

**American College of Radiology  
ACR Appropriateness Criteria®  
Pulsatile Abdominal Mass, Suspected Abdominal Aneurysm**

**Variant 1: Pulsatile abdominal mass, suspected abdominal aortic aneurysm. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
US aorta abdomen	Usually Appropriate	○
MRA abdomen and pelvis with IV contrast	Usually Appropriate	○
MRA abdomen and pelvis without and with IV contrast	Usually Appropriate	○
MRA abdomen and pelvis without IV contrast	Usually Appropriate	○
CTA abdomen and pelvis with IV contrast	Usually Appropriate	☼☼☼☼
CTA abdomen and pelvis without and with IV contrast	Usually Appropriate	☼☼☼☼
MRI abdomen and pelvis with IV contrast	May Be Appropriate	○
MRI abdomen and pelvis without and with IV contrast	May Be Appropriate	○
MRI abdomen and pelvis without IV contrast	May Be Appropriate	○
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 and with IV contrast	May Be Appropriate	☼☼☼☼☼
US intravascular aorta abdomen	Usually Not Appropriate	○
Aortography abdomen	Usually Not Appropriate	☼☼☼
Radiography abdomen and pelvis	Usually Not Appropriate	☼☼☼
FDG-PET/CT skull base to mid-thigh	Usually Not Appropriate	☼☼☼☼

## PULSATILE ABDOMINAL MASS, SUSPECTED ABDOMINAL AORTIC ANEURYSM

Expert Panel on Vascular Imaging: David S. Wang, MD<sup>a</sup>; Jody Shen, MD<sup>b</sup>; Bill S. Majdalany, MD<sup>c</sup>; Minhaj S. Khaja, MD, MBA<sup>d</sup>; Salman Bhatti, MD<sup>e</sup>; Maros Ferencik, MD, PhD, MCR<sup>f</sup>; Suvranu Ganguli, MD<sup>g</sup>; Andrew J. Gunn, MD<sup>h</sup>; John F. Heitner, MD<sup>i</sup>; Amer M. Johri, MD, MSc<sup>j</sup>; Piotr Obara, MD<sup>k</sup>; Robert Ohle, MD<sup>l</sup>; Mehran M. Sadeghi, MD<sup>m</sup>; Marc Schermerhorn, MD<sup>n</sup>; Jeffrey J. Siracuse, MD, MBA<sup>o</sup>; Scott D. Steenburg, MD<sup>p</sup>; Patrick D. Sutphin, MD, PhD<sup>q</sup>; Kanupriya Vijay, MD, MBBS<sup>r</sup>; Kathleen Waite, MD<sup>s</sup>; Michael L. Steigner, MD.<sup>t</sup>

### **Summary of Literature Review**

#### **Introduction/Background**

A pulsatile abdominal mass identified on physical examination may indicate the presence of an abdominal aortic aneurysm (AAA) [1,2]. Most AAAs are clinically silent and incidentally discovered [3-5]. An aortic aneurysm is broadly defined as a segmental, full-thickness dilation of the aorta with a maximal diameter >1.5 times larger than the adjacent normal segment [6]. The majority of AAAs are fusiform in morphology, attributable to degenerative and atherosclerotic changes in the aortic wall, and located in the infrarenal abdominal aorta, in which an aortic diameter  $\geq 3.0$  cm is the threshold size for diagnosis [3,7-10]. The prevalence of AAA in persons >65 years of age ranges from 1.7% to 4.5% for men and 0.5% to 1.3% for women [3,4,11]. Major risk factors for AAA include advanced age, male sex, smoking, and family history of AAA [9]. The natural history of AAA is progressive expansion and potential rupture, which is a medical emergency with high mortality [9]. Indications for open or endovascular repair of nonruptured AAA include an aortic diameter  $\geq 5.5$  cm in men or  $\geq 5.0$  cm in women, onset of symptoms portending rupture, and rapid aneurysm growth [7,10].

In cases of suspected AAA, imaging is required to confirm the diagnosis and characterize the aneurysm to inform management planning. This document focuses on imaging evaluation for the initial diagnosis of nonruptured AAAs. For information on follow-up after initial diagnosis and interventional planning of AAAs, please see the ACR Appropriateness Criteria<sup>®</sup> topics on “[Abdominal Aortic Aneurysm Follow-up \(Without Repair\)](#)” [12] and “[Abdominal Aortic Aneurysm: Interventional Planning and Follow-Up](#)” [13].

