow-up imaging.
B. Aortography abdomen and pelvis

Due to the relatively invasive nature of aortography, it is not practical for routine post-EVAR surveillance. However, in the setting of a known endoleak, aortography may be more accurate than CTA in classifying endoleaks. One study revealed only 86% agreement in endoleak classification between aortography and CTA, in which subsequent correct classification by aortography significantly improved patient management [32]. It therefore stands to reason that aortography may be best used as a second-line imaging modality in post-EVAR patients, playing a vital role in endoleak classification and reintervention [24].

Variant 3:Adult. After endovascular aneurysm repair (EVAR) of abdominal aortic aneurysm or dissection. Follow-up imaging.

C. CT abdomen and pelvis with IV contrast

The majority of evidence regarding aortic intervention follow-up using CT is based on CTA data and is primarily related to contrast bolus timing. Contrast-enhanced CT is well established in the literature and is capable of identifying aortic dissections and aneurysms [12, 18, 45, 47-50]. However, in postoperative follow-up, a multiphase angiographic phase CT provides more usefulness [43, 73-75].

Variant 3:Adult. After endovascular aneurysm repair (EVAR) of abdominal aortic aneurysm or dissection. Follow-up imaging.
D. CT abdomen and pelvis without and with IV contrast

The majority of evidence regarding aortic intervention follow-up using CT is based on CTA data and is primarily related to contrast bolus timing. Contrast-enhanced CT is well established in the literature and is capable of identifying aortic dissections and aneurysms [12, 18, 45, 47-50]. However, in postoperative follow-up, a multiphase angiographic phase CT provides more usefulness [43, 73-75].

Variant 3:Adult. After endovascular aneurysm repair (EVAR) of abdominal aortic aneurysm or dissection. Follow-up imaging.
E. CT abdomen and pelvis without IV contrast

The majority of evidence regarding aortic intervention follow-up using CT is based on CTA data and is primarily related to contrast bolus timing. Contrast-enhanced CT is well established in the literature and is capable of identifying aortic dissections and aneurysms [12, 18, 45, 47-50]. However, in postoperative follow-up, a multiphase angiographic phase CT provides more usefulness [43, 73-75]. CT abdomen and pelvis without IV contrast can be used to monitor the aortic size and/or excluded sac size.

Variant 3:Adult. After endovascular aneurysm repair (EVAR) of abdominal aortic aneurysm or dissection. Follow-up imaging.
F. CT abdomen and pelvis without IV contrast and US aorta abdomen with duplex Doppler

The majority of evidence regarding aortic intervention follow-up using CT is based on CTA data and is primarily related to contrast bolus timing. Contrast-enhanced CT is well established in the literature and is capable of identifying aortic dissections and aneurysms [12, 18, 45, 47-50]. However, in postoperative follow-up, a multiphase angiographic phase CT provides more usefulness.

Benefits for the addition of US with the addition of duplex Doppler are mixed, although there is a growing body of literature to support its role as an adjunct imaging tool, especially when combined with the use of CEUS to aid in endoleak detection. [37, 38, 54, 74, 84-95].

Variant 3:Adult. After endovascular aneurysm repair (EVAR) of abdominal aortic aneurysm or dissection. Follow-up imaging.
G. CTA abdomen and pelvis with IV contrast

The exceptional spatial resolution and the fast imaging speed of CTA has made it the de facto reference standard for post-EVAR and post-open repair imaging surveillance. After EVAR, the most widely used surveillance regimen uses multiphasic contrast-enhanced CT at 1 month, 12 months, and yearly thereafter. If an abnormality is detected 1 month post-EVAR, a follow-up scan at 6 months is performed. In the absence of adverse outcomes at the 1-month follow-up imaging, the intensity and frequency of the surveillance program may be modulated accordingly [65-68]. Compared to aortography, CTA has higher sensitivity in detecting endoleaks after EVAR. Compared to US, CTA is better able to visualize kinking and migration of the stent-graft and is equivalent in quantifying aneurysm sac size [23].

Initial post-EVAR surveillance studies monitored the maximum diameter of the aneurysm sac as a marker for response to therapy [69]. This method has been shown to be unreliable due to substantial interobserver variability [47]. Volume analysis of the aneurysm sac has since proven to be the most reliable indicator for aneurysm rupture and/or need for reintervention [70-72].
In most cases, a CTA of the abdomen and pelvis is appropriate to ensure coverage of the treated aneurysm and stent graft. The CTA should include the chest in patients with TAAA.

