ACR Appropriateness Criteria® pulsatile abdominal mass, suspected abdominal aortic aneurysm

Benoit Desjardins · Karin E. Dill · Scott D. Flamm · Christopher J. Francois · Marie D. Gerhard-Herman · Sanjeeva P. Kalva · M. Ashraf Mansour · Emile R. Mohler III · Isabel B. Oliva · Matthew P. Schenker · Clifford Weiss · Frank J. Rybicki

Received: 20 March 2012 / Accepted: 23 March 2012 / Published online: 27 May 2012 © American College of Radiology 2012

Abstract Clinical palpation of a pulsating abdominal mass alerts the clinician to the presence of a possible abdominal aortic aneurysm (AAA). Generally an arterial aneurysm is defined as a localized arterial dilatation ≥50 % greater than the normal diameter. Imaging studies are important in diagnosing the cause of a pulsatile abdominal mass and, if an AAA is found, in determining its size and involvement of abdominal branches. Ultrasound (US) is the initial imaging modality of choice when a pulsatile abdominal mass is present. Noncontrast computed tomography (CT) may be substituted in patients for whom US is not suitable. When aneurysms have reached the size threshold for intervention or are clinically symptomatic, contrast-enhanced multidetector CT angiography (CTA) is the best diagnostic and preintervention planning study, accurately delineating the location, size, and extent of aneurysm and the involvement of branch vessels. Magnetic resonance angiography (MRA) may be substituted if CT cannot be performed. Catheter arteriography has some utility in patients with significant contraindications to both CTA and MRA. The American College of Radiology Appropriateness Criteria® are evidence-based guidelines for specific clinical conditions that are reviewed every 2 years by a multidisciplinary expert panel. The guideline
Ultrasonography of the abdominal aorta and other major artery branches is a noninvasive examination that can clearly visualize the outer wall of the aorta and detect any abnormal dilatations [1]. However, the normal dimension of the infrarenal abdominal aorta is up to 2 cm in anteroposterior (AP) diameter. Thus, the infrarenal abdominal aorta is considered aneurysmal if it is ≥3 cm in diameter or ectatic between 2 and 3 cm in diameter [2]. The absolute threshold for aneurysm decreases along the length of the aorta and is about 10 % smaller in women than in men [3].

Imaging studies are important in diagnosing the cause of a pulsatile abdominal mass and, if an AAA is found, in determining its size, involvement of abdominal branches, both visceral and parietal, and any associated significant stenosis or aneurysm involving abdominal visceral and extremity arteries [4]. Imaging studies should also categorize the extent of aneurysm (i.e., infrarenal aorta; infrarenal aorta and iliac; isolated iliac; or juxtarenal, suprarenal, or thoracoabdominal aorta) [5]. Imaging can also be used for routine surveillance of AAAs [6].

Currently, elective repair is considered for AAAs ≥5.5 cm in diameter [7]. For smaller AAAs, periodic surveillance is recommended at intervals based on their maximum size [8]: every 6 months for those 4.5–5.4 cm in diameter, every 12 months for those 3.5–4.4 cm in diameter, every 3 years for those 3.0–3.4 cm in diameter, and every 5 years for those 2.6–2.9 cm in diameter.

Population-based ultrasound (US) screening studies have been recommended for male patients >65 years of age [9]. Risk of AAA increases with a history of hypertension and smoking. For AAAs between 3 and 5.5 cm in diameter, periodic US or computed tomography (CT) imaging at 6–12-month intervals depending on rate of aneurysm enlargement on prior studies is recommended. When aneurysms have reached the size threshold for intervention (5.5 cm) or are considered clinically symptomatic, additional preintervention imaging studies should be performed to help define the optimal surgical or endovascular approach. For preintervention studies, either multidetector CT (MDCT) or CT angiography (CTA) is the optimal choice. Magnetic resonance angiography (MRA) may be substituted if CT cannot be performed (for example, because the patient is allergic to iodinated contrast). However, MRA is usually performed with gadolinium contrast, which is not suitable for patients with severe renal insufficiency. In such patients, the center where it is being performed must be able to perform MRA of AAA without the use of gadolinium contrast [10] (see Table 1).

Other types of imaging studies that have been used in the past to delineate AAAs—including abdominal radiographs, intravenous urography, and blood pool radionuclide imaging—are not recommended for diagnosis, surveillance, or preintervention imaging.

