REVIEW ARTICLE

# Usefulness of Multi-Detector Row Computed Tomography Angiography in Aortic Diseases

MIGUEL CERDÁ[†,1], DIEGO HABERMAN, GUILLERMO GANUM, MARTÍN MELA, ENRIQUE GURFINKEL[†]

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*Address for reprints:*
Dr. Miguel Cerdá
Department of Cardiovascular Imaging at the University Hospital of Fundación Favaloro.
Av. Belgrano 1746
E-mail: mcerda@ffavaloro.org

## SUMMARY

### Background

The goal of the present review is to demonstrate the usefulness of multi-detector row computed tomography (MDCT) angiography in the evaluation of diseases of the aorta. The high morbidity and mortality associated with this condition requires a rapid diagnostic tool with diagnostic accuracy at the moment of evaluating patients with known or clinically suspected disease of the aorta. The non-invasive nature of and the rapid evaluation provided by MDCT angiography are the main advantages of the method that is widely accepted by the patients. MDCT angiography is the reference-standard method for the evaluation of aneurysms of the aorta, describing its location in the spatial planes, extension, diameters and characteristics of the aortic wall. The clinical presentation of the acute aortic syndromes - aortic dissection, intramural hematoma and penetrating aortic ulcer - is similar. MDCT angiography is a diagnostic tool with the greatest efficacy to confirm or rule out aortic lesions. The multiple visualization techniques and the possibility of multiplanar and three-dimensional reconstructions make it easy to choose between surgical or endovascular treatment.

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**Key words >** Diagnostic Imaging, aorta, Tomography, aneurysm, dissection

## BACKGROUND

The multi-detector row computed tomography angiography (MDCTA) is a highly effective method in the evaluation of the arterial anatomy. The acquisition of isovolumetric images allows us to study with great accuracy the whole of the arterial tree in axial, coronal and sagital planes. Three-dimensional (3D) reconstructions provide information that is relevant to potential surgical or endovascular treatment.

Moreover, this technique can detect the associated diseases that go beyond the vascular system.

In this article, we will review the 64-slice MDCT applications for the most common aortic disease in our facility.

## MATERIAL AND METHODS

The studies were performed with a 64-slice, multi-detector CT scanner (Toshiba, Aquilion).

Images were 0.5 mm thick with a reconstruction interval of 0.3 mm (0.828 pitch factor; tube rotation in 0.5 s).

We administered 70-100 mL of nonionic intravenous contrast agent (Iopamiron 370, Schering) using an injection pump (Medrad, Stellant) at a flow of 3.5-5 mL/s.

In certain situations, we acquire the images with ECG-cardiac gating in order to reduce the movements caused by the cardiac cycle. This is particularly important in suspected type A dissection, in which the aortic movement causes artifacts that can simulate intimal tear.

In all the cases of acute aortic syndrome, we have included a phase without intravenous contrast agent, especially designed to detect mural hematoma, which appears more evident without intraarterial contrast.

In all the cases, multiplanar and three-dimensional reconstructions were performed using workstation (Vital, Vitrea 2).

### Clinical applications

#### *Dilatations*

Aneurysms

Aneurysms are defined as 'permanent focal (saccular) or diffuse (fusiform) dilatation' in any aortic segment by 50% or more of the normal vessel diameter. True aneurysms involve the three layers of the aortic wall (intima, media and adventitia) (Figures 1 and 2).1,2

In the ascending aorta, we observe the aortic annulus, the limb of the sinus, the sinotubular junction, and the limb of the tube, because different conditions may selectively affect some of these regions (Figure 3). For the sinus portion of the ascending aorta, the maximum normal limit is 40 mm in diameter.3,4

This parameter may vary according to age, sex and size of the patient.

Annuloaortic ectasia is the uniform aneurysmal dilatation of the Valsalva sinuses extending towards the ascending aorta, with associated rectification of the sinotubular joint (Figure 4).5 This is typical of the Marfan syndrome, in which cystic medial necrosis causes weakening of the aortic wall, resulting in dilatation at an early age.

Involvement of the infrarenal portion of the abdominal

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aorta is observed in more than 90% of patients. Depending on their anatomical location, thoracoabdominal aneurysms are classified into four types:
I: It involves the descending aorta distal to the left subclavian artery, up to the third of the upper abdominal aorta.
II: It involves both the thoracic descending aorta and most of the abdominal aorta.
III: It involves the lower portion of both the thoracic descending aorta and abdominal aorta.
IV: The aneurysm begins at the diaphragm and extends caudally.6

At present, MDCTA is considered the reference standard for the evaluation of aneurysms, because it can accurately determine their extension, maximum diameters, wall features, presence of thrombus, wall calcifications, and aspect of effective lumen.7

It is extremely important to determine the relationship between the aneurysm and the emerging arteries, particularly when there is the possibility of endovascular repair. In thorax, we make reference to the left subclavian artery; in abdomen, to the distance between the flow and the emergence of the renal artery, and the origin of the aneurysm.

We also documented the diameter of the dilatation of the proximal neck, and the diameter of suprarenal aorta (Figure 5).

