

**American College of Radiology
ACR Appropriateness Criteria®**

Clinical Condition: **Blunt Chest Trauma — Suspected Aortic Injury**

Radiologic Procedure	Rating	Comments	<u>RRL*</u>
X-ray chest	9	Chest x-ray and CTA are complementary examinations. Both should be done.	☢
CTA chest (noncoronary) with contrast	9	Chest x-ray and CTA are complementary examinations. Both should be done.	☢ ☢ ☢
Aortography thoracic	8		☢ ☢ ☢
MRA chest (noncoronary) without and with contrast	7	See statement regarding contrast in text under “Anticipated Exceptions.”	O
CT chest without contrast	6	Useful to detect mediastinal hematoma when contrast is contraindicated.	☢ ☢ ☢
US echocardiography transesophageal	5	Invasive. Suitable for bedside use.	O
MRA chest (noncoronary) without contrast	4		O
US intravascular aorta	4	Problem-solving tool in the setting of invasive angiography.	O
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

BLUNT CHEST TRAUMA — SUSPECTED AORTIC INJURY

Expert Panel on Vascular Imaging: Shadpour Demehri, MD¹; Frank J. Rybicki, MD, PhD²; Karin E. Dill, MD³; Benoit Desjardins, MD, PhD⁴; Chieh-Min Fan, MD⁵; Scott D. Flamm, MD⁶; Christopher J. Francois, MD⁷; Marie D. Gerhard-Herman, MD⁸; Sanjeeva P. Kalva, MD⁹; Hyun S. Kim, MD¹⁰; M. Ashraf Mansour, MD¹¹; Emile R. Mohler III, MD¹²; Isabel B. Oliva, MD¹³; Matthew P. Schenker, MD¹⁴; Clifford Weiss, MD.¹⁵

Summary of Literature Review

Introduction/Background

Trauma ranks fifth behind cardiovascular diseases, cancer, cerebrovascular diseases, and chronic lower respiratory diseases as a cause of death in the United States. Seventy-five percent of the deaths from blunt trauma are due entirely or in part to chest injuries. Rupture of the thoracic aorta is a common cause of death following blunt chest trauma. In more than 80% of cases, rupture is through all three layers of the aorta, resulting in exsanguination and death at the accident site. Individuals who survive have maintained the adventitia intact but are at risk for subsequent complete rupture. For these near-full-thickness injuries, 30% of initial survivors will die within 6 hours and 20% within 24 hours if the diagnosis is not made and treatment instituted. With technological advancements, a spectrum of disease is now being appreciated. Small tears of the intima can now be diagnosed, but the natural history of these “minimal aortic injuries” is not yet known [1,2]. Imaging may play a role in grading the severity of aortic injuries to help guide clinical management [3].

Pathophysiology

Traumatic injury of the aorta is thought by most investigators to result from unequal horizontal shear forces that are applied during high-speed deceleration to different parts of the thoracic aorta [4]. During rapid deceleration, torsion and shearing forces are produced

against the aorta at levels of relative immobility, mainly the aortic root, ligamentum arteriosum, and diaphragm. Injury occurs most commonly at the ligamentum arteriosum (80%) and less commonly to the ascending aorta. A mechanism involving compressive forces between anterior and posterior bony thoracic structures has also been proposed (the “osseous pinch”) [5].

Because the adventitia remains intact as a barrier to exsanguination in survivors, the most common pathologic findings are tears of the intima and media. The mediastinal hematoma associated with these injuries is therefore most commonly due to rupture of small arteries and veins in the mediastinum [6]. Traumatic laceration of the aorta is the most common lesion seen at autopsy, although survival even from this injury has been reported. In these rare cases, a pseudoaneurysm is contained by periaortic tissue. Chronic pseudoaneurysm has been described and may present many years after the traumatic event.

Clinical Presentation

Variation in clinical presentation is the rule with thoracic aortic injuries. Patients may present in full cardiovascular collapse or complain of chest pain, midscapular pain, or shortness of breath. Almost half of patients with aortic disruption have no external signs of chest trauma. Because of the variable presentation, a high index of suspicion for traumatic rupture of the aorta must be assumed for any patient who has sustained high-speed rapid deceleration.

Chest Radiograph

Despite the advent of newer imaging modalities, the chest radiograph remains the primary screening method for detecting mediastinal hemorrhage following blunt thoracic trauma. It is included in most trauma center protocols in the initial evaluation of patients with polytrauma [7].

Because of the trauma setting in which chest radiographs of these patients are obtained, they are usually portable anteroposterior supine radiographs. This results in a lordotic view with a shortened focal spot-film distance, magnifying the width of the superior mediastinum and decreasing resolution. Sitting the patient upright when feasible for an anteroposterior radiograph should result in fewer falsely abnormal radiographs [8].