Catheter arteriography has very limited utility in the preintervention evaluation of patients with AAAs, its sole utility being in patients with significant contraindications to both CTA (significant renal dysfunction) and MRA (significant renal dysfunction, cardiac pacemakers, claustrophobia). In patients with significant renal dysfunction, the combination of noncontrast CT and the lower load of iodinated contrast material that can be used with intraarterial injection can decrease the risk of contrast-induced nephropathy.

Many imaging studies for assessing AAA can also identify other disease that could affect preoperative management of AAA, such as coronary artery disease [11] and thoracic aortic aneurysm [12]. Screening for AAA can also be performed during unrelated imaging studies, such as transthoracic echocardiography [13, 14], peripheral vascular US [15], and imaging studies to assess coronary artery disease [16, 17] and stroke or transient ischemic attack [18].

Ultrasound

US examination of the abdominal aorta should be a dedicated examination and not a component of a generalized abdominal US study. If possible, complete longitudinal evaluation of the full extent of the aneurysm and involvement of common iliac arteries should be performed. These studies should include a measurement of the leading-edge-to-leading-edge AP diameter in the proximal, mid, and distal infrarenal aorta and of the common iliac arteries.
Lining mural thrombus should be delineated. Right and left kidneys should be imaged to determine size, parenchymal thickness, and presence or absence of hydronephrosis. In order to permit US to be used instead of CT for AAA follow-up, interindividual reproducibility of diameter measurements should be within \( \pm 4 \) mm [24]. US tend to underestimate the size of aneurysms by 4 mm compared to CTA [25]. Color Doppler imaging is not a necessary component of sonographic screening or surveillance examination. New, 3-D volumetric US techniques offer similar measurements but speed up imaging significantly [26, 27].

Approximately 5 % of AAAs will be juxtarenal or juxta/suprarenal [28], and it may not be possible to accurately delineate the upper margin of such aneurysms or the precise involvement of abdominal visceral branches by sonographic study. That is why a more definitive study, such as CTA, should be performed prior to intervention.

Computed tomography

Noncontrast CT is diagnostically equivalent to US for AAA detection and is recommended in patients for whom US is not suitable (for example, those with obese body habitus). CT may be used as a diagnostic and preintervention study, suitable for patients presenting with pulsatile abdominal mass with or without clinical suspicion of contained aortic rupture, and in planning endovascular or surgical intervention in patients with AAAs >5.5 cm in external AP diameter [29–31]. In tortuous aneurysms, where a single dimension may be artifactually accentuated by the curvature of the aorta, the short-axis diameter of the aorta may be substituted for the AP diameter.

Contrast-enhanced multidetector CTA is the best diagnostic and preintervention planning study, accurately delineating the location, size, and extent of aneurysm and the involvement of branch vessels, allowing for accurate quantitative 3-D measurements [32]. CTA can also assess thrombus in aneurysm. Larger thrombus and eccentric thrombus seem associated with rapid enlargement of the aneurysm and increased incidence of cardiovascular events [33, 34]. There are several research protocols that use modern CT technologies. Multiphase MDCT can assess compressibility of thrombus that can act as a biomechanical buffer [35]. Using delayed imaging, aortic wall enhancement is associated with AAA diameter, biochemical markers of inflammation, and thrombus size [36]. Short-term follow up by CTA does not decrease the suitability of aneurysms for endovascular intervention [37]. In patients with suspected thoraco AAA, CTA may be tailored for an angiographic examination of the chest, abdomen, and pelvis [38–40]. In patients with suspected coexistent lower-extremity arterial disease, the arterial system from the diaphragm to the feet can be studied with MDCT or CTA [41].

Volume rendering, subvolume maximum-intensity projection (MIP), and curved planar reformations are integral components of the 3-D analysis. Semiautomated measurements of vessel diameter and length in relation to the proximal and distal aneurysm margins and branch vessels can be readily obtained with software supplied by multiple vendors. Additional research methods include ECG-gated MDCT that can assess decreased distensibility of aortic aneurysms [42]. Advanced postprocessing of CT data can assess wall stress. Rapidly expanding AAAs has higher shoulder and wall stress [43, 44]. Calcification of the aneurysm increases wall stress and decreases the biomechanical stability of AAA [45]. AAA peak wall stress at maximal blood pressure is higher in symptomatic or ruptured aneurysms compared to asymptomatic aneurysms [46, 47].