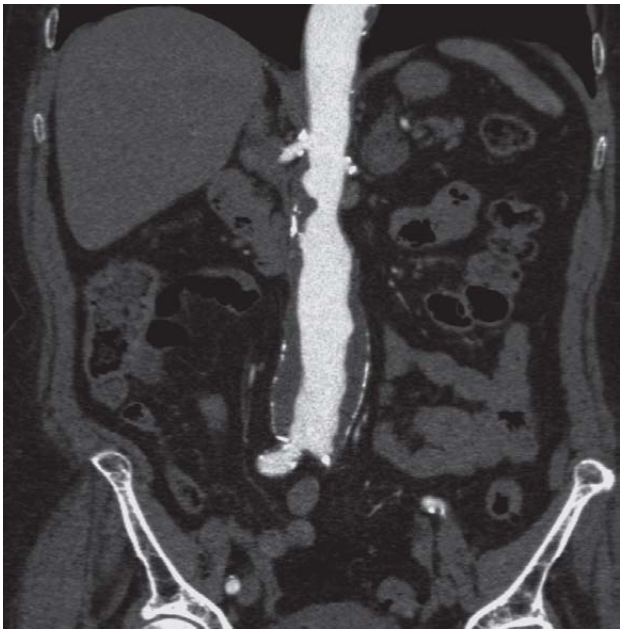


Fig. 1

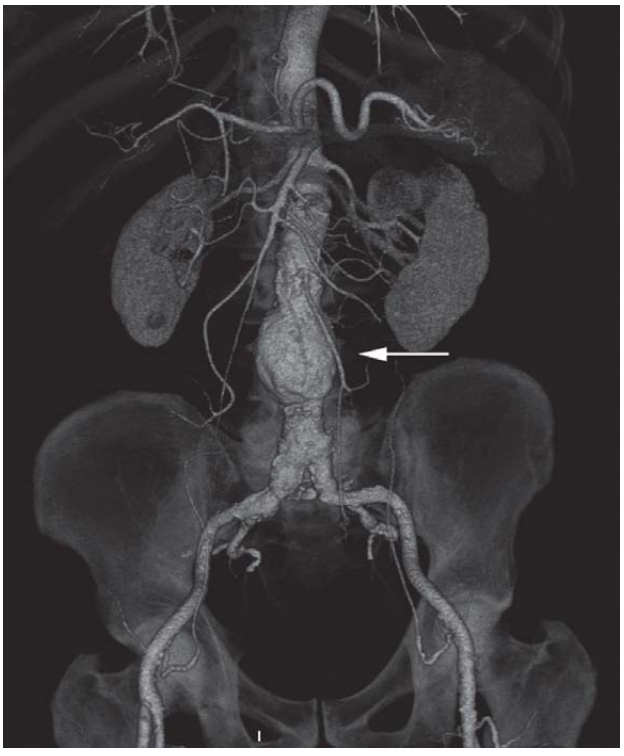


Fig. 2

## Acute aortic syndromes

### *Dissection*

Dissection is characterized by a tear in the intima layer, which lets the blood flow enter the middle layer, causing double lumen of the vessels.

The main predisposing factor is hypertension; other associated conditions include connective tissue disorders, congenital valve defects, aneurysms, coarctation.8-10

It is considered acute when the development of the process takes less than two weeks.11

Regarding the anatomical extent, the Stanford classification is the most widely used nowadays:

Type A: It involves the ascending aorta irrespective of the site of the primary intimal tear; it represents about 60% of the cases and requires surgical repair because of its potential fatal complications (Figure 6).

Type B: Its origin is located distal to the emergence of the left subclavian artery (Figure 7).12

In most cases, dissections present anterograde extension from the site where the intimal flap typically occurs, then progressing distally. However, there may be dissections with retrograde propagation, and flow progressing from distal to proximal; in certain circumstances, a chronic type B dissection may even become a type A.12

The key and typical image of dissection is the presence of a tear or intimal flap dividing the vascular lumen into two (Figure 8).13

There are different CT features that distinguish false lumen from true lumen, and this is a key factor to be considered in all the studies.

In most cases, it is possible to identify the true lumen by its continuity with the non-dissected section of the aorta; however, this is not always simple, and other elements have to be considered.14

The cobweb sign is an exclusive indicator of false lumen, but it is not commonly found. It is determined by the presence of small, linear, low-attenuation images, which correspond to incomplete media detachments originated at the beginning of dissection (Figure 9).14

The beak sign is defined as an acute angle that represents the gap formed by the blood flow through the false lumen, providing space for propagation.
In both acute and chronic cases, true lumen is often smaller and with greater contrast-enhancement due to higher flow rate. In general, intimal tears are predominantly convex toward the false lumen (Figure 10). Eccentric calcifications are commonly located toward the true lumen.14-16

It is important to evaluate the origin of the different

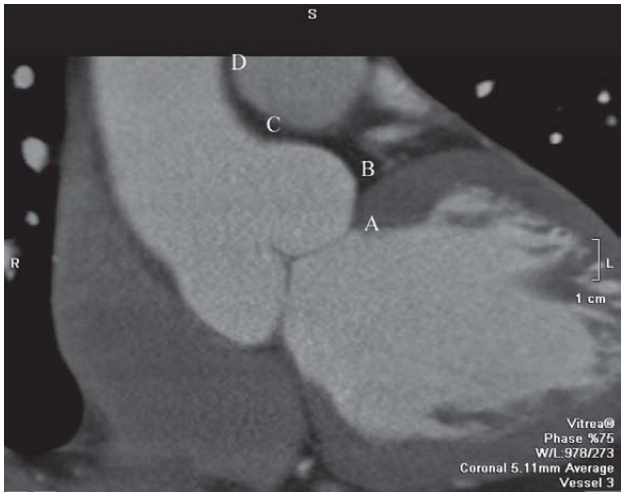
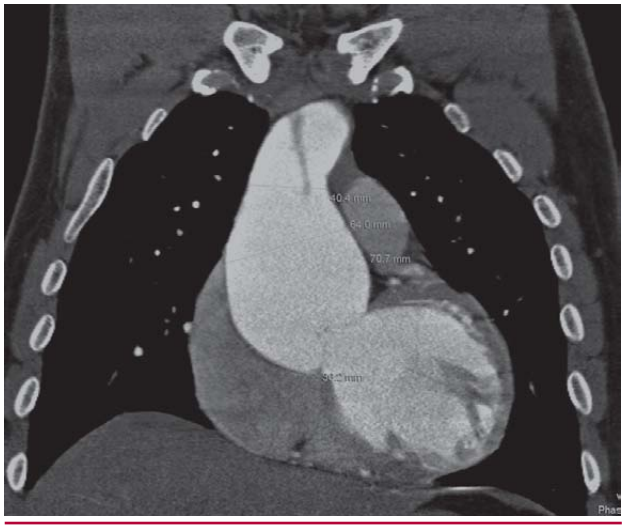



Fig. 3

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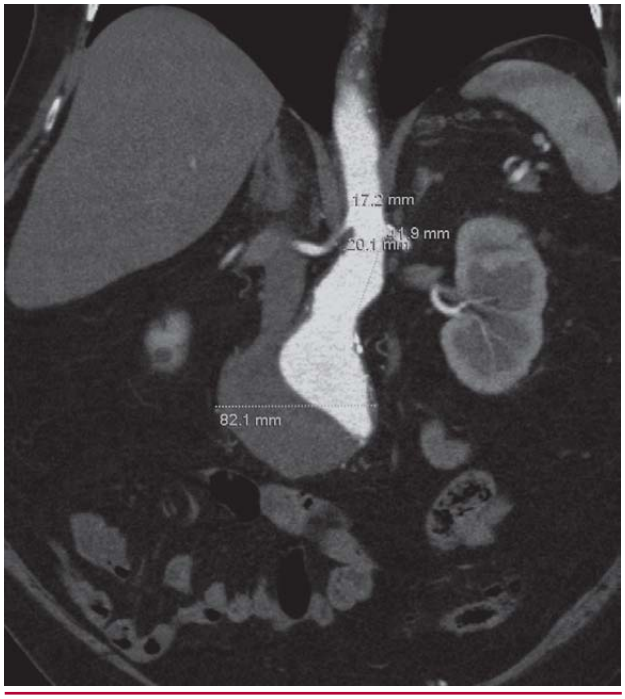