Most of the radiograph findings in aortic rupture are related to mediastinal hemorrhage rather to the aortic injury itself. The most common chest radiograph finding, widening of the mediastinum, has been defined as a transverse distance of 8 cm from the left side of the aortic arch to the right margin of the mediastinum. It must be emphasized that the vast majority of patients with mediastinal widening do not have aortic injuries. Angiographically confirmed aortic injury is found in only 10%-20% of these patients. Mediastinal widening has

¹Research Author, Brigham and Women’s Hospital, Boston, Massachusetts.

²Principal Author and Panel Chair, Brigham and Women’s Hospital, Boston, Massachusetts.

³Panel Vice-chair, University of Chicago, Chicago, Illinois.

⁴University of Pennsylvania, Philadelphia, Pennsylvania.

⁵Brigham and Women’s Hospital, Boston, Massachusetts.

⁶Cleveland Clinic, Cleveland, Ohio.

⁷University of Wisconsin, Madison, Wisconsin.

⁸Brigham and Women’s Hospital, Boston, Massachusetts, American College of Cardiology.

⁹Massachusetts General Hospital, Boston, Massachusetts.

¹⁰Emory University School of Medicine, Atlanta, Georgia

¹¹Vascular Associates, Grand Rapids, Michigan, Society of Vascular Surgeons.

¹²University of Pennsylvania, Philadelphia, Pennsylvania, American College of Cardiology.

¹³Yale University School of Medicine, New Haven, Connecticut.

¹⁴Brigham and Women’s Hospital, Boston, Massachusetts.

¹⁵Johns Hopkins Bayview Medical Center, Baltimore, Maryland.

The American College of Radiology seeks and encourages collaboration with other organizations on the development of the ACR Appropriateness Criteria through society representation on expert panels. Participation by representatives from collaborating societies on the expert panel does not necessarily imply individual or society endorsement of the final document.

Reprint requests to: Department of Quality & Safety, American College of Radiology, 1891 Preston White Drive, Reston, VA 20191-4397.

90% sensitivity but only 10% specificity for aortic disruption.

Approximately 7% of patients with aortic rupture have a normal initial chest radiograph [9]. A prior pilot study has also suggested that a chest radiograph and an abdominal computed tomography (CT) scan will identify most occult intrathoracic injuries, and thoracic CT may be reserved for patients with an abnormal chest radiograph or severe blunt trauma, which could safely reduce cost and radiation exposure while still diagnosing significant thoracic injuries [10]. However, the diagnostic evaluation of patients with blunt chest trauma now includes chest CT at most facilities. CT has proven to be very sensitive for detecting aortic injury. When no mediastinal hematoma is detected on chest CT, the probability of a significant aortic injury is very low [11].

Thoracic Aortography

Thoracic aortography has been widely accepted as the gold standard for evaluating patients with suspected aortic injury [12,13]. The aortogram establishes the diagnosis, defines the anatomy of the lesion, and, because approximately 20% of patients have multiple tears, identifies additional sites of injury [14]. At most institutions, aortography is performed on patients who have suffered rapid deceleration injury and who have a widened mediastinum or obscure aortic knob and descending aorta on a chest radiograph, or who have indirect or direct signs of aortic injury detected by CT [15].

Various film sequences have been used, including anteroposterior, lateral, and oblique projections. It should be emphasized that more than one projection may be necessary to detect an aortic injury. Because acutely injured patients are in a hyperdynamic state, high contrast volumes of 60 to 70 cc rapidly injected are needed.

Computed Tomography

With the increasing availability of multidetector rows, CT plays a more prominent, and in many cases dominant, role in the assessment of patients with suspected aortic injury [16-18]. CT's strength lies in its ability to distinguish mediastinal blood from other causes of mediastinal widening detected on initial chest radiographs (eg, artifacts of magnification, mediastinal fat, or anatomic variation) [19]. It has been suggested that routine CT has relatively lower, though still substantial, added diagnostic value compared with selective CT of the chest in patients with severe blunt trauma [20]. If no mediastinal hematoma is detected on CT, the probability of a significant aortic injury is very low, and aortography is generally not needed [21,22]. Studies have confirmed that patients with a negative chest CT in this setting have favorable clinical outcomes [23]. It has also been shown that CT may be a useful diagnostic method for assessing chest trauma in forensic medicine as a supplement to autopsy [24].