### Table 1

| Radiologic procedure       | Rating | Comments                                      | RRLa |
|---------------------------|--------|-----------------------------------------------|------|
| US aorta abdomen          | 9      | Initial examination. May be limited by body habitus or acoustic window | O    |
| CT abdomen without contrast| 8      | Preferred for symptomatic patients. Suitable for patients in whom US is not useful | 三星 |
| CTA abdomen with contrast  | 7      | Also enables preinterventional planning      | 三星 |
| MRA abdomen without contrast | 6    | Alternative to CTA. Unable to detect calcium. Site-specific expertise important | O    |
| MRA abdomen without and with contrast | 6 | Alternative to CTA. Unable to detect calcium. Site-specific expertise important. See statement regarding contrast in text under “anticipated exceptions” | O    |
| Aortography abdomen       | 2      | Essentially replaced by cross-sectional imaging for diagnostic purposes. May be used for preinterventional planning | 三星 |
| FDG-PET/CT abdomen        | 2      |                                               | 三星 |

Rating scale: 1–3 usually not appropriate, 4–6 may be appropriate, 7–9 usually appropriate

a Relative radiation level
In patients with suspected contained rupture, nonintra-
venous contrast-enhanced CT is performed to better diag-
nose dissecting hematoma in the lining of the intra-aortic
thrombus (the crescent sign) and other signs consistent with
imminent or contained rupture [48–50], including a draped
aorta and adjacent vertebral erosion [51]. In patients who
have contained rupture, a rapid CT angiographic study
provides a template for decision making about endovas-
cular aneurysm repair or surgical aneurysmectomy [52].

Magnetic resonance angiography

Contrast-enhanced MRA is an alternative and effective
diagnostic and preintervention study [53]. The acquisition
speed and spatial resolution of contrast-enhanced MRA has
improved with the introduction of parallel imaging tech-
niques, narrowing the gap with CTA in relation to image
quality [54, 55]. The introduction of blood pool contrast
agents now enables longer image acquisition to improve
image resolution [56]. Caution should be used in patients with
severe renal dysfunction, generally considered as estimated
glomerular filtration rate (GFR) <30 ml/kg/min, who may be
at risk for nephrogenic systemic fibrosis [57]. In these
patients, a non-contrast-enhanced study may be substituted.
Sequences and imaging expertise required for a full evalua-
tion of AAA without contrast are becoming more mainstream.

Three-dimensional display techniques, including multi-
planar reformation, MIP display, and volume rendering, are
integral to the display and analysis of 3-D MRA. Cine
techniques can also assess distensibility and, with suitable
measurements of central venous pressure, can assess aortic
compliance [58]. Vessel wall shear stress can also be mea-
sured using newer 4-D flow-sensitive MRI techniques [59].

Catheter arteriography

Patients with significant contraindications to both CTA and
MRA may have diagnostic catheter arteriography per-
formed with a relatively low-contrast material load fol-
lowing US documentation of AAA and/or noncontrast CT
findings [60].

Catheter arteriography may not demonstrate the aneu-
rysm diameter accurately, as only the contrast column of an
aneurysm containing lining mural thrombus may be dis-
played. In patients with marginal renal function, rapid
intra-arterial injection of a relatively low volume of dilute
contrast material from a catheter located in the mid descending
thoracic aorta can be used for a diagnostic CTA study.

Positron emission tomography

Although primarily a research tool, positron emission
tomography using fluorine-18-2-fluoro-2-deoxy-d-glucose
(FDG–PET) imaging has promise in the evaluation of
patients with AAA. Increased metabolic activity and FDG
uptake (SUV_{max} > 2.5) is noted in aneurysms [61, 62]
and even higher in inflammatory aneurysms and symp-
tomatic aneurysms and correlates well with histologic and
metabolic evidence of inflammation [63]. Increased FDG
uptake is also seen in areas of high wall stress and rupture
[64]. Aneurysm calcification is unrelated to FDG uptake
[61].