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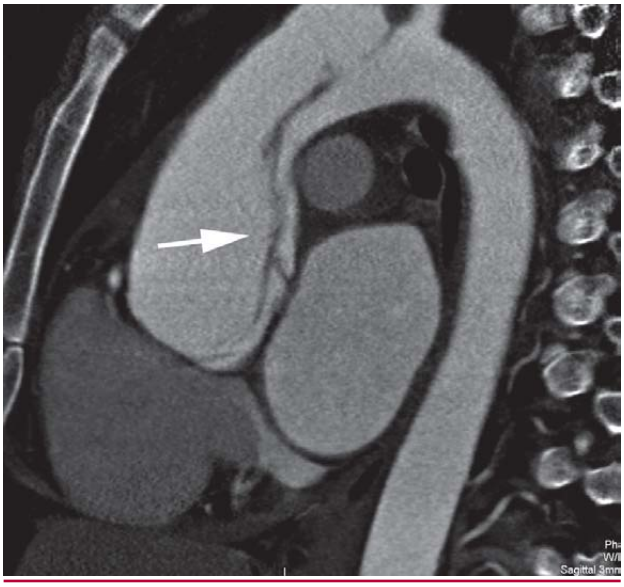


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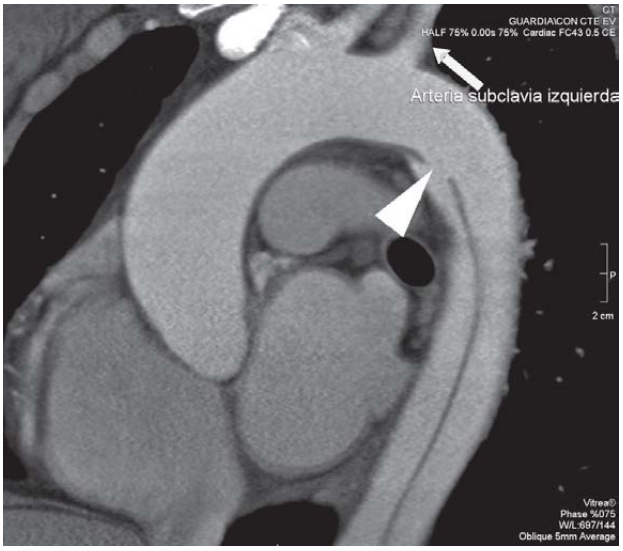


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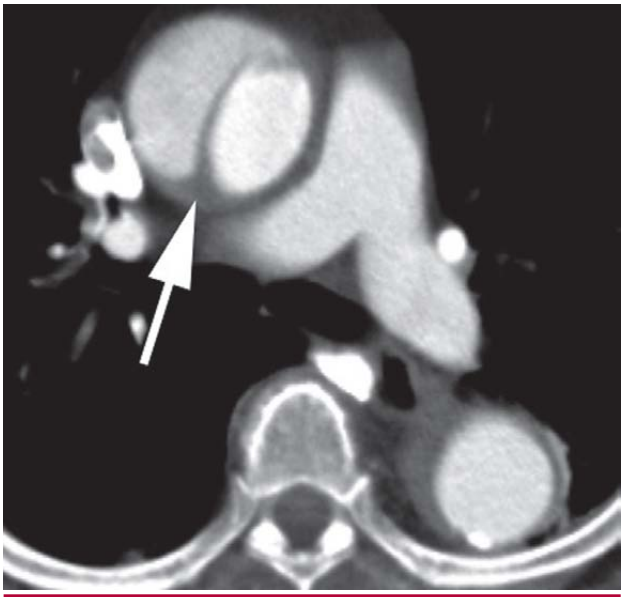

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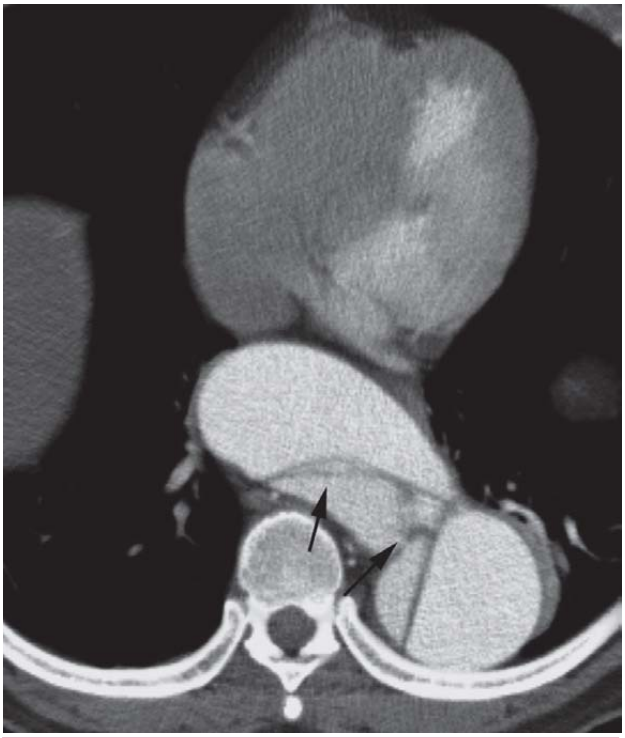


