

UP DATE

Clinical Decision-Making Based on Cardiac Diagnostic Imaging Techniques (IV)

Imaging Diagnosis in Acute Aortic Syndromes

José Luis Zamorano, Leopoldo Pérez de Isla, Rosa González, Carlos Almería and José Luis Rodrigo

Laboratorio de Ecocardiografía, Instituto Cardiovascular, Hospital Clínico San Carlos, Madrid, Spain

Acute aortic dissection is a clinical emergency. Its prognosis is related mainly with prompt and accurate diagnosis, as well as rapid treatment. In this paper we review the importance of different imaging techniques in the diagnosis of patients with acute aortic syndrome. Aortic dissection, intramural haematoma, and penetrating aortic ulcer are discussed.

Key words: *Aorta. Imaging. Diagnostic.*

Full English text available at: www.revespcardiol.org

INTRODUCTION

The aorta is a unique organ, both in its structure and functional behavior. In a person's lifetime, the heart may beat up to 3000 million times and pump some 200 million liters of blood. In systole, the aorta is distended owing to the pressure exerted by the ejected blood. The strength of the left ventricle is thus transformed into potential energy, which is stored in the dilated wall of the aorta. During diastole, this stored energy is converted into kinetic energy or the force required for moving the blood. In order for it to act as an energy reservoir, the aorta is more elastic than the peripheral arteries of the musculature. The aorta is the biggest artery, beginning at the aortic valve annulus and ending where it divides into the iliac arteries at the level of the fourth lumbar vertebra. Four segments of the aorta can be differentiated: the ascending thoracic

Diagnóstico por imagen en el síndrome aórtico agudo

La enfermedad aórtica aguda es una situación clínica crítica cuyo pronóstico suele depender de un diagnóstico certero y rápido, así como de la instauración temprana de su tratamiento. En el siguiente capítulo se realiza una revisión de la importancia de las diferentes técnicas de imagen en el diagnóstico de la enfermedad aórtica aguda. Se describen las entidades de disección aórtica, hematoma intramural y úlcera aórtica.

Palabras clave: *Aorta. Imagen. Diagnóstico.*

aorta, the aortic arch, the descending thoracic aorta, and the abdominal aorta. Table 1 shows the normal dimensions of the aorta.

Acute aortic disease is a clinical emergency. Prognosis normally depends upon rapid and accurate diagnosis and early treatment. Over the last 20 years, new imaging methods have been developed: computerized tomography (CT), magnetic resonance (MR) and intravascular and intracardiovascular ultrasound have all improved our ability to examine the aorta, providing greater detail than chest X-ray or angiography. At present, not only can the lumen and the shape of the aorta be visualized but also the wall of the aorta, allowing diseases of the latter to be detected. Hematomas, intramural hemorrhages and noncommunicating aortic dissections, which until now have only been described in histological studies, can all be diagnosed in this way.

Section sponsored by Laboratorio Dr. Esteve

Correspondence: Dr. J. Zamorano
Laboratorio de Ecocardiografía, Hospital Clínico San Carlos,
Plaza de Cristo Rey, s/n, 28040 Madrid, Spain
E-mail: jlzamorano@navegalia.com

TABLE 1. Aortic diameters: normal values

	Male	Female
Aortic annulus	2.6±0.3	2.3±0.2
Sinus of Valsalva	3.4±0.3	3.0±0.3
Aorta wall	<4 mm	
Ascending aorta	1.4–2.1 cm/m ²	
Descending aorta	1.0–1.6 cm/m ²	

ABBREVIATIONS

TEE: transesophageal echocardiography
 TTE: transthoracic echocardiography
 IH: intramural hemorrhage
 MR: magnetic resonance
 CT: computerized tomography
 PU: penetrating ulcer

This review describes the information that can be obtained with current imaging diagnosis techniques and their role in the diagnosis of acute aortic disease (aortic dissection, hematoma and aortic ulcer).

AORTIC DISSECTION: ETIOLOGY AND CLASSIFICATION

Aortic dissection is an uncommon problem, but when it occurs it is dramatic and can be fatal. Immediate mortality is 1% within one hour, and the two-week survival rate is only 25% in patients who receive no treatment.¹ The problem is characterized by the formation of a false lumen in the tunica media of the aorta wall. Depending on the presence of primary tears and their location, and the anterograde and retrograde propagation of the dissection, different types of aortic dissection can be differentiated, each with their own clinical, therapeutic and prognostic implications. Types A and B are distinguished depending upon whether the ascending aorta is involved.¹ DeBakey differentiates between dissection Types I, II and III, thus demonstrating that an isolated problem of the ascending aorta can occur.² Types IIIa –limited to the thoracic aorta– and IIIb –affecting the abdominal aorta– have also been described.³ However, thanks to new imaging techniques, the classification of aortic dissection has been modified (see below).⁴

Different physiopathological mechanisms have been postulated in aortic dissection. The problem can be caused by: *a*) tearing and breakage of the intima, and *b*) tearing of the medial layer and the formation of a hematoma.

A typical aortic dissection begins with the tearing of the aortic intima, which exposes the diseased underlying medial layer to the pulsating blood flow. The blood then penetrates this layer, dissecting it. This dissection can then extend distally (occasionally proximally) for a variable distance, creating a false lumen. Shearing forces can then cause the tearing of the internal part of the dissected aorta wall (the intimal flap), producing additional entry and exit zones.