Variant 3:Adult. After endovascular aneurysm repair (EVAR) of abdominal aortic aneurysm or dissection. Follow-up imaging.
H. CTA abdomen and pelvis without and with IV contrast

The exceptional spatial resolution and the fast imaging speed of CTA has made it the de facto reference standard for post-EVAR and post-open repair imaging surveillance. After EVAR, the most widely used surveillance regimen uses multiphasic contrast-enhanced CT at 1 month, 12 months, and yearly thereafter. If an abnormality is detected 1 month post-EVAR, a follow-up scan at 6 months is performed. In the absence of adverse outcomes at the 1-month follow-up imaging, the intensity and frequency of the surveillance program may be modulated accordingly [65-68]. Compared to aortography, CTA has higher sensitivity in detecting endoleaks after EVAR. Compared to US, CTA is better able to visualize kinking and migration of the stent-graft and is equivalent in quantifying aneurysm sac size [23].

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Multiphasic CTA is a reliable imaging tool to evaluate aortic aneurysm and endovascular repair [43].

In most cases, a CTA of the abdomen and pelvis is appropriate to ensure coverage of the treated aneurysm and stent graft. The CTA should include the chest in patients with TAAA.

Variant 3:Adult. After endovascular aneurysm repair (EVAR) of abdominal aortic aneurysm or dissection. Follow-up imaging.
I. MRA abdomen and pelvis without and with IV contrast

When considering using MRA for post-EVAR surveillance, stent material and orientation are important considerations. Typical stent construction employs nitinol, elgiloy, or stainless steel. Nitinol is a nickel-titanium alloy that causes relatively few artifacts on MRA, while allowing adequate visualization of the stent lumen and adjacent structures. Elgiloy is an alloy of cobalt, chromium, and nickel that may obscure the stent lumen but still allows for visualization of adjacent structures. Patients with nitinol stents are the optimal candidates for MRA, whereas those with elgiloy or stainless steel stents may experience significant artifacts that compromise visualization of the stent lumen and limit morphological resolution of the stent wall [76]. However, artifacts may arise even with nitinol stents secondary to stent geometry [77]. Due to severe susceptibility artifact associated with stainless steel embolization coils, MRA is poor in the follow-up of patients who have undergone coil embolization of the internal iliac artery before EVAR [24].

MRA of the post-EVAR aorta shares multiple features with CTA. Like CTA, isotropic 3-D MRA images may be reformatted in any plane for volume analysis or orthogonal diameter measurements. In patients with nitinol stents, aortic diameter measurements for MRA have been shown to be as reliable as those obtained with CTA [78]. MRA has been shown to be more sensitive than CTA for the detection of endoleaks [24, 79]. Consequently, the higher rate of endoleak detection seen by MRA in cases with a negative CTA may shed light on the phenomenon of endotension [73]. More recently, time-resolved MRA has been used in the characterization of endoleaks and may provide relevant information regarding contrast and flow dynamics within endoleaks [24, 80].

In most cases, MRA of the abdomen and pelvis is useful to ensure coverage of the treated aneurysm and stent graft. The MRA should include the chest in patients with TAAA.

Blood pool contrast materials such as ferumoxytol [81, 82] remain intravascular for a prolonged duration, thereby allowing for generation of high-resolution 3-D multiplanar images [81, 82]. Use of these contrast materials may improve detection of slow-flow endoleaks [81, 82].

One small retrospective study found that noncontrast balance steady-state free precession (bSSFP) images can be used to exclude endoleak after EVAR, with postcontrast imaging reserved for verification and further characterization of a suspected endoleak [83].

Variant 3:Adult. After endovascular aneurysm repair (EVAR) of abdominal aortic aneurysm or dissection. Follow-up imaging.
J. MRA abdomen and pelvis without IV contrast

When considering using MRA for post-EVAR surveillance, stent material and orientation are important considerations. Typical stent construction employs nitinol, elgiloy, or stainless steel. Nitinol is a nickel-titanium alloy that causes relatively few artifacts on MRA, while allowing adequate visualization of the stent lumen and adjacent structures. Elgiloy is an alloy of cobalt, chromium, and nickel that may obscure the stent lumen but still allows for visualization of adjacent structures. Patients with nitinol stents are the optimal candidates for MRA, whereas those with elgiloy or stainless steel stents may experience significant artifacts that compromise visualization of the stent lumen and limit morphological resolution of the stent wall [76]. However, artifacts may arise even with nitinol stents secondary to stent geometry [77]. Due to severe susceptibility artifact associated with stainless steel embolization coils, MRA is poor in the follow-up of patients who have undergone coil embolization of the internal iliac artery before EVAR [24].