Fig. 9

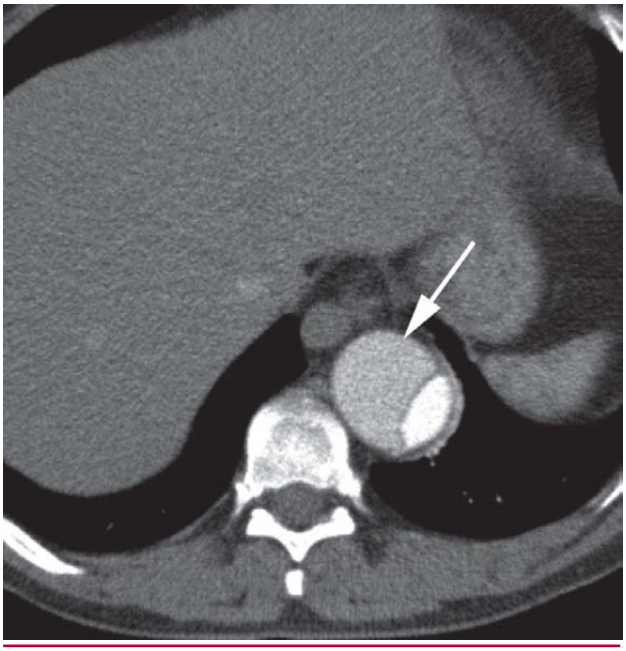
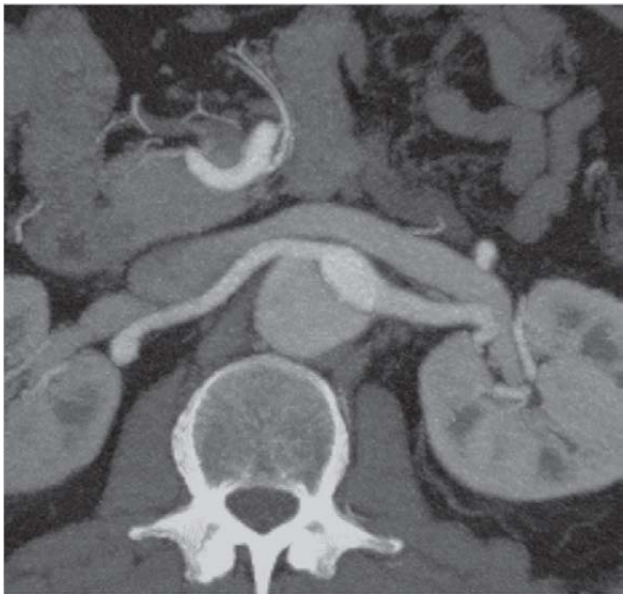


Fig. 10



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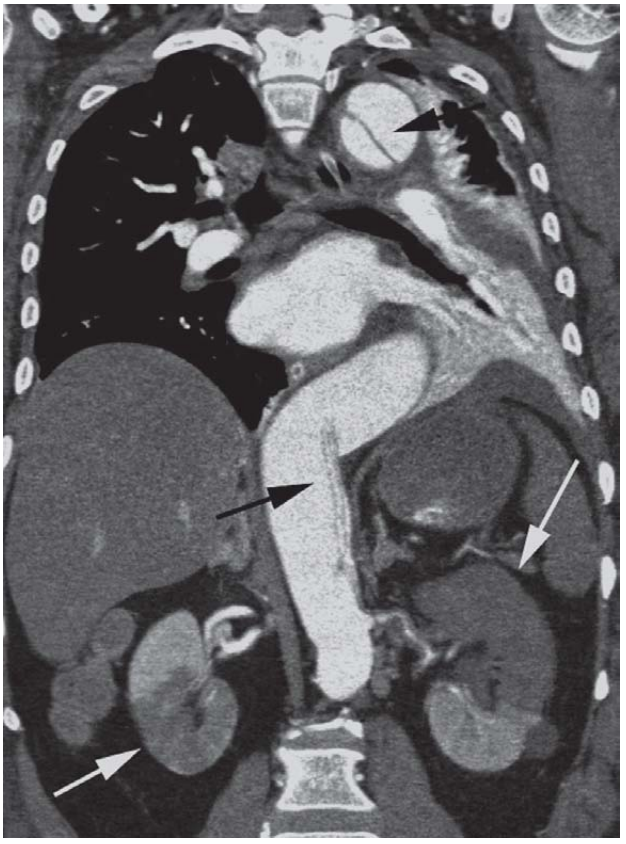

Fig. 12

branches arising from the aorta, regarding their false-lumen or true-lumen dependence, and their possibility of developing ischemia in their territories (Figure 11).17,18

Different complications are identified, including hemopericardium, hemothorax and organ ischemia due to involvement of the visceral branches (Figure 12).

*Intramural hematoma*

Basically, it is an acute hemorrhage in the middle layer of the aortic wall, and its pathogenesis is still unclear.

The major pathophysiological mechanism is the spontaneous rupture of the vasa vasorum that feeds the middle layer. Another proposed theory is that of the thrombus in the false lumen of a classical dissection which does not show intima involvement.19

Hypertension is the main predisposing factor observed in 53% of the patients with intramural hematoma.20

In MDCT, the typical finding is observed in the non-contrast phase, in which crescent-shaped hyperdensity of