Summary

- The consensus of the literature supports aortic US as
  the initial imaging modality of choice when a pulsatile
  abdominal mass is present. Noncontrast CT may be
  substituted in patients for whom US is not suitable (for
  example, those with obese body habitus).
- US is recommended as a screening technique in the
  Medicare-eligible male population at highest risk.
- For definitive diagnosis and preintervention imaging,
  CTA and MRA are recommended.
- Currently, CTA is regarded as the superior test, as it is
  readily available, is robust, and provides high spatial
  resolution 3-D displays suitable for interventional
  planning as well as delineation of pathology in abdom-
  inal visceral arterial branches and extremity outflow
  vessels.
- Contrast-enhanced MRA has improved significantly in
terms of speed and spatial resolution with the advent of
  parallel processing techniques and blood pool contrast
  agents. It may replace CTA for interventional planning
  in patients for whom iodinated contrast is contraindicated.
- Noncontrast MRA sequences for full evaluation of AAA
  are becoming more mainstream and should only be
  performed in centers with expertise in this technique.
- Appropriate preintervention measurements of the aorto-
  iliaceal arterial system can be obtained with either technique.
- Both CTA and MRA can be used for thoracoabdominal
  aortic and extremity studies, all in the same imaging
  session.
- FDG–PET remains primarily a research tool but
  shows promise for assessing the metabolic activity of
  aneurysms.

Anticipated exceptions

Nephrogenic systemic fibrosis (NSF) is a disorder with a
scleroderma-like presentation and a spectrum of manifesta-
tions that can range from limited clinical sequelae to
fatality. It appears to be related to both underlying severe
renal dysfunction and the administration of gadolinium-
Table 2  RRL designations

| RRLa | Adult effective dose estimate range (mSv) | Pediatric effective dose estimate range (mSv) |
|------|------------------------------------------|---------------------------------------------|
|      |                                          |                                             |
|      | 0                                        | 0                                           |
|      | <0.1                                     | <0.03                                       |
|      | 0.1–1                                    | 0.03–0.3                                    |
|      | 1–10                                     | 0.3–3                                       |
|      | 10–30                                    | 3–10                                        |
|      | 30–100                                   | 10–30                                       |

a  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 NS not specified.

Table 2  RRL designations

| RRLa | Adult effective dose estimate range (mSv) | Pediatric effective dose estimate range (mSv) |
|------|------------------------------------------|---------------------------------------------|
|      |                                          |                                             |
|      | 0                                        | 0                                           |
|      | <0.1                                     | <0.03                                       |
|      | 0.1–1                                    | 0.03–0.3                                    |
|      | 1–10                                     | 0.3–3                                       |
|      | 10–30                                    | 3–10                                        |
|      | 30–100                                   | 10–30                                       |

- 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, both because of 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 to those specified for adults (see Table 2). Additional information regarding radiation dose assessment for imaging examinations can be found in the ACR Appropriateness Criteria® radiation dose assessment introduction document [66].

For additional information on ACR Appropriateness Criteria®, refer to http://www.acr.org/ac.

Conflict of interest  None.