MRA of the post-EVAR aorta shares multiple features with CTA. Like CTA, isotropic 3-D MRA images may be reformatted in any plane for volume analysis or orthogonal diameter measurements. In patients with nitinol stents, aortic diameter measurements for MRA have been shown to be as reliable as those obtained with CTA [78]. MRA has been shown to be more sensitive than CTA for the detection of endoleaks [24, 79]. Consequently, the higher rate of endoleak detection seen by MRA in cases with a negative CTA may shed light on the phenomenon of endotension [73]. More recently, time-resolved MRA has been used in the characterization of endoleaks and may provide relevant information regarding contrast and flow dynamics within endoleaks [24]. As such, replacing aortography as an effective and noninvasive method for endoleak characterization shows promise [96].

In most cases, MRA of the abdomen and pelvis is useful to ensure coverage of the treated aneurysm and stent graft. The MRA should include the chest in patients with TAAA.

Blood pool contrast materials such as ferumoxytol [81, 82], remain intravascular for a prolonged duration, thereby allowing for generation of high-resolution 3-D multiplanar images [81, 82]. Use of these contrast materials may improve detection of slow-flow endoleaks [81, 82].

One small retrospective study found that noncontrast bSSFP images can be used to exclude endoleak after EVAR, with postcontrast imaging reserved for verification and further characterization of a suspected endoleak [83].

Variant 3:Adult. After endovascular aneurysm repair (EVAR) of abdominal aortic aneurysm or dissection. Follow-up imaging.
K. Radiography abdomen and pelvis

Radiographs were previously considered a useful adjunct to CT for detecting stent graft migration and underlying structural change. This modality cannot be used as a stand-alone study, as it is unable to assess aneurysm sac size or detect endoleak. Radiography alone therefore does not meet guideline criteria outlined by the Society of Interventional Radiology [52] in AAA postoperative surveillance. Despite its limitations, anterior and lateral radiographs have been shown to be useful for detecting stent migration, kinking, or modular separation of the stent graft components, whereas oblique projections may detect wire fractures [108]. Three-dimensional-reconstructed CTA images also provide this information, in addition to detecting endoleaks and changes in aneurysm size. As such, advances in 3-D visualization tools will likely render radiographs redundant and unnecessary when used in conjunction with CT. However, if US is used as the primary imaging modality in post-EVAR surveillance, radiographs become a vital adjunct examination [37, 41, 83, 87, 88, 90].

Variant 3:Adult. After endovascular aneurysm repair (EVAR) of abdominal aortic aneurysm or dissection. Follow-up imaging.
L. US abdomen and pelvis

CDUS and CEUS are being increasingly recommended for post-EVAR follow-up. These modalities are convenient. In the evaluation of endoleak, CDUS has high specificity but limited sensitivity, reported in two large meta-analyses to be 91% to 93% and 66% to 69%, respectively [97, 98]. The major limitations of US are the inability to detect stent-graft kinking, fracture, migration, or component separation [88-90]. For this reason, adjunct four-view radiographs are recommended to be obtained with all post-EVAR US examinations [37, 41, 83, 87, 88, 90]. For FEVARs that involve the celiac trunk, US is unable to adequately visualize the proximal sealing zone [88].

Not unexpectedly, published results regarding the accuracy of CDUS in post-EVAR follow-up are varied [39, 74, 85, 86, 91, 92, 97, 99-102]. Nevertheless, US offers the ability to determine endoleak flow direction and therefore assist in guiding management. Spectral waveform analysis of reperfusion to the aneurysm sac has been shown to have prognostic value, in which Type II endoleaks with bidirectional flow [84] and low flow velocities [103] have been associated with spontaneous closure.