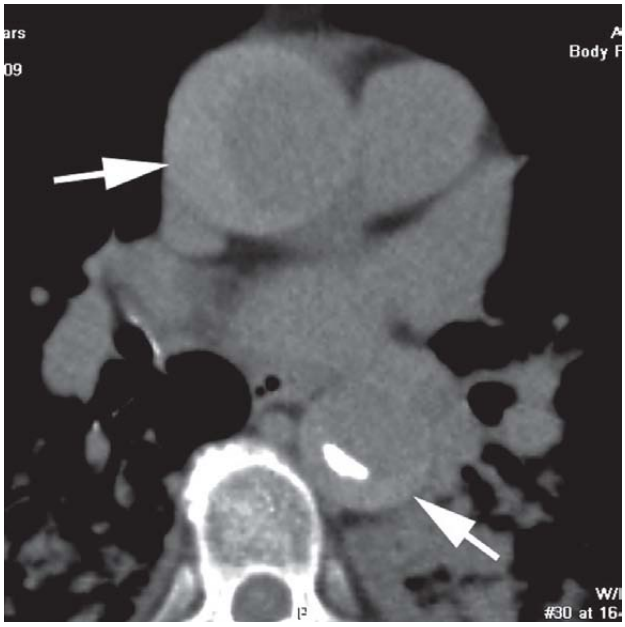

Fig. 13

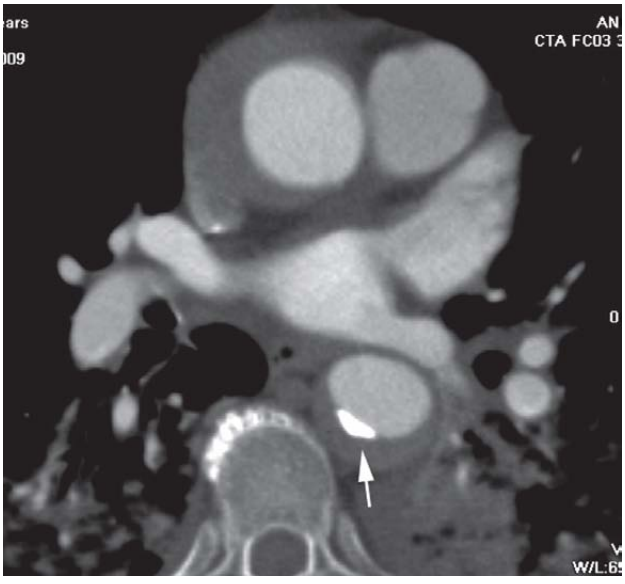

Fig. 14

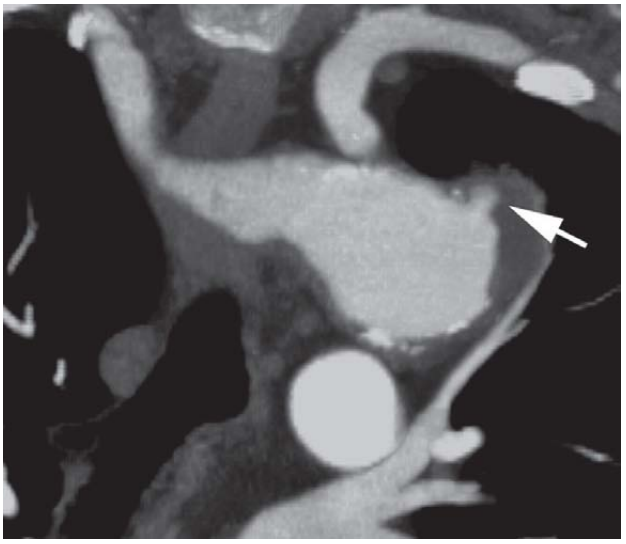

Fig. 15

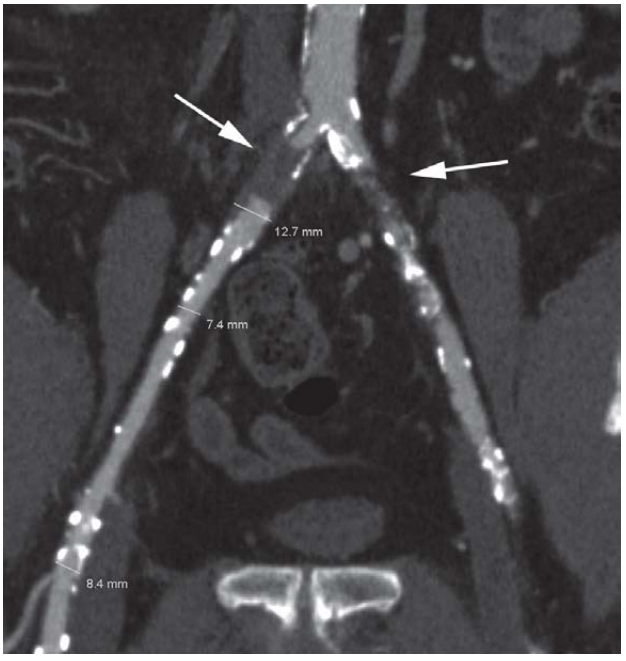


Fig. 16

the aortic wall is visualized. A common finding is the medial displacement of intimal calcifications.21

When the angiographic phase is acquired, no intimal tear is demonstrated (Figures 13 and 14).

### *Symptomatic penetrating ulcer*

It is defined as an atherosclerotic lesion characterized by the erosion of the inner layer, with extended flow toward the media in a delimited sector –typically the descending portion of the aorta. It is important because it predisposes to intramural hematomas, dissection, and even rupture.22-24

The CT angiography shows a contrast collection outside the aortic lumen in an area that typically presents atheromatous wall thicknening. Ocassionally, there may be reinforcement of that area of the aortic wall. Lesions may be unique or multiple (Figure 15).[25,26]

## Stenosing conditions

### *Occlusive atherosclerotic disease*

It is common in the infrarenal abdominal aorta. In certain circumstances, depending on the severity of atherosclerotic changes, it may cause vascular stenosis of different magnitude.27 Severe stenosis of the iliac artery bifurcation is also known as "Leriche syndrome".28

MDCT reveals the site and degree of stenosis, its extension, involvement of visceral artery branches, and presence of collateral vessels, which would provide blood flow to tissues distal to that stenosis (Figures 16 and 17).[29]

### *Coarctation*

Coarctation is a congenital anomaly characterized by a focal narrowing of the arterial lumen located in the