Computed Tomographic Angiography

With newer multidetector CT protocols and image postprocessing tools, angiographic images of the aorta and great vessels in multiple planes can be created [25]. In addition, imaging of the aortic root with electrocardiography (ECG) gating [26] decreases the pulsation artifact that can leave questions regarding traumatic aortic injury and require catheter-based aortography after CT angiography (CTA) performed without ECG gating. Studies have shown high sensitivity and negative predictive value in the evaluation of suspected traumatic aortic injury when there are no signs of direct aortic injury such as an intimal flap, change in aortic contour or caliber, intraluminal irregularity, pseudoaneurysm, or intramural hematoma. Some authors have found that even in the presence of mediastinal hematoma, aortic injury is very unlikely without direct evidence of aortic injury [27]. Others have shown a high specificity for aortic injury when such direct signs are present [28]. Many centers have abandoned aortography in the initial evaluation of patients at risk of aortic injury and instead use CTA [29] that has the additional advantage of visualizing other structures in the thorax, including bone fractures.

Magnetic Resonance Angiography

Although magnetic resonance (MR) can demonstrate acute and subacute mediastinal hematoma [30], it currently does not have a role in the initial evaluation of the critically ill, hemodynamically unstable trauma patient. MR, however, has proven to be useful in evaluating chronic traumatic aortic pseudoaneurysms [31]. In the setting of trauma, restricted access to critically ill patients in the MR scanner also poses problem. Moreover, the strong magnetic field can be very limiting for those patients who require extensive monitoring a interventions such as a ventilator. However, despite these limitations, ECG-gated contrast-enhanced MR angiography (MRA) with breath-holding can provide diagnostic images of the thoracic aorta in cooperative hemodynamically stable patients with blunt chest trauma. This procedure is most applicable for patients with significant contraindication to iodinated contrast [32]. MR may also be a useful diagnostic tool in forensic medicine for evaluating blunt chest trauma [24].

Transesophageal Echocardiography

Transesophageal echocardiography (TEE) has been used in the acute trauma setting to study both the heart (for contusion) and the thoracic aorta. It appears to be much more sensitive than transthoracic echocardiography for detecting cardiac contusions.

TEE is more operator-dependent and more invasive than CT. The procedure usually requires sedation. In some patients, blind spots created by the tracheal-bronchial bifurcation may preclude adequate visualization of portions of the aortic arch. Other blind spots for TEE are the distal ascending aorta and the aortic arch vessels, sites of traumatic injury in up to 20% of patients with blunt chest trauma [33]. When CTA must be delayed for

emergent abdominal exploration, intraoperative TEE may be a useful modality to evaluate for aortic injury [34].

Recent studies have reported excellent diagnostic accuracy using TEE for recognizing aortic injury [35-39]. This experience, however, has not been uniformly positive. Further studies are required before TEE can be recommended as part of the imaging workup in patients with blunt chest trauma.

Intravascular Ultrasound

The continued development of intravascular ultrasound (IVUS) has offered an adjunct to standard transfemoral aortography. Although the routine use of IVUS is neither indicated nor practical, in a few cases it has been found to be useful in confirming or excluding thoracic aortic injury when angiographic findings are subtle or uncertain [37,40].

Summary

- The literature supports the continued use of the chest radiograph as the initial screening examination in the patient who has sustained blunt chest trauma.
- In the appropriate clinical setting and with a chest radiograph demonstrating mediastinal widening or other signs of mediastinal hemorrhage, thoracic aortography or helical chest CT is indicated.
- CTA is emerging as a very sensitive and specific examination for aortic injury and has replaced thoracic aortography as the primary aortic imaging tool in many trauma centers.
- With this expanding role for CTA, the role of IVUS and TEE is diminishing, but they may be useful in select cases.

Anticipated Exceptions

Nephrogenic systemic fibrosis (NSF) is a disorder with a scleroderma-like presentation and a spectrum of manifestations 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-based contrast agents. It has occurred primarily in patients on dialysis, rarely in patients with very limited glomerular filtration rate (GFR) (ie, <30 mL/min/1.73m²), and almost never in other patients. There is growing literature regarding NSF. Although some controversy and lack of clarity remain, there is a consensus that it is advisable to avoid all gadolinium-based contrast agents in dialysis-dependent patients unless the possible benefits clearly outweigh the risk, and to limit the type and amount in patients with estimated GFR rates <30 mL/min/1.73m². For more information, please see the [ACR Manual on Contrast Media](#) [41].

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 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 (eg, 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).		