Several studies have compared 2-D CEUS to CDUS in the setting of post-EVAR follow-up, with a meta-analysis finding no clinically significant differences between the two modalities [104]. In the setting of post-FEVAR follow-up, 2-D CEUS was found to be equivalent to CTA in aneurysm sac measurement and in assessing patency of visceral vessels [83, 88]. Additional studies have demonstrated the superiority of 3-D CEUS over standard 2-D methods in both endoleak detection [41] and sac measurement [38]. Three-dimensional CEUS has been found to be equivalent or superior to CTA in endoleak detection [41, 89] and sac measurement, in addition to being highly reproducible [38, 105].

Variant 3:Adult. After endovascular aneurysm repair (EVAR) of abdominal aortic aneurysm or dissection. Follow-up imaging.
M. US abdomen and pelvis with IV contrast

CDUS and CEUS are being increasingly recommended for post-EVAR follow-up. These modalities are convenient. In the evaluation of endoleak, CDUS has high specificity but limited sensitivity, reported in two large meta-analyses to be 91% to 93% and 66% to 69%, respectively [97, 98]. The major limitations of US are the inability to detect stent-graft kinking, fracture, migration, or component separation [88-90]. For this reason, adjunct four-view radiographs are recommended to be obtained with all post-EVAR US examinations [37, 41, 83, 87, 88, 90]. For FEVARs that involve the celiac trunk, US is unable to adequately visualize the proximal sealing zone [88].

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Variant 3:Adult. After endovascular aneurysm repair (EVAR) of abdominal aortic aneurysm or dissection. Follow-up imaging.
N. US aorta abdomen with IV contrast

CDUS and CEUS are being increasingly recommended for post-EVAR follow-up [41, 92, 100, 106, 107]. These modalities are convenient. In the evaluation of endoleak, CDUS has high specificity but limited sensitivity, reported in two large meta-analyses to be 91% to 93% and 66% to 69%, respectively [97, 98]. The major limitations of US are the inability to detect stent-graft kinking, fracture, migration, or component separation [88-90]. For this reason, adjunct four-view radiographs are recommended to be obtained with all post-EVAR US examinations [37, 41, 83, 87, 88, 90]. For FEVARs that involve the celiac trunk, US is unable to adequately visualize the proximal sealing zone [88].

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Variant 3:Adult. After endovascular aneurysm repair (EVAR) of abdominal aortic aneurysm or dissection. Follow-up imaging.
O. US duplex Doppler aorta abdomen

CDUS and CEUS are being increasingly recommended for post-EVAR follow-up. These modalities are convenient. In the evaluation of endoleak, CDUS has high specificity but limited sensitivity, reported in two large meta-analyses to be 91% to 93% and 66% to 69%, respectively [97, 98]. The major limitations of US are the inability to detect stent-graft kinking, fracture, migration, or component separation [88-90]. For this reason, adjunct four-view radiographs are recommended to be obtained with all post-EVAR US examinations [37, 41, 83, 87, 88, 90]. For FEVARs that involve the celiac trunk, US is unable to adequately visualize the proximal sealing zone [88].

Not unexpectedly, published results regarding the accuracy of CDUS in post-EVAR follow-up are varied [39, 74, 85, 86, 91, 92, 97, 99-102]. Nevertheless, US offers the ability to determine endoleak flow direction and therefore assist in guiding management. Spectral waveform analysis of reperfusion to the aneurysm sac has been shown to have prognostic value, in which Type II endoleaks with bidirectional flow [84] and low flow velocities [103] have been associated with spontaneous closure.

Several studies have compared 2-D CEUS to CDUS in the setting of post-EVAR follow-up, with a meta-analysis finding no clinically significant differences between the two modalities [104]. In the setting of post-FEVAR follow-up, 2-D CEUS was found to be equivalent to CTA in aneurysm sac measurement and in assessing patency of visceral vessels [83, 88]. Additional studies have demonstrated the superiority of 3-D CEUS over standard 2-D methods in both endoleak detection [41] and sac measurement [38]. Three-dimensional CEUS has been found to be equivalent or superior to CTA in endoleak detection [41, 89] and sac measurement, in addition to being highly reproducible [38, 105].

Variant 4:Adult. After open repair of abdominal aortic aneurysm or dissection. Follow-up imaging.

The goal of imaging for this variant is to detect anatomical changes in repaired aortic aneurysm or dissection. With the information from imaging, the expected patient benefits include making the best treatment plan based on the morphology of the aneurysm/dissection.

Variant 4:Adult. After open repair of abdominal aortic aneurysm or dissection. Follow-up imaging.
A. Aortography abdomen

Due to the relatively invasive nature of aortography, it is not practical for routine surveillance.