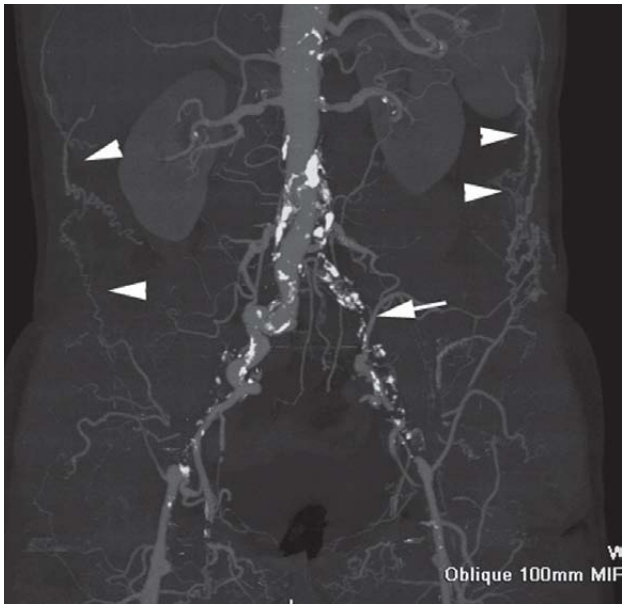


Fig. 17

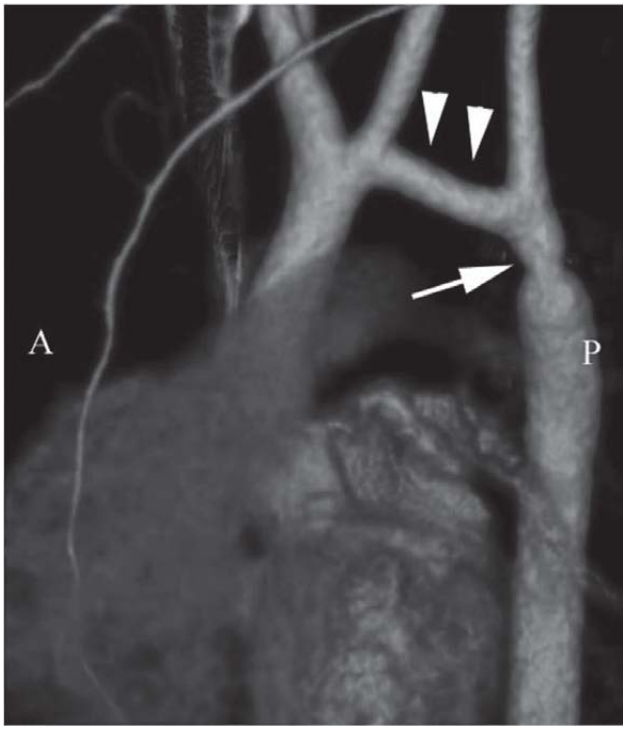


Fig. 18

proximal descending aorta, after the emergence of the left subclavian artery (Figure 18).27 It is often associated with other cardiovascular anomalies, including hypoplasy of the transverse portion of the aortic arch, dilatation of supraaortic vessels, interatrial septum defects, persistent ductus, bicuspid aortic valve, aneurysm of the ascending aorta, and aberrant right subclavian artery (Figure 19).

Depending on the severity of the blood flow blockage, collateral circulation to irrigate areas distal to coarctation through intercostal branches may be developed.30

MDCTA allows us to clearly assess the site and extension

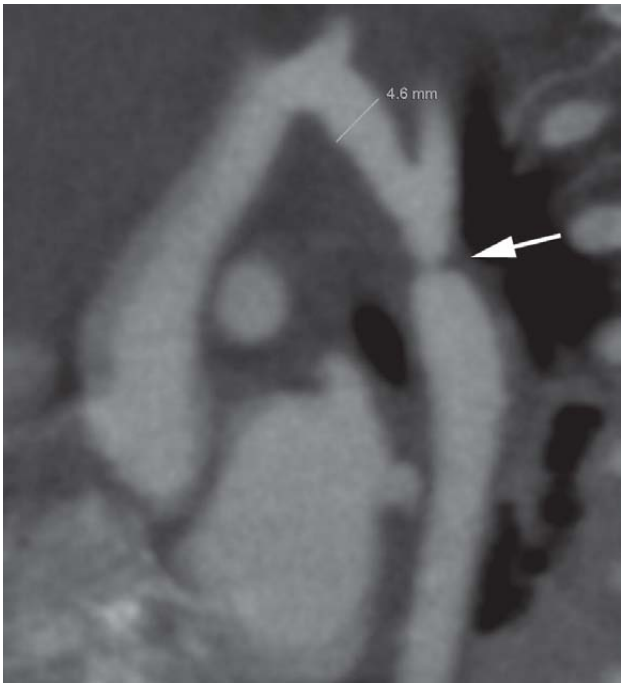


Fig. 19

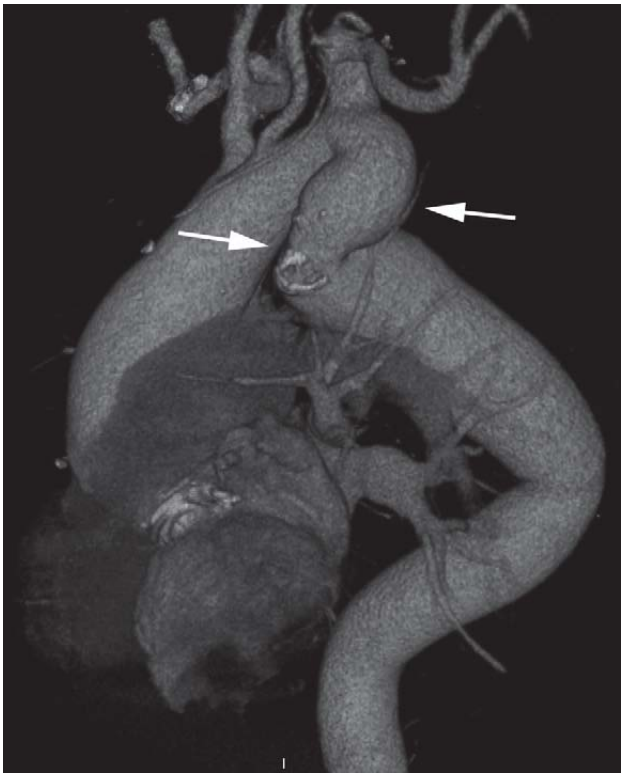

Fig. 20

of the obstruction, and the presence of collaterals, providing useful data for possible therapeutic procedures.31

*Pseudocoarctation*

It is a very uncommon anomaly consisting of a tortuous elongation and kinking of the aortic arch and proximal descending aorta, at the site of the ligamentum arteriosus.32

It does not usually present significant pressure gradient or collateral circulation development.

The theory proposed for its origin consists of a traction caused by the ligamentum arteriosus after the ductus closure, which can develop severe aortic kinking over time.

It is considered differential diagnosis of true coarctation, aortic aneurysm and vascular annulus (Figures 20 and 21).[33]

*Takayasu arteritis*

It is a primary inflammatory disease that affects the great vessels and is characterized by a diffuse thickening of ththe aorta, resulting in segmental stenosis. It is possible to detect increased thickness in early stages of the disease without significant stenosis (Figures 22 and 23).