Supporting Document(s)

- [ACR Appropriateness Criteria® Overview](#)
- [Procedure Information](#)
- [Evidence Table](#)

References

1. Feliciano DV, Rozycki GS. Advances in the diagnosis and treatment of thoracic trauma. *Surg Clin North Am* 1999; 79(6):1417-1429.
2. Kepros J, Angood P, Jaffe CC, Rabinovici R. Aortic intimal injuries from blunt trauma: resolution profile in nonoperative management. *J Trauma* 2002; 52(3):475-478.
3. Calhoun JH, Grover FL, Trinkle JK. Chest trauma. Approach and management. *Clin Chest Med* 1992; 13(1):55-67.
4. Parmley LF, Mattingly TW, Manion WC, Jahnke EJ, Jr. Nonpenetrating traumatic injury of the aorta. *Circulation* 1958; 17(6):1086-1101.
5. Crass JR, Cohen AM, Motta AO, Tomashefski JF, Jr., Wiesen EJ. A proposed new mechanism of traumatic aortic rupture: the osseous pinch. *Radiology* 1990; 176(3):645-649.
6. Ayella RJ, Hankins JR, Turney SZ, Cowley RA. Ruptured thoracic aorta due to blunt trauma. *J Trauma* 1977; 17(3):199-205.
7. Ungar TC, Wolf SJ, Haukoos JS, Dyer DS, Moore EE. Derivation of a clinical decision rule to exclude thoracic aortic injury in patients with blunt chest trauma after motor vehicle collisions. *J Trauma* 2006; 61(5):1150-1155.