Variant 4:Adult. After open repair of abdominal aortic aneurysm or dissection. Follow-up imaging.
B. Aortography abdomen and pelvis

Due to the relatively invasive nature of aortography, it is not practical for routine surveillance.

Variant 4:Adult. After open repair of abdominal aortic aneurysm or dissection. Follow-up imaging.
C. CT abdomen and pelvis with IV contrast

The majority of evidence regarding aortic intervention follow-up using CT is based on CTA data and is primarily related to contrast bolus timing. Contrast-enhanced CT is well established in the literature and is capable of identifying aortic dissections and aneurysms [12, 18, 45, 47-50]. However, in postoperative follow-up, an angiographic phase CT provides more usefulness.

Variant 4:Adult. After open repair of abdominal aortic aneurysm or dissection. Follow-up imaging.
D. CT abdomen and pelvis without and with IV contrast

The exceptional spatial resolution and the fast imaging speed of CTA has made it the de facto reference standard for post-open repair imaging surveillance. Compared to aortography, CTA has higher sensitivity in detecting complicating features.

In most cases, a CTA of the abdomen and pelvis is useful to ensure coverage of the treated aneurysm and stent graft. The CTA should include the chest in patients with TAAA.

Variant 4:Adult. After open repair of abdominal aortic aneurysm or dissection. Follow-up imaging.
E. CT abdomen and pelvis without IV contrast

The exceptional spatial resolution and the fast imaging speed of CTA has made it the de facto reference standard for post-EVAR and post-open repair imaging surveillance. Some patients can be observed with noncontrast imaging of the abdomen and pelvis to evaluate aortic size [47, 113-115].

In most cases, a CTA of the abdomen and pelvis is appropriate to ensure coverage of the treated aneurysm and stent graft. The CTA should include the chest in patients with TAAA.

Variant 4:Adult. After open repair of abdominal aortic aneurysm or dissection. Follow-up imaging.
F. CT abdomen and pelvis without IV contrast and US aorta abdomen with duplex Doppler

The majority of evidence regarding aortic intervention follow-up using CT is based on CTA data and is primarily related to contrast bolus timing. Noncontrast CT is well established in the literature and is capable of identifying aortic vessel size. However, in postoperative follow-up, a multiphase angiographic phase CT provides more usefulness.

Benefits for the addition of US with the addition of duplex Doppler are mixed, although there is a growing body of literature to support its role as an adjunct imaging tool [37, 38, 54, 74, 84-95].

Variant 4:Adult. After open repair of abdominal aortic aneurysm or dissection. Follow-up imaging.
G. CTA abdomen and pelvis with IV contrast

The exceptional spatial resolution and the fast imaging speed of CTA has made it the de facto reference standard for post-open repair imaging surveillance.There is no one consensus on timing of imaging follow-up after open repair. However, CTA can accurately detect the most commonly encountered complicating features after repair [109-111]

In most cases, a CTA of the abdomen and pelvis is appropriate to ensure coverage of the treated aneurysm and stent graft. The CTA should include the chest in patients with TAAA.

Variant 4:Adult. After open repair of abdominal aortic aneurysm or dissection. Follow-up imaging.
H. CTA abdomen and pelvis without and with IV contrast

The exceptional spatial resolution and the fast imaging speed of CTA has made it the de facto reference standard for post-open repair imaging surveillance. There is no one consensus on timing of imaging follow-up after open repair. However, CTA can accurately detect the most commonly encountered complicating features after repair [109-111]. The role of multiphase imaging after open repair is not well described.

In most cases, a CTA of the abdomen and pelvis is appropriate to ensure coverage of the treated aneurysm. The CTA should include the chest in patients with TAAA.

CTA can show many complications that occur following open surgical repair [112]. Many of these complications are increasingly being managed using endovascular approaches.

Variant 4:Adult. After open repair of abdominal aortic aneurysm or dissection. Follow-up imaging.
I. MRA abdomen and pelvis without and with IV contrast

When considering using MRA for postoperative surveillance, material and orientation are important considerations. Patients may have nitinol stents, which are the optimal candidates for MRA, whereas those with elgiloy or stainless steel stents may experience significant artifacts that compromise visualization of the stent lumen and limit morphological resolution of the stent wall [76]. However, artifacts may arise even with nitinol stents secondary to stent geometry [77]. Due to severe susceptibility artifact associated with stainless steel embolization coils, MRA is poor in the follow-up of patients who have undergone adjunctive coil embolization [24].