#### **Special Imaging Considerations**

*Measurement Technique:* Maximum aortic diameter is the determinant parameter for AAA diagnosis; however, standardization of measurement technique is lacking [14-16]. There is general consensus that maximum aortic diameter should be measured in the plane perpendicular to the longitudinal axis of the aorta [7,8,10,17]. Measurements obtained in the axial plane relative to the long axis of a patient’s body may overestimate aortic diameter in tortuous aortas. For cross-sectional imaging procedures, it is recommended that maximum aortic diameter be measured perpendicular to the centerline of the aorta using 3-D and multiplanar reformatted images when feasible [18,19]. There is, however, no consensus on whether the aortic wall should be included in aortic diameter measurements across imaging modalities. Diameter measurements between the inner-to-inner (ITI) aortic wall can be 3 to 6 mm smaller than outer-to-outer (OTO) wall measurements, with leading-to-leading (LTL) edge measurements being intermediate between the two [10,16]. In the absence of a global standard for measuring aortic diameter, it is imperative to consistently use one measurement technique and document the method employed [14].

---

<sup>a</sup>Stanford University Medical Center, Stanford, California. <sup>b</sup>Research Author, Stanford University Medical Center, Stanford, California. <sup>c</sup>Panel Chair, University of Vermont Medical Center, Burlington, Vermont. <sup>d</sup>Panel Vice-Chair, University of Michigan, Ann Arbor, Michigan. <sup>e</sup>University of Pittsburgh Medical Center, Pittsburgh, Pennsylvania; Society for Cardiovascular Magnetic Resonance. <sup>f</sup>Knight Cardiovascular Institute, Oregon Health & Science University, Portland, Oregon; Society of Cardiovascular Computed Tomography. <sup>g</sup>Boston Medical Center/Boston University School of Medicine, Boston, Massachusetts. <sup>h</sup>University of Alabama at Birmingham, Birmingham, Alabama. <sup>i</sup>New York University Langone Health, New York, New York; Society for Cardiovascular Magnetic Resonance. <sup>j</sup>Queen’s University, Kingston, Ontario, Canada; American Society of Echocardiography. <sup>k</sup>NorthShore University HealthSystem, Evanston, Illinois. <sup>l</sup>Northern Ontario School of Medicine, Sudbury, Ontario, Canada; American College of Emergency Physicians. <sup>m</sup>Yale School of Medicine, New Haven, Connecticut; American Society of Nuclear Cardiology. <sup>n</sup>Harvard Medical School and Beth Israel Deaconess Medical Center, Boston, Massachusetts; Society for Vascular Surgery. <sup>o</sup>Boston Medical Centers, Boston University, and Chobanian and Avedisian School of Medicine, Boston, Massachusetts; Society for Vascular Surgery. <sup>p</sup>Indiana University School of Medicine and Indiana University Health, Indianapolis, Indiana; Committee on Emergency Radiology-GSER. <sup>q</sup>Massachusetts General Hospital, Boston, Massachusetts. <sup>r</sup>UT Southwestern Medical Center, Dallas, Texas. <sup>s</sup>Duke University Medical Center, Durham, North Carolina, Primary care physician. <sup>t</sup>Specialty Chair, Brigham & Women’s Hospital, Boston, Massachusetts.

The American College of Radiology seeks and encourages collaboration with other organizations on the development of the ACR Appropriateness Criteria through representation of such organizations on expert panels. Participation on the expert panel does not necessarily imply endorsement of the final document by individual contributors or their respective organization.

Reprint requests to: [publications@acr.org](mailto:publications@acr.org)

For the purposes of distinguishing between CT and CT angiography (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 \(CTA\)](#) [20]:

*“CTA uses a thin-section CT acquisition that is timed to coincide with peak arterial or venous enhancement. The resultant volumetric dataset 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.

### **Initial Imaging Definition**

Initial imaging is defined as imaging at the beginning of the care episode for the medical condition defined by the variant. More than one procedure can be considered usually appropriate in the initial imaging evaluation when:

- There are procedures that are equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient’s care).

OR

- There are complementary procedures (ie, more than one procedure is ordered as a set or simultaneously where each procedure provides unique clinical information to effectively manage the patient’s care).