8. Schwab CW, Lawson RB, Lind JF, Garland LW. Aortic injury: comparison of supine and upright portable chest films to evaluate the widened mediastinum. *Ann Emerg Med* 1984; 13(10):896-899.
9. Woodring JH. The normal mediastinum in blunt traumatic rupture of the thoracic aorta and brachiocephalic arteries. *J Emerg Med* 1990; 8(4):467-476.
10. Barrios C, Jr., Pham J, Malinoski D, Dolich M, Lekawa M, Cinat M. Ability of a chest X-ray and an abdominal computed tomography scan to identify traumatic thoracic injury. *Am J Surg* 2010; 200(6):741-744; discussion 744-745.
11. Malhotra AK, Fabian TC, Croce MA, Weiman DS, Gavant ML, Pate JW. Minimal aortic injury: a lesion associated with advancing diagnostic techniques. *J Trauma* 2001; 51(6):1042-1048.
12. Abrams HL. Thoracic aortography: techniques, indications and hazards. In: Abrams HL, ed. *Abrams Angiography: vascular and interventional radiology*. Vol 1. 3rd ed. Boston, MA: Little Brown & Co; 1983:38-352.
13. Parker MS, Matheson TL, Rao AV, et al. Making the transition: the role of helical CT in the evaluation of potentially acute thoracic aortic injuries. *AJR* 2001; 176(5):1267-1272.
14. Chen MY, Regan JD, D'Amore MJ, Routh WD, Meredith JW, Dyer RB. Role of angiography in the detection of aortic branch vessel injury after blunt thoracic trauma. *J Trauma* 2001; 51(6):1166-1171; discussion 1172.
15. Chen MY, Miller PR, McLaughlin CA, Kortesis BG, Kavanagh PV, Dyer RB. The trend of using computed tomography in the detection of acute thoracic aortic and branch vessel injury after blunt thoracic trauma: single-center experience over 13 years. *J Trauma* 2004; 56(4):783-785.
16. Dyer DS, Moore EE, Ilke DN, et al. Thoracic aortic injury: how predictive is mechanism and is chest computed tomography a reliable screening tool? A prospective study of 1,561 patients. *J Trauma* 2000; 48(4):673-682; discussion 682-673.
17. Gavant ML. Helical CT grading of traumatic aortic injuries. Impact on clinical guidelines for medical and surgical management. *Radiol Clin North Am* 1999; 37(3):553-574, vi.
18. Wicky S, Capasso P, Meuli R, Fischer A, von Segesser L, Schwyder P. Spiral CT aortography: an efficient technique for the diagnosis of traumatic aortic injury. *Eur Radiol* 1998; 8(5):828-833.
19. Mirvis SE, Shanmuganathan K, Miller BH, White CS, Turney SZ. Traumatic aortic injury: diagnosis with contrast-enhanced thoracic CT--five-year experience at a major trauma center. *Radiology* 1996; 200(2):413-422.
20. Deunk J, Brink M, Dekker HM, et al. Routine versus selective multidetector-row computed tomography (MDCT) in blunt trauma patients: level of agreement on the influence of additional findings on management. *J Trauma* 2009; 67(5):1080-1086.
21. Bruckner BA, DiBardino DJ, Cumbie TC, et al. Critical evaluation of chest computed tomography scans for blunt descending thoracic aortic injury. *Ann Thorac Surg* 2006; 81(4):1339-1346.
22. Scaglione M, Pinto A, Pinto F, Romano L, Ragozzino A, Grassi R. Role of contrast-enhanced helical CT in the evaluation of acute thoracic aortic injuries after blunt chest trauma. *Eur Radiol* 2001; 11(12):2444-2448.
23. Ellis JD, Mayo JR. Computed tomography evaluation of traumatic rupture of the thoracic aorta: an outcome study. *Can Assoc Radiol J* 2007; 58(1):22-26.
24. Aghayev E, Christe A, Sonnenschein M, et al. Postmortem imaging of blunt chest trauma using CT and MRI: comparison with autopsy. *J Thorac Imaging* 2008; 23(1):20-27.
25. Alkadhi H, Wildermuth S, Desbiolles L, et al. Vascular emergencies of the thorax after blunt and iatrogenic trauma: multi-detector row CT and three-dimensional imaging. *Radiographics* 2004; 24(5):1239-1255.
26. Schertler T, Glucker T, Wildermuth S, Jungius KP, Marincek B, Boehm T. Comparison of retrospectively ECG-gated and nongated MDCT of the chest in an emergency setting regarding workflow, image quality, and diagnostic certainty. *Emerg Radiol* 2005; 12(1-2):19-29.
27. Sammer M, Wang E, Blackmore CC, Burdick TR, Hollingworth W. Indeterminate CT angiography in blunt thoracic trauma: is CT angiography enough? *AJR* 2007; 189(3):603-608.
28. Ng CJ, Chen JC, Wang LJ, et al. Diagnostic value of the helical CT scan for traumatic aortic injury: correlation with mortality and early rupture. *J Emerg Med* 2006; 30(3):277-282.
29. Methodius-Ngwodo WC, Burkett AB, Kochupura PV, Wellons ED, Fuhrman G, Rosenthal D. The role of CT angiography in the diagnosis of blunt traumatic thoracic aortic disruption and unsuspected carotid artery injury. *Am Surg* 2008; 74(7):580-585; discussion 585-586.
30. Seelos KC, Funari M, Chang JM, Higgins CB. Magnetic resonance imaging in acute and subacute mediastinal bleeding. *Am Heart J* 1992; 123(5):1269-1272.
31. Link KM, Lesko NM. The role of MR imaging in the evaluation of acquired diseases of the thoracic aorta. *AJR* 1992; 158(5):1115-1125.
32. Arpasi PJ, Bis KG, Shetty AN, White RD, Simonetti OP. MR angiography of the thoracic aorta with an electrocardiographically triggered breath-hold contrast-enhanced sequence. *Radiographics* 2000; 20(1):107-120.
33. Ahrar K, Smith DC, Bansal RC, Razzouk A, Catalano RD. Angiography in blunt thoracic aortic injury. *J Trauma* 1997; 42(4):665-669.
34. Benjamin ER, Tillou A, Hiatt JR, Cryer HG. Blunt thoracic aortic injury. *Am Surg* 2008; 74(10):1033-1037.
35. Brooks SW, Young JC, Cmolik B, et al. The use of transesophageal echocardiography in the evaluation of chest trauma. *J Trauma* 1992; 32(6):761-765; discussion 765-768.
36. Kearney PA, Smith DW, Johnson SB, Barker DE, Smith MD, Sapin PM. Use of transesophageal echocardiography in the evaluation of traumatic aortic injury. *J Trauma* 1993; 34(5):696-701; discussion 701-693.
37. Patel NH, Hahn D, Comess KA. Blunt chest trauma victims: role of intravascular ultrasound and transesophageal echocardiography in cases of abnormal thoracic aortogram. *J Trauma* 2003; 55(2):330-337.
38. Shapiro MJ, Yanofsky SD, Trapp J, et al. Cardiovascular evaluation in blunt thoracic trauma using transesophageal echocardiography (TEE). *J Trauma* 1991; 31(6):835-839; discussion 839-840.
39. Sparks MB, Burchard KW, Marrin CA, Bean CH, Nugent WC, Jr., Plehn JF. Transesophageal echocardiography. Preliminary results in patients with traumatic aortic rupture. *Arch Surg* 1991; 126(6):711-713; discussion 713-714.
40. Williams DM, Dake MD, Bolling SF, Deeb GM. The role of intravascular ultrasound in acute traumatic aortic rupture. *Semin Ultrasound CT MR* 1993; 14(2):85-90.
41. American College of Radiology. *Manual on Contrast Media*. Available at: http://www.acr.org/SecondaryMainMenuCategories/quality_safety/contrast_manual.aspx.

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.