In most cases, MRA of the abdomen and pelvis is useful to ensure coverage of the treated aneurysm. The MRA should include the chest in patients with TAAA.

Blood pool contrast materials such as ferumoxytol [81, 82], remain intravascular for a prolonged duration, thereby allowing for generation of high-resolution 3-D multiplanar images [81, 82]. Use of these contrast materials may improve detection of slow-flow complications [81, 82].

Variant 4:Adult. After open repair of abdominal aortic aneurysm or dissection. Follow-up imaging.

J. MRA abdomen and pelvis without IV contrast

When considering using MRA for postoperative surveillance, material and orientation are important considerations. Patients may have nitinol stents, which are the optimal candidates for MRA, whereas those with elgiloy or stainless steel stents may experience significant artifacts that compromise visualization of the stent lumen and limit morphological resolution of the stent wall [76]. However, artifacts may arise even with nitinol stents secondary to stent geometry [77]. Due to severe susceptibility artifact associated with stainless steel embolization coils, MRA is poor in the follow-up of patients who have undergone adjunctive coil embolization [24].

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Variant 4:Adult. After open repair of abdominal aortic aneurysm or dissection. Follow-up imaging.

K. Radiography abdomen and pelvis

Radiography lacks the spatial resolution to survey the abdominal aorta after open repair for aneurysm or dissection.

Variant 4:Adult. After open repair of abdominal aortic aneurysm or dissection. Follow-up imaging.

L. US abdomen and pelvis

CDUS and CEUS are being increasingly recommended for post-EVAR follow-up; however, their role after open repair is less well defined.US is convenient and noninvasive, and has a favorable safety profile, and has a favorable safety profile. In the evaluation of endoleak, CDUS has high specificity but limited sensitivity, reported in two large meta-analyses to be 91% to 93% and 66% to 69%, respectively [97, 98]. However, the role of US to evaluate the abdominal aorta after open repair remains less well defined, given the focus and frequency of complicating factors after endovascular repair. Authors have well-defined US and its ability to define aortic wall size [58].

Variant 4:Adult. After open repair of abdominal aortic aneurysm or dissection. Follow-up imaging.

M. US abdomen and pelvis with IV contrast

CDUS and CEUS are being increasingly recommended for post-EVAR follow-up; however, their role after open repair is less well defined. US is convenient and noninvasive, and has a favorable safety profile. In the evaluation of endoleak, CDUS has high specificity but limited sensitivity, reported in two large meta-analyses to be 91% to 93% and 66% to 69%, respectively [97, 98]. However, the role of US to evaluate the abdominal aorta after open repair remains less well defined, given the focus and frequency of complicating factors after endovascular repair. Authors have well defined US and its ability to define aortic wall size [54, 58].

Variant 4:Adult. After open repair of abdominal aortic aneurysm or dissection. Follow-up imaging.
N. US aorta abdomen with IV contrast

CDUS and CEUS are being increasingly recommended for post-EVAR follow-up; however, their role after open repair is less well defined. US is convenient and noninvasive, and has a favorable safety profile. In the evaluation of endoleak, CDUS has high specificity but limited sensitivity, reported in two large meta-analyses to be 91% to 93% and 66% to 69%, respectively [97, 98]. CDUS and CEUS are being increasingly recommended for post-EVAR follow-up; however, their role after open repair is less well defined. However, the role of US to evaluate the abdominal aorta after open repair remains less well defined, given the focus and frequency of complicating factors after endovascular repair. Authors have well defined US and its ability to define aortic wall size [54, 58].

Variant 4:Adult. After open repair of abdominal aortic aneurysm or dissection. Follow-up imaging.
O. US duplex Doppler aorta abdomen

CDUS and CEUS are being increasingly recommended for post-EVAR follow-up; however, their role after open repair is less well defined. US is convenient and noninvasive, and has a favorable safety profile. In the evaluation of endoleak, CDUS has high specificity but limited sensitivity, reported in two large meta-analyses to be 91% to 93% and 66% to 69%, respectively [97, 98]. However, the role of US to evaluate the abdominal aorta after open repair remains less well defined, given the focus and frequency of complicating factors after endovascular repair. Authors have well defined US and its ability to define aortic wall size [54, 58].