References

1. Bickerstaff LK, Hollier LH, Van Peenen HJ, Melton LJ III, Patrulero PC, Cherry KJ (1984) Abdominal aortic aneurysms: the changing natural history. J Vasc Surg 1(1):6–12
2. Ernst CB (1993) Abdominal aortic aneurysm. N Engl J Med 328(16):1167–1172
3. Guirguis EM, Barber GG (1991) The natural history of abdominal aortic aneurysms. Am J Surg 162(5):481–483
4. Neville A, Herts BR (2004) CT characteristics of primary retroperitoneal neoplasms. Crit Rev Comput Tomogr 45(4):247–270
5. Johnston KW, Rutherford RB, Tilson MD, Shah DM, Hollier L, Stanley JC (1991) 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 13(3):452–458
6. Wanhaien A, Themudo R, Ahlstrom H, Lind L, Johansson L (2008) Thoracic and abdominal aortic dimension in 70-year-old men and women—a population-based whole-body magnetic resonance imaging (MRI) study. J Vasc Surg 47(3):504–512
7. Richards T, Dharmadasa A, Davies R, Murphy M, Perera R, Walton J (2009) Natural history of the common iliac artery in the presence of an abdominal aortic aneurysm. J Vasc Surg 49(4):881–885
8. Schermerhorn ML, Cronenwett JL (2005) Abdominal aortic and iliac aneurysms. In: Rutherford CV (ed) Vascular Surgery, 6th edn. Elsevier, Philadelphia, Pennsylvania
9. Ashton HA, Buxton MJ, Day NE et al (2002) The multicentre aneurysm screening study (MASS) into the effect of abdominal aortic aneurysm screening on mortality in men: a randomised controlled trial. Lancet 360(9345):1531–1539
10. Lederle FA, Johnson GR, Wilson SE et al (2000) The aneurysm detection and management study screening program: validation cohort and final results. Aneurysm detection and management veterans affairs cooperative study investigators. Arch Intern Med 160(10):1425–1430
11. Lederle FA (2006) A summary of the contributions of the VA cooperative studies on abdominal aortic aneurysms. Ann NY Acad Sci 1085:29–38
12. Chaikoff EL, Brewster DC, Dalman RL et al (2009) The care of patients with an abdominal aortic aneurysm: the society for vascular surgery practice guidelines. J Vasc Surg 50(4 Suppl):S2–S49
13. Fleming C, Whitlock EP, Beil TL, Lederle FA (2005) Screening for abdominal aortic aneurysm: a best-evidence systematic review for the U.S. preventive services task force. Ann Intern Med 142(3):203–211
14. Diehm N, Herrmann P, Dinkel HP (2004) Multidetector CT angiography versus digital subtraction angiography for aortoiliac length measurements prior to endovascular AAA repair. J Endovasc Ther 11(5):527–534
15. Wyers MC, Fillingler MF, Schermerhorn ML et al (2003) Endovascular repair of abdominal aortic aneurysm without preoperative arteriography. J Vasc Surg 38(4):730–738
16. Buddle RP, Huo F, Cramer MJ et al (2010) Simultaneous aortic and coronary assessment in abdominal aortic aneurysm patients by thoraco-abdominal 64-detector-row CT angiography: estimate of the impact on preoperative management—a pilot study. Eur J Vasc Endovasc Surg 40(2):196–201
17. Larsson E, Vichevskaia L, Kalin B, Granath F, Swedenborg J, Hulgren R (2011) High frequency of thoracic aneurysms in patients with abdominal aortic aneurysms. Ann Surg 253(1):180–184
55. Wilson GI, Hoogeveen RM, Willinek WA, Muthupillai R, Maki JH (2004) Parallel imaging in MR angiography. Top Magn Reson Imaging 15(3):169–185
56. Wolf F, Plank C, Beitzke D et al (2011) Prospective evaluation of high-resolution MRI using gadofosveset for stent-graft planning: comparison with CT angiography in 30 Patients. AJR 197(5):1251–1257
57. Collidge TA, Thomson PC, Mark PB et al (2007) Gadolinium-enhanced MR imaging and nephrogenic systemic fibrosis: retrospective study of a renal replacement therapy cohort. Radiology 245(1):168–175
58. van’t Veer M, Buth J, Merkx M et al (2008) Biomechanical properties of abdominal aortic aneurysms assessed by simultaneously measured pressure and volume changes in humans. J Vasc Surg 48(6):1401–1407
59. Harloff A, Nussbaumer A, Bauer S et al (2010) In vivo assessment of wall shear stress in the atherosclerotic aorta using flow-sensitive 4D MRI. Magn Reson Med 63(6):1529–1536
60. Hoornweg LL, Wisselink W, Vahl A, Balm R (2007) The Amsterdam acute aneurysm trial: suitability and application rate for endovascular repair of ruptured abdominal aortic aneurysms. Eur J Vasc Endovasc Surg 33(6):679–683
61. Kotze CW, Menezes LJ, Endozo R, Groves AM, Ell PJ, Yusuf SW (2009) Increased metabolic activity in abdominal aortic aneurysm detected by 18F-fluorodeoxyglucose (18F-FDG) positron emission tomography/computed tomography (PET/CT). Eur J Vasc Endovasc Surg 38(1):93–99
62. Truijers M, Kurvers HA, Bredie SJ, Oyen WJ, Blankensteijn JD (2008) In vivo imaging of abdominal aortic aneurysms: increased FDG uptake suggests inflammation in the aneurysm wall. J Endovasc Ther 15(4):462–467
63. Reeps C, Essler M, Pelisek J, Seidl S, Eckstein HH, Krause BJ (2008) Increased 18F-fluorodeoxyglucose uptake in abdominal aortic aneurysms in positron emission/computed tomography is associated with inflammation, aortic wall instability, and acute symptoms. J Vasc Surg 48(2):417–423; Discussion 424
64. Xu XY, Borghi A, Nchimi A et al (2010) High levels of 18F-FDG uptake in aortic aneurysm wall are associated with high wall stress. Eur J Vasc Endovasc Surg 39(3):295–301
65. American College of Radiology Manual on contrast media. Available at: http://www.acr.org/SecondaryMainMenuCategories/quality_safety/contrast_manual.aspx
66. American College of Radiology ACR Appropriateness Criteria®: radiation dose assessment introduction. http://www.acr.org/SecondaryMainMenuCategories/quality_safety/app_criteria/RRLInformation.aspx. Accessed 13 Mar 2012