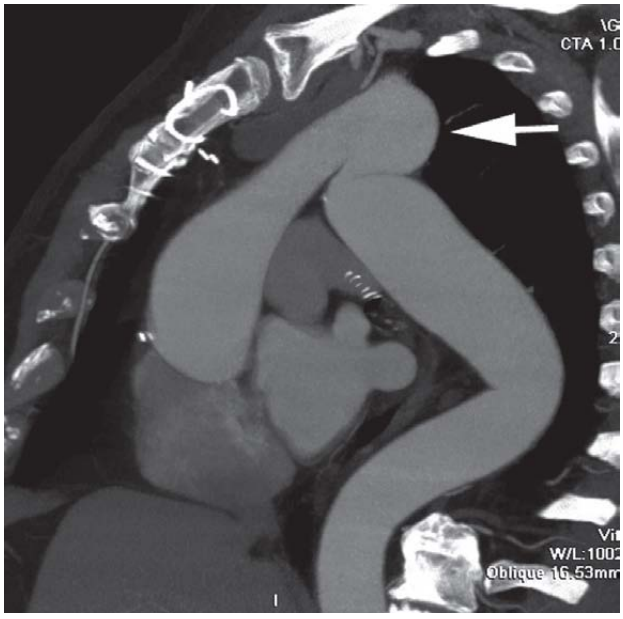


**Fig. 21**

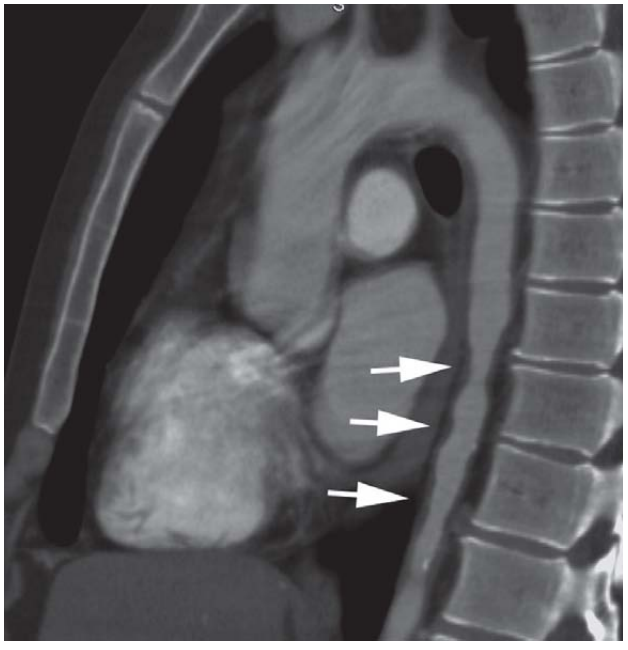

**Fig. 22**

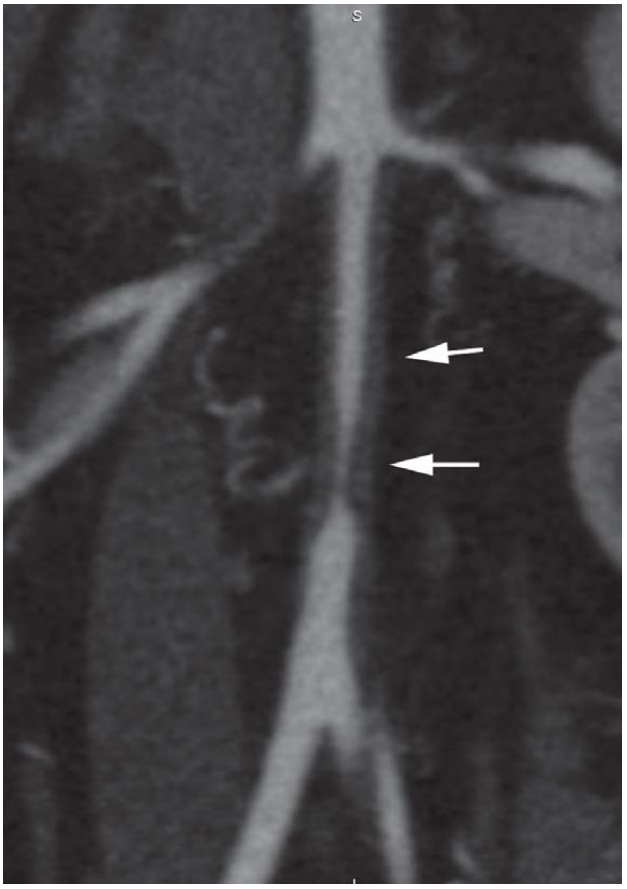

**Fig. 23**

## CONCLUSION

This article reviews the pathological entities that are part of the broad spectrum of diseases of the aorta. Today, 64-slice MDCTA is a reference method which stands out for its high spatial resolution and ability to produce isovolumetric images that can obtain multiplanar and three-dimensional reconstructions at high reproducibility.

## RESUMEN

### Usefulness of Multi-Detector Row Computed Tomography Angiography in Aortic Diseases

#### Introducción

El propósito de esta revisión es demostrar mediante imágenes la utilidad de la angiotomografía computarizada multidetector (angio-TCMD) en el estudio de la patología aórtica. La elevada morbimortalidad de éstas exige precisión diagnóstica y rapidez al momento de evaluar al paciente con patología conocida o sospecha clínica. Una de las principales ventajas de la angio-TCMD es su carácter de no invasiva y la velocidad con la que se realiza, lo que la convierte en un método ampliamente aceptado por los pacientes. La angio-TCMD es el estándar de referencia para la evaluación de los aneurismas aórticos caracterizando su ubicación en los planos del espacio, extensión y diámetros además de las particulares de la pared. Los síndromes aórticos agudos: el aneurisma disecante, el hematoma intramural y la úlcera arteriosclerótica penetrante son de presentación clínica similar. La angio_TCMD constituye la herramienta de mayor

eficacia para confirmar o descartar lesiones. Las múltiples técnicas de visualización y la posibilidad de reconstrucciones multiplanares y tridimensionales facilitan la elección del tratamiento quirúrgico o endovascular.