Summary of Highlights

• Variants 1 and 2: Unrepaired known AAA or dissection may require follow-up imaging. Usually appropriate imaging will provide both good spatial resolution and vessel evaluation. This includes CTA abdomen and pelvis, MRA abdomen and pelvis, and their variants with and without IV contrast. US with color duplex is also usually appropriate. These procedures are alternatives. Venous only phase imaging or noncontrasted cross-sectional imaging may be appropriate but will not provide as much detail regarding vessel size, morphology, and evolution over time. Invasive procedures, US without color flow, and plain radiographs are usually not appropriate. For these unrepaired patients, where the imaging serves as preprocedural planning, the role of contrasted arterial phase cross-sectional imaging is of paramount importance. This makes CTA abdomen and pelvis and MRA abdomen and pelvis using IV contrast usually appropriate. Noncontrast imaging, US, and invasive studies are usually not appropriate.

• Variants 3 and 4: Both open and endovascular repairs will undergo follow-up imaging. This is particularly true for patients who undergo endovascular repair. In these circumstances, contrasted high resolution multi-slice cross-sectional imaging is usually appropriate, such as CTA abdomen and pelvis or MRA abdomen and pelvis. These procedures are alternatives. Both CT or MRI without IV contrast may be appropriate for certain patient populations. Venous phase CT imaging or CT paired with US and duplex evaluation may be appropriate. Invasive procedures and US imaging without duplex is usually not appropriate when doing routine follow-up imaging after both open and endovascular repair.

Supporting Documents

The evidence table, literature search, and appendix for this topic are available at https://acsearch.acr.org/list. The appendix includes the strength of evidence assessment and the final rating round tabulations for each recommendation.

For additional information on the Appropriateness Criteria methodology and other supporting documents, please go to the ACR website at https://www.acr.org/Clinical-Resources/Clinical-Tools-and-Reference/Appropriateness-Criteria.

Gender Equality and Inclusivity Clause

The ACR acknowledges the limitations in applying inclusive language when citing research studies that predates the use of the current understanding of language inclusive of diversity in sex, intersex, gender, and gender-diverse people. The data variables regarding sex and gender used in the cited literature will not be changed. However, this guideline will use the terminology and definitions as proposed by the National Institutes of Health.

Appropriateness Category Names and Definitions

Appropriateness Category Name	Appropriateness Rating	Appropriateness Category Definition
Usually Appropriate	7, 8, or 9	The imaging procedure or treatment is indicated in the specified clinical scenarios at a favorable risk-benefit ratio for patients.
May Be Appropriate	4, 5, or 6	The imaging procedure or treatment may be indicated in the specified clinical scenarios as an alternative to imaging procedures or treatments with a more favorable risk-benefit ratio, or the risk-benefit ratio for patients is equivocal.
May Be Appropriate (Disagreement)	5	The individual ratings are too dispersed from the panel median. The different label provides transparency regarding the panel's recommendation. "May be appropriate" is the rating category and a rating of 5 is assigned.
Usually Not Appropriate	1, 2, or 3	The imaging procedure or treatment is unlikely to be indicated in the specified clinical scenarios, or the risk-benefit ratio for patients is likely to be unfavorable.

Relative Radiation Level Information

Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposures associated with different diagnostic procedures, a relative radiation level (RRL) indication has been included for each imaging examination. The RRLs are based on effective dose, which is a radiation dose quantity that is used to estimate population total radiation risk associated with an imaging procedure. Patients in the pediatric age group are at inherently higher risk from exposure, because of both organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the RRL dose estimate ranges for pediatric examinations are lower as compared with those specified for adults (see Table below). Additional information regarding radiation dose assessment for imaging examinations can be found in the ACR Appropriateness Criteria® Radiation Dose Assessment Introduction document.

Relative Radiation Level Designations

Relative Radiation Level*	Adult Effective Dose Estimate Range	Pediatric Effective Dose Estimate Range
O	0 mSv	0 mSv
☢	<0.1 mSv	<0.03 mSv
☢☢	0.1-1 mSv	0.03-0.3 mSv
☢☢☢	1-10 mSv	0.3-3 mSv
☢☢☢☢	10-30 mSv	3-10 mSv
☢☢☢☢☢	30-100 mSv	10-30 mSv

*RRL assignments for some of the examinations cannot be made, because the actual patient doses in these procedures vary as a function of a number of factors (e.g., region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as "Varies."

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