### **Discussion of Procedures by Variant**

#### **Variant 1: Pulsatile abdominal mass, suspected abdominal aortic aneurysm. Initial imaging.**

##### **Aortography Abdomen**

Although AAAs can be diagnosed by catheter-based aortography of the abdominal aorta, it is invasive and has low sensitivity [3,7]. The width of the contrast column on aortography may underestimate the true aortic diameter if there is significant mural thrombus obscuring the luminal contour of the aneurysm or if the 2-D image acquisition plane is not orthogonal to the plane of maximum aortic diameter. Aortography is the main diagnostic component of endovascular AAA interventions and may be particularly useful in emergent cases of ruptured AAA.

##### **CT Abdomen and Pelvis**

CT abdomen and pelvis with intravenous (IV) contrast, CT abdomen and pelvis without and with IV contrast, and CT abdomen and pelvis without IV contrast are noninvasive, fast, and commonly used to evaluate various abdominopelvic pathologies, including aortic and nonaortic causes of a pulsatile abdominal mass.

There is no specific literature regarding aortic measurements on standard CT images, with or without IV contrast, for the initial imaging evaluation of suspected AAA; however, aortic diameters can be accurately assessed on CT images if the abdominal aortic contour is well visualized and can be distinguished from adjacent structures. AAAs can be incidentally diagnosed on both contrast- and noncontrast-enhanced CT scans performed for various other clinical indications [4,5,21-23].

In determining maximum aortic diameter on CT, the OTO aortic diameter perpendicular to the long axis of the aorta is recommended [7]. This is obligatory for noncontrast CT images in which the aortic wall and lumen cannot be distinguished. Noncontrast CT has been found to be more sensitive than ultrasound (US) in identifying AAAs [24].

##### **CTA Abdomen and Pelvis**

CTA abdomen and pelvis with IV contrast and CTA abdomen and pelvis without and with IV contrast provide rapid image acquisition of submillimeter, isotropic, 3-D data sets of the aorta and its branch vessels with high spatial resolution [25-27]. Measurement of the maximal aortic diameter based on the OTO wall diameter perpendicular to the long axis of the aorta on CTA is considered the reference standard for AAA diagnosis and management decision making [7].

CTA is also the imaging procedure of choice for preoperative assessment before endovascular or open surgical repair [10,13,26,28]. The scan range should include the iliofemoral arteries to evaluate the access vessels and also the chest in patients with thoracoabdominal AAA.

CT, preferably CTA, is recommended for evaluation of symptomatic patients who present with acute onset abdominal or back pain, particularly in the presence of a pulsatile abdominal mass or significant risk factors for AAA [7]. Whether CTA should be the initial imaging modality used for evaluation of asymptomatic patients suspected to have an AAA is less clear.

Dual-energy CTA, which allows for simultaneous acquisition of CT data with 2 different photon energy spectra, can be used to characterize AAAs with reduced IV iodinated contrast dose without compromising imaging quality [29,30].

#### **FDG-PET/CT Skull Base to Mid-Thigh**

There is no relevant literature supporting the use of fluorine-18-2-fluoro-2-deoxy-D-glucose (FDG)-PET/CT for initial imaging evaluation of suspected AAA. The CT component of PET/CT can be used for the incidental diagnosis of AAA. FDG-PET/CT can play a role in the diagnosis of inflammatory and mycotic aortic aneurysms [10,31,32] and in predicting risk for AAA rupture [33].

#### **MRA Abdomen and Pelvis**

MR angiography (MRA) abdomen and pelvis with IV contrast and MRA abdomen and pelvis without and with IV contrast are alternatives to CTA for the diagnosis and preintervention evaluation of AAAs [8,10,13,25,27,28]. Limitations of MRA and MRI in general include longer imaging acquisition times and limited ability to characterize aortic wall calcifications.

MRA abdomen and pelvis without IV contrast can also be used for evaluation of suspected AAA. MRA can be performed without gadolinium-based contrast agents (GBCAs) using techniques such as time-of-flight, balanced steady-state free precession, phase-contrast, and quiescent-interval single-shot imaging [34]. Disadvantages of noncontrast-enhanced MRA include longer image acquisition times and increased motion artifacts [34]. Contrast-enhanced MRA is used more commonly than noncontrast-enhanced MRA for imaging evaluation of AAAs.

Ferumoxytol, an ultrasmall superparamagnetic iron oxide particle, is an emerging alternative to GBCAs for contrast-enhanced MRA [35,36]. Ferumoxytol was originally designed as a blood pool contrast agent for MRI and has a longer duration of intravascular signal than GBCAs.