**Palabras clave >** Diagnóstico por imágenes - Aorta - Tomografía - Aneurisma - Disección

## BIBLIOGRAPHY

**1.** Lee J, Sagel S, Stanley R, Heiken J. Body CT. Third edition 1999: 301-10.
**2.** Frist WH, Miller DC. Aneurysm of ascending thoracic aorta and transverse aortic arch. Cardiovasc Clinic 1987; 17:263-87.
**3.** Griepp RB, Ergin MA, Lansman SL, Galla JD, Pogo G. The natural history of thoracic aortic aneurysm. Semin Thorac Cardiovasc Surg 1991; 3:258-65.
**4.** Frauenfelder T, Wildermuth S, Marincek B, Boehm T. Nontraumatic emergent abdominal vascular conditions: advantages of multi-detector row CT and three-dimensional imaging. Radiographics 2004; 24:481-96.
**5.** Ha HI, Seo JB, Lee SH, Kang JW, Goo HW, Lim TH, Shin MJ. Imaging of Marfan syndrome: multisystemic manifestations. Radiographics. 2007; 27: 989-1004.
**6.** Crawford ES, DeNatale RW. Thoracoabdominal aortic aneurysm: observations regarding the natural course of the disease. J Vasc Surg 1986; 3: 578-82.
**7.** Agarwal PP, Chughtai A, Matzinger FR, Kazerooni EA. Multidetector CT of thoracic aortic aneurysms. Radiographics 2009; 29:537-52.
**8.** Khan IA, Nair CK. Clinical, diagnostic, and management perspectives of aortic dissection. Chest 2002; 122:311-28.
**9.** Hagan PG, Nienaber CA, Isselbacher EM, Bruckman D, Karavite DJ, Russman PL, et al. The International Registry of Acute Aortic Dissection (IRAD): new insights into an old disease. JAMA 2000; 283:897-903.
**10.** Eisenberg MJ, Rice SA, Paraschos A, Caputo GR, Schiller NB. The clinical spectrum of patients with aneurysms of the ascending aorta. Am Heart J 1993;125:1380-5.
**11.** Prêtre R, Von Segesser LK. Aortic dissection. Lancet 1997; 349: 1461-4.
**12.** Daily PO, Trueblood HW, Stinson EB, Wuerflein RD, Shumway NE. Management of acute aortic dissections. Ann Thorac Surg 1970;10:237-47.
**13.** Fisher ER, Stern EJ, Godwin JD 2nd, Otto CM, Johnson JA. Acute aortic dissection: typical and atypical imaging features. Radiographics 1994; 14: 1263-71.
**14.** LePage MA, Quint LE, Sonnad SS, Deeb GM, Williams DM. Aortic dissection: CT features that distinguish true lumen from false lumen. AJR Am J Roentgenol 2001; 177:207-11.
**15.** Williams DM, Joshi A, Dake MD, Deeb GM, Miller DC, Abrams GD. Aortic cobwebs: an anatomic marker identifying the false lumen in aortic dissection--imaging and pathologic correlation. Radiology. 1994;190:167-74.
**16.** Lee DY, Williams DM, Abrams GD. The dissected aorta: part II. Differentiation of the true from the false lumen with intravascular US. Radiology 1997; 203:32-6.
**17.** Williams DM, Lee DY, Hamilton BH, Marx MV, Narasimham DL, Kazanjian SN, Prince MR, Andrews JC, Cho KJ, Deeb GM. The dissected aorta: percutaneous treatment of ischemic complications--principles and results. J Vasc Interv Radiol 1997; 8:605-25.
**18.** Williams DM, Lee DY, Hamilton BH, Marx MV, Narasimham DL, Kazanjian SN, Prince MR, Andrews JC, Cho KJ, Deeb GM. The dissected aorta: part III. Anatomy and radiologic diagnosis of branch-vessel compromise. Radiology 1997; 203:37-44.
**19.** Chao CP, Walker TG, Kalva SP. Natural history and CT appearances of aortic intramural hematoma. Radiographics 2009;29:791-804.
**20.** Yoshida S, Akiba H, Tamakawa M, Yama N, Hareyama M, Morishita K, Abe T. Thoracic involvement of type A aortic dissection and intramural hematoma: diagnostic accuracy--comparison of emergency helical CT and surgical findings. Radiology 2003; 228:430-5.
**21.** Sueyoshi E, Matsuoka Y, Imada T, Okimoto T, Sakamoto I, Hayashi K. New development of an ulcerlike projection in aortic intramural hematoma: CT evaluation. Radiology. 2002; 224:536-41.
**22.** Sebastià C, Pallisa E, Quiroga S, Álvarez-Castells A, Domínguez R, Evangelista A. Aortic dissection: diagnosis and follow-up with helical CT. Radiographics 1999; 19:45-60.
**23.** Castañer E, Andreu M, Gallardo X, Mata JM, Cabezuelo MA, Pallardó Y. CT in nontraumatic acute thoracic aortic disease: typical and atypical features and complications. Radiographics. 2003; 23:S93-110.
**24.** Welch TJ, Stanson AW, Sheedy PF 2nd, Johnson CM, McKusick MA. Radiologic evaluation of penetrating aortic atherosclerotic ulcer. Radiographics 1990; 10:675-85.
**25.** Stanson AW, Kazmier FJ, Hollier LH, Edwards WD, Pairolero PC, Sheedy PF, Joyce JW, Johnson MC. Penetrating atherosclerotic ulcers of the thoracic aorta: natural history and clinicopathologic correlations. Ann Vasc Surg 1986; 1:15-23.
**26.** Kazerooni EA, Bree RL, Williams DM. Penetrating atherosclerotic ulcers of the descending thoracic aorta: evaluation with CT and distinction from aortic dissection. Radiology. 1992; 183:759-65.
**27.** Sebastià C, Quiroga S, Boyé R, Pérez-Lafuente M, Castellà E, Álvarez-Castells A. Aortic stenosis: spectrum of diseases depicted at multisection CT. Radiographics. 2003; 23:S79-91.
**28.** Ruehm SG, Weishaupt D, Debatin JF. Contrast-enhanced MR angiography in patients with aortic occlusion (Leriche syndrome). J Magn Reson Imaging 2000; 11:401-10.
**29.** Panayiotopoulos YP, Tyrrell MR, Koffman G, Reidy JF, Haycock GB, Taylor PR. Mid-aortic syndrome presenting in childhood. Br J Surg 1996;83: 235-40.
**30.** Philips RR, Gordon JA. Coarctation of the aorta. In: Bawm S, eds. Abrams Angiography. 4th ed. Boston, Mass: Little, Brown, 1997; 434-63.
**31.** Becker C, Soppa C, Fink U, Haubner M, Müller-Lisse U, Englmeier KH, Bühlmeyer K, Reiser M. Spiral CT angiography and 3D reconstruction in patients with aortic coarctation. Eur Radiol 1997; 7:1473-7.
**32.** Bluemke DA. Pseudocoarctation of the aorta. Cardiol J 2007; 14:205-6.
**33.** Matsunaga N, Hayashi K, Sakamoto I, Ogawa Y, Matsumoto T. Takayasu arteritis: protean radiologic manifestations and diagnosis. Radiographics 1997; 17:579-94.
**34.** Fukushima T. Radiological study in Takayasu's arteritis with special reference to angiographic manifestations. Nagasaki Igakkai Zasshi 1984; 59:141-53.
**35.** Yamada I, Nakagawa T, Himeno Y, Numano F, Shibuya H. Takayasu arteritis: evaluation of the thoracic aorta with CT angiography. Radiology 1998; 209:103-9.