Although the latest recommendations from the International Society for Magnetic Resonance in Medicine are for measurement of ITI aortic wall diameter on double-oblique reformatted images perpendicular to the vessel long-axis for measurement technique, the OTO aortic wall diameter should also be reported in cases of aneurysm or wall thickening if that approach is adopted [37]. The ITI wall measurement method was recommended because of its high conformity to the LTL measurements used in echocardiography, which is a consideration more relevant to the thoracic aorta [25,37]. The Society for Cardiovascular Magnetic Resonance and others advocate measurement of the outer aortic wall contour for aneurysms [38,39].

#### **MRI Abdomen and Pelvis**

For the initial imaging evaluation of suspected AAA, the considerations for MRI of the abdomen and pelvis without dedicated MRA sequences are similar to that of MRA [8,10,25]. As with CT, a routine MRI abdomen and pelvis with IV contrast or MRI abdomen and pelvis without and with IV contrast can be used to measure abdominal aortic diameter if the aortic contour is well depicted. Either procedure may also characterize possible nonaortic causes of a pulsatile abdominal mass. AAAs can also be incidentally detected on MRI of the abdomen and pelvis performed for other reasons [5].

Accurate and reproducible aortic diameter measurements, comparable to CTA measurements, can be obtained from MRI without IV contrast by using black-blood sequences acquired with spin-echo techniques [40]. With advanced imaging methods, MRI can also provide functional and hemodynamic data, such as quantification of aortic wall stiffness and blood flow [25].

#### **Radiography Abdomen and Pelvis**

There is no relevant literature supporting the use of radiography for the initial imaging evaluation of a pulsatile abdominal mass suspected to be an AAA. Radiography is not recommended for initial imaging for suspected AAA because of its low sensitivity for AAA detection [3,7]. AAA can be incidentally discovered on abdominal radiographs obtained for other purposes if aortic wall calcifications are visible and allow for assessment of aortic diameter; however, AAA morphology and extent may not be accurately or fully evaluated [3].

## US Aorta Abdomen

Transabdominal US of the abdominal aorta poses negligible risk to patients and can reliably detect the presence of an AAA in nearly all patients with sensitivity and specificity approaching 100% [3,9,10,16]. With the portability of US machines, sonographic evaluation of the abdominal aorta can be performed in a wide range of settings, including in the emergency department [16,41]. US of the abdominal aorta is the mainstay imaging procedure for AAA screening and surveillance [7,12,16,42,43] and is often the first-line imaging study performed for evaluation of asymptomatic patients suspected to have an AAA [9,10,16,44].

In 1% to 2% of cases, the abdominal aorta cannot be adequately evaluated by US because of large patient body habitus or excessive overlying bowel gas [14,45]. Pre-evaluation overnight fasting is recommended to reduce bowel gas in patients [3,10,16].

There remains debate over the optimal method to measure maximum aortic diameter on US with conflicting data from several studies comparing the accuracy and reproducibility of OTO, ITI, and LTL measurement techniques [16,46-52]. The American Institute of Ultrasound in Medicine recommends measuring the greatest diameter of the abdominal aorta from the OTO edges of the aortic wall [53], whereas the United Kingdom's National Health Services AAA Screening Programme uses the maximal anterior to posterior ITI diameter as the standard measurement parameter for AAA diagnosis [44].

Compared to CT, US underestimates AAA diameters by an average of 1 to 3 mm [15,16,54-56]. For preintervention planning for AAA endovascular or surgical repair, US is insufficiently precise and does not provide imaging information on access vessels and abdominal aortic branches [7,13]. A CTA, or alternatively MRA, is needed when the size threshold for repair is reached [10,13,44].

To overcome variations in imaging plane orientation that can occur with conventional 2-D US, 3-D US has shown promise for improved accuracy and reproducibility in aortic diameter measurements by allowing for measurements to be made in the plane orthogonal to the centerline of the abdominal aorta [57,58].

## US Intravascular Aorta Abdomen

Intravascular US of the abdominal aorta provides accurate and reproducible measurements of aortic diameter and length [59,60]. It is, however, an invasive procedure that does not have a significant role in the initial diagnosis of AAAs. Intravascular US is commonly used during endovascular AAA repair procedures for stent-graft sizing and treatment planning [60].

## Summary of Recommendations

- **Variant 1:** US of the abdominal aorta, CTA of the abdomen and pelvis with IV contrast, CTA of the abdomen and pelvis without and with IV contrast, MRA of the abdomen and pelvis with IV contrast, MRA of the abdomen and pelvis without and with IV contrast, or MRA abdomen and pelvis without IV contrast is usually appropriate for initial imaging in a patient who is suspected to have an AAA. In this variant, these procedures are generally equivalent alternatives (ie, only one procedure will be ordered to provide the clinical information to effectively manage the patient's care).

## 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 go to [www.acr.org/ac](http://www.acr.org/ac).

## 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 [61].

Relative Radiation Level Designations		
Relative Radiation Level*	Adult Effective Dose Estimate Range	Pediatric Effective Dose Estimate Range
○	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 (eg, region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as "Varies."

## References

1. Fink HA, Lederle FA, Roth CS, Bowles CA, Nelson DB, Haas MA. The accuracy of physical examination to detect abdominal aortic aneurysm. Arch Intern Med 2000;160:833-6.

2. Lederle FA, Simel DL. The rational clinical examination. Does this patient have abdominal aortic aneurysm? *JAMA* 1999;281:77-82.
3. Hirsch AT, Haskal ZJ, Hertzner NR, et al. ACC/AHA 2005 Practice Guidelines for the management of patients with peripheral arterial disease (lower extremity, renal, mesenteric, and abdominal aortic): a collaborative report from the American Association for Vascular Surgery/Society for Vascular Surgery, Society for Cardiovascular Angiography and Interventions, Society for Vascular Medicine and Biology, Society of Interventional Radiology, and the ACC/AHA Task Force on Practice Guidelines (Writing Committee to Develop Guidelines for the Management of Patients With Peripheral Arterial Disease): endorsed by the American Association of Cardiovascular and Pulmonary Rehabilitation; National Heart, Lung, and Blood Institute; Society for Vascular Nursing; TransAtlantic Inter-Society Consensus; and Vascular Disease Foundation. *Circulation* 2006;113:e463-654.
4. Claridge R, Arnold S, Morrison N, van Rij AM. Measuring abdominal aortic diameters in routine abdominal computed tomography scans and implications for abdominal aortic aneurysm screening. *J Vasc Surg* 2017;65:1637-42.
5. van Walraven C, Wong J, Morant K, Jennings A, Jetty P, Forster AJ. Incidence, follow-up, and outcomes of incidental abdominal aortic aneurysms. *J Vasc Surg* 2010;52:282-9 e1-2.
6. Johnston KW, Rutherford RB, Tilson MD, Shah DM, Hollier L, Stanley JC. Suggested standards for reporting on arterial aneurysms. Subcommittee on Reporting Standards for Arterial Aneurysms, Ad Hoc Committee on Reporting Standards, Society for Vascular Surgery and North American Chapter, International Society for Cardiovascular Surgery. *J Vasc Surg* 1991;13:452-8.
7. Chaikof EL, Dalman RL, Eskandari MK, et al. The Society for Vascular Surgery practice guidelines on the care of patients with an abdominal aortic aneurysm. *J Vasc Surg* 2018;67:2-77 e2.
8. Erbel R, Aboyans V, Boileau C, et al. 2014 ESC Guidelines on the diagnosis and treatment of aortic diseases: Document covering acute and chronic aortic diseases of the thoracic and abdominal aorta of the adult. The Task Force for the Diagnosis and Treatment of Aortic Diseases of the European Society of Cardiology (ESC). *Eur Heart J* 2014;35:2873-926.
9. Sakalihan N, Michel JB, Katsargyris A, et al. Abdominal aortic aneurysms. *Nat Rev Dis Primers* 2018;4:34.
10. Wanhainen A, Verzini F, Van Herzele I, et al. Editor's Choice - European Society for Vascular Surgery (ESVS) 2019 Clinical Practice Guidelines on the Management of Abdominal Aorto-iliac Artery Aneurysms. *Eur J Vasc Endovasc Surg* 2019;57:8-93.
11. Lo RC, Schermerhorn ML. Abdominal aortic aneurysms in women. *J Vasc Surg* 2016;63:839-44.
12. Collard M, Sutphin PD, Kalva SP, et al. ACR Appropriateness Criteria® Abdominal Aortic Aneurysm Follow-up (Without Repair). *J Am Coll Radiol* 2019;16:S2-S6.
13. Francois CJ, Skulborstad EP, Majdalany BS, et al. ACR Appropriateness Criteria® Abdominal Aortic Aneurysm: Interventional Planning and Follow-Up. *J Am Coll Radiol* 2018;15:S2-S12.
14. Long A, Rouet L, Lindholt JS, Allaire E. Measuring the maximum diameter of native abdominal aortic aneurysms: review and critical analysis. *Eur J Vasc Endovasc Surg* 2012;43:515-24.
15. Lederle FA, Wilson SE, Johnson GR, et al. Variability in measurement of abdominal aortic aneurysms. Abdominal Aortic Aneurysm Detection and Management Veterans Administration Cooperative Study Group. *J Vasc Surg* 1995;21:945-52.
16. Fadel BM, Mohty D, Kazzi BE, et al. Ultrasound Imaging of the Abdominal Aorta: A Comprehensive Review. *J Am Soc Echocardiogr* 2021;34:1119-36.
17. Hiratzka LF, Bakris GL, Beckman JA, et al. 2010 ACCF/AHA/AATS/ACR/ASA/SCA/SCAI/SIR/STS/SVM guidelines for the diagnosis and management of patients with Thoracic Aortic Disease: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines, American Association for Thoracic Surgery, American College of Radiology, American Stroke Association, Society of Cardiovascular Anesthesiologists, Society for Cardiovascular Angiography and Interventions, Society of Interventional Radiology, Society of Thoracic Surgeons, and Society for Vascular Medicine. *Circulation* 2010;121:e266-369.
18. Ihara T, Komori K, Yamamoto K, Kobayashi M, Banno H, Kodama A. Three-dimensional workstation is useful for measuring the correct size of abdominal aortic aneurysm diameters. *Ann Vasc Surg* 2013;27:154-61.
19. Dugas A, Therasse E, Kauffmann C, et al. Reproducibility of abdominal aortic aneurysm diameter measurement and growth evaluation on axial and multiplanar computed tomography reformations. *Cardiovasc Intervent Radiol* 2012;35:779-87.

20. American College of Radiology. ACR–NASCI–SIR–SPR Practice Parameter for the Performance and Interpretation of Body Computed Tomography Angiography (CTA). Available at: <https://www.acr.org/-/media/ACR/Files/Practice-Parameters/body-cta.pdf>. Accessed March 31, 2023.
21. Ruff A, Patel K, Joyce JR, Gornik HL, Rothberg MB. The use of pre-existing CT imaging in screening for abdominal aortic aneurysms. *Vasc Med* 2016;21:515-19.
22. Al-Thani H, El-Menyar A, Shabana A, Tabea A, Al-Sulaiti M, Almalki A. Incidental abdominal aneurysms: a retrospective study of 13,115 patients who underwent a computed tomography scan. *Angiology* 2014;65:388-95.
23. Khashram M, Jones GT, Roake JA. Prevalence of abdominal aortic aneurysm (AAA) in a population undergoing computed tomography colonography in Canterbury, New Zealand. *Eur J Vasc Endovasc Surg* 2015;50:199-205.
24. Liisberg M, Diederichsen AC, Lindholt JS. Abdominal ultrasound-scanning versus non-contrast computed tomography as screening method for abdominal aortic aneurysm - a validation study from the randomized DANCAVAS study. *BMC Med Imaging* 2017;17:14.
25. Goldstein SA, Evangelista A, Abbara S, et al. Multimodality imaging of diseases of the thoracic aorta in adults: from the American Society of Echocardiography and the European Association of Cardiovascular Imaging: endorsed by the Society of Cardiovascular Computed Tomography and Society for Cardiovascular Magnetic Resonance. *J Am Soc Echocardiogr* 2015;28:119-82.
26. Hallett RL, Ullery BW, Fleischmann D. Abdominal aortic aneurysms: pre- and post-procedural imaging. *Abdom Radiol (NY)* 2018;43:1044-66.
27. Rengier F, Geisbusch P, Vosschenrich R, et al. State-of-the-art aortic imaging: part I - fundamentals and perspectives of CT and MRI. *Vasa* 2013;42:395-412.
28. Evangelista A. Imaging aortic aneurysmal disease. *Heart* 2014;100:909-15.
29. Agrawal MD, Oliveira GR, Kalva SP, Pinho DF, Arellano RS, Sahani DV. Prospective Comparison of Reduced-Iodine-Dose Virtual Monochromatic Imaging Dataset From Dual-Energy CT Angiography With Standard-Iodine-Dose Single-Energy CT Angiography for Abdominal Aortic Aneurysm. *AJR Am J Roentgenol* 2016;207:W125-W32.
30. Patino M, Parakh A, Lo GC, et al. Virtual Monochromatic Dual-Energy Aortoiliac CT Angiography With Reduced Iodine Dose: A Prospective Randomized Study. *AJR Am J Roentgenol* 2019;212:467-74.
31. Truijers M, Kurvers HA, Bredie SJ, Oyen WJ, Blankensteijn JD. In vivo imaging of abdominal aortic aneurysms: increased FDG uptake suggests inflammation in the aneurysm wall. *J Endovasc Ther* 2008;15:462-7.
32. Murakami M, Morikage N, Samura M, Yamashita O, Suehiro K, Hamano K. Fluorine-18-fluorodeoxyglucose positron emission tomography-computed tomography for diagnosis of infected aortic aneurysms. *Ann Vasc Surg* 2014;28:575-8.
33. Jalalzadeh H, Indrakusuma R, Planken RN, Legemate DA, Koelemay MJ, Balm R. Inflammation as a Predictor of Abdominal Aortic Aneurysm Growth and Rupture: A Systematic Review of Imaging Biomarkers. *Eur J Vasc Endovasc Surg* 2016;52:333-42.
34. Hartung MP, Grist TM, Francois CJ. Magnetic resonance angiography: current status and future directions. *J Cardiovasc Magn Reson* 2011;13:19.
35. Hope MD, Hope TA, Zhu C, et al. Vascular Imaging With Ferumoxytol as a Contrast Agent. *AJR Am J Roentgenol* 2015;205:W366-73.
36. Nguyen KL, Yoshida T, Kathuria-Prakash N, et al. Multicenter Safety and Practice for Off-Label Diagnostic Use of Ferumoxytol in MRI. *Radiology* 2019;293:554-64.
37. van Hout MJ, Scholte AJ, Juffermans JF, et al. How to Measure the Aorta Using MRI: A Practical Guide. *J Magn Reson Imaging* 2020;52:971-77.
38. Elefteriades JA, Mukherjee SK, Mojibian H. Discrepancies in Measurement of the Thoracic Aorta: JACC Review Topic of the Week. *J Am Coll Cardiol* 2020;76:201-17.
39. Schulz-Menger J, Bluemke DA, Bremerich J, et al. Standardized image interpretation and post-processing in cardiovascular magnetic resonance - 2020 update : Society for Cardiovascular Magnetic Resonance (SCMR): Board of Trustees Task Force on Standardized Post-Processing. *J Cardiovasc Magn Reson* 2020;22:19.
40. Zhu C, Tian B, Leach JR, et al. Non-contrast 3D black blood MRI for abdominal aortic aneurysm surveillance: comparison with CT angiography. *Eur Radiol* 2017;27:1787-94.
41. Rubano E, Mehta N, Caputo W, Paladino L, Sinert R. Systematic review: emergency department bedside ultrasonography for diagnosing suspected abdominal aortic aneurysm. *Acad Emerg Med* 2013;20:128-38.



42. Guirguis-Blake JM, Beil TL, Senger CA, Whitlock EP. Ultrasonography screening for abdominal aortic aneurysms: a systematic evidence review for the U.S. Preventive Services Task Force. *Ann Intern Med* 2014;160:321-9.
43. Owens DK, Davidson KW, Krist AH, et al. Screening for Abdominal Aortic Aneurysm: US Preventive Services Task Force Recommendation Statement. *JAMA* 2019;322:2211-18.
44. NICE Guideline Updates Team. Imaging techniques to diagnose abdominal aortic aneurysms. *Imaging techniques to diagnose abdominal aortic aneurysms: Abdominal aortic aneurysm: diagnosis and management: Evidence review B*. London; 2020.
45. Blaivas M, Theodoro D. Frequency of incomplete abdominal aorta visualization by emergency department bedside ultrasound. *Acad Emerg Med* 2004;11:103-5.
46. Matthews EO, Pinchbeck J, Elmore K, Jones RE, Moxon JV, Golledge J. The reproducibility of measuring maximum abdominal aortic aneurysm diameter from ultrasound images. *Ultrasound J* 2021;13:13.
47. Borgbjerg J, Bogsted M, Lindholt JS, Behr-Rasmussen C, Horlyck A, Frokjaer JB. Superior Reproducibility of the Leading to Leading Edge and Inner to Inner Edge Methods in the Ultrasound Assessment of Maximum Abdominal Aortic Diameter. *Eur J Vasc Endovasc Surg* 2018;55:206-13.
48. Chiu KW, Ling L, Tripathi V, Ahmed M, Shrivastava V. Ultrasound measurement for abdominal aortic aneurysm screening: a direct comparison of the three leading methods. *Eur J Vasc Endovasc Surg* 2014;47:367-73.
49. Gurtelschmid M, Bjorck M, Wanhainen A. Comparison of three ultrasound methods of measuring the diameter of the abdominal aorta. *Br J Surg* 2014;101:633-6.
50. Hartshorne TC, McCollum CN, Earnshaw JJ, Morris J, Nasim A. Ultrasound measurement of aortic diameter in a national screening programme. *Eur J Vasc Endovasc Surg* 2011;42:195-9.
51. Beales L, Wolstenhulme S, Evans JA, West R, Scott DJ. Reproducibility of ultrasound measurement of the abdominal aorta. *Br J Surg* 2011;98:1517-25.
52. Thapar A, Cheal D, Hopkins T, Ward S, Shalhoub J, Yusuf SW. Internal or external wall diameter for abdominal aortic aneurysm screening? *Ann R Coll Surg Engl* 2010;92:503-5.
53. AIUM practice guideline for the performance of diagnostic and screening ultrasound examinations of the abdominal aorta in adults. *J Ultrasound Med* 2011;30:121-6.
54. Foo FJ, Hammond CJ, Goldstone AR, et al. Agreement between computed tomography and ultrasound on abdominal aortic aneurysms and implications on clinical decisions. *Eur J Vasc Endovasc Surg* 2011;42:608-14.
55. Manning BJ, Kristmundsson T, Sonesson B, Resch T. Abdominal aortic aneurysm diameter: a comparison of ultrasound measurements with those from standard and three-dimensional computed tomography reconstruction. *J Vasc Surg* 2009;50:263-8.
56. Sprouse LR, 2nd, Meier GH, 3rd, Lesar CJ, et al. Comparison of abdominal aortic aneurysm diameter measurements obtained with ultrasound and computed tomography: Is there a difference? *J Vasc Surg* 2003;38:466-71; discussion 71-2.
57. Bredahl K, Sandholt B, Lonn L, et al. Three-dimensional ultrasound evaluation of small asymptomatic abdominal aortic aneurysms. *Eur J Vasc Endovasc Surg* 2015;49:289-96.
58. Lowe C, Ghulam Q, Bredahl K, et al. Three-dimensional Ultrasound in the Management of Abdominal Aortic Aneurysms: A Topical Review. *Eur J Vasc Endovasc Surg* 2016;52:466-74.
59. van Essen JA, Gussenhoven EJ, van der Lugt A, et al. Accurate assessment of abdominal aortic aneurysm with intravascular ultrasound scanning: validation with computed tomographic angiography. *J Vasc Surg* 1999;29:631-8.
60. Garret HE, Jr., Abdullah AH, Hodgkiss TD, Burgar SR. Intravascular ultrasound aids in the performance of endovascular repair of abdominal aortic aneurysm. *J Vasc Surg* 2003;37:615-8.
61. American College of Radiology. ACR Appropriateness Criteria® Radiation Dose Assessment Introduction. Available at: <https://www.acr.org/-/media/ACR/Files/Appropriateness-Criteria/RadiationDoseAssessmentIntro.pdf>. Accessed March 31, 2023.

The ACR Committee on Appropriateness Criteria and its expert panels have developed criteria for determining appropriate imaging examinations for diagnosis and treatment of specified medical condition(s). These criteria are intended to guide radiologists, radiation oncologists and referring physicians in making decisions regarding radiologic imaging and treatment. Generally, the complexity and severity of a patient's clinical condition should dictate the selection of appropriate imaging procedures or treatments. Only those examinations generally used for evaluation of the patient's condition are ranked. Other imaging studies necessary to evaluate other co-existent diseases or other medical consequences of this condition are not considered in this document. The availability of equipment or personnel may influence the selection of appropriate imaging procedures or treatments. Imaging techniques classified as investigational by the FDA have not been considered in developing these criteria; however, study of new equipment and applications should be encouraged. The ultimate decision regarding the appropriateness of any specific radiologic examination or treatment must be made by the referring physician and radiologist in light of all the circumstances presented in an individual examination.