The most common locations for primary intimal tears are: in the ascending aorta 1-5 cm above the right

sinus of Valsalva (65% of cases), in the proximal descending aorta under the left subclavian artery (20%), in the transverse aortic arch (10%), and in the distal thoracic-abdominal aorta (5%).⁵

Recently, two other etiological forms of aortic dissection have been described: intramural hematoma (IH) and penetrating atherosclerotic aortic ulcer (PU).⁶

IH is also known as aortic dissection without intimal tear. It is essentially a hemorrhage of the medial layer, extending to the adventitia, produced by a breakage of the vasa vasorum. It corresponds to 3%-13% of the dissections without intimal tear recorded in older pathological studies. The suggestion that IH can cause aortic dissection has been confirmed by follow-up studies. Intramural hematomas are circumscribed and are one of the first signs that a dissection is in progress (which may develop into a dissection or into communicating or noncommunicating scarring). This was first shown by Zotz and Erbel who recorded an IH that, after three days, gave rise to a complete communicating dissection with the formation of a false lumen at the site of the hematoma.⁶ This was later confirmed in other studies with more patients.

A penetrating ulcer, as its name suggests, is an ulceration of an aortic atherosclerotic lesion that penetrates the internal elastic layer, forming a hematoma in the medial layer of the descending thoracic aorta. This is either localized or extends for a few centimeters without forming a second lumen. Saccular or fusiform aortic aneurysms frequently occur. An aortic pseudoaneurysm may occur in 25% of cases of acute aortic disease. In 8% of patients, rupture of the aorta occurs.

DIAGNOSTIC IMAGING TECHNIQUES IN ACUTE AORTIC DISEASE

A diagnostic algorithm has been developed (which varies slightly from center to center) for patients with suspected acute aortic dissection. Basically, it consists of the judicious use of aortography, contrast CT, transesophageal echography (TEE) and MR. The relative precision, particular indications and limitations of each of these diagnostic imaging methods have been amply documented.⁷ Table 2 shows the sensitivities and specificities of each. It can reasonably be said that, although MR is more exact, in most cases TEE has a similar diagnostic performance while being versatile, cheap and available at most centers.

Ultrasound

This should be the first step in the diagnosis of patients with a suspected aortic dissection since it can obviate the need for more aggressive or complicated diagnostic procedures. The diagnosis of aortic dissection by TEE requires the demonstration of a true and a false lumen separated by an intimal flap (Figure 1).

TABLE 2. Sensitivity and specificity of the different diagnostic techniques for aortic dissection

	TEE	CT	Angiography	MR*
Sensitivity, %	99	83	88	100
Specificity, %	98	100	94	100
Positive predictive value, %	98	100	96	100
Negative predictive value, %	99	86	84	100

*Except for discrete forms.

TEE indicates transesophageal echography; CT, computerized tomography; MR, nuclear magnetic resonance.

Therapeutic implications demand the involvement of the ascending aorta be checked so that a Type A (proximal) or Type B (distal) classification can be assigned. In addition to its high precision in diagnosing and locating an aortic dissection, TEE provides detailed information on other aspects critical to surgical and/or immediate medical treatment including the site of the original tear, the characteristics of the blood flow and clot formation in the false lumen, and the co-existence and seriousness of aortic incompetence and its etiological mechanism. Ventricular function and the presence of pericardial effusion also provide useful information on the therapeutic strategy to follow. In addition, in many cases, it provides information on the relative position of the coronary arteries and the involvement of the blood vessels of the neck.

M-mode ultrasound allows the detection of intimal flaps in the ascending aorta and the description of specific diagnostic criteria.⁷ Enlargement of the aortic wall, dilation of the aortic root and enlarging of the posterior wall is possible. M-mode ultrasound has also been described useful for differentiating between authentic flaps and possible artifacts⁸ (Figure 2). However, it really only allows the tip of the iceberg to be studied, although it is still useful in combination with two-dimensional ultrasound. The introduction of TEE has allowed the limits of transthoracic echography (TTE) imposed by thoracic deformations, obesity, mechanical ventilation, dyspnea and pulmonary emphysema to be transcended. Its use is essential in patients with suspected aortic dissection.

If, after TTE examination, the need for surgery is evident, it is advisable to stabilize the patient by intubation or mechanical ventilation before performing TEE. Alternatively, TEE can be performed during surgery to obtain further transaortic details. In the near future, three dimensional ultrasound will be available, opening a new range of diagnostic possibilities.

Computed tomography (CT) is the imaging technique most commonly used in patients with suspected aortic dissection (Figure 3). Its diagnostic precision has improved spectacularly since the introduction of helical CT to routine clinical practice.⁹ Its sensitivity and specificity are above 90 and 85% respectively.^{10,11} Among



Fig. 1. Transesophageal ultrasound image showing an aortic dissection with two lumens separated by an intimal flap.

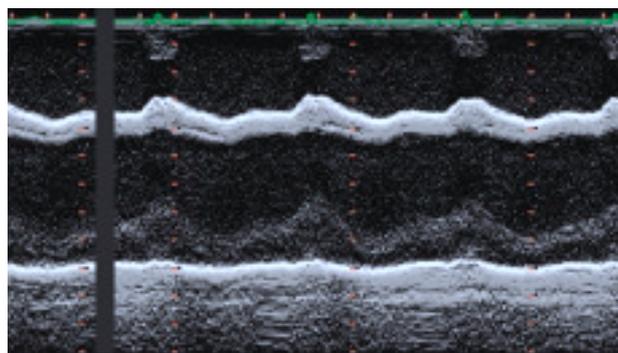


Fig. 2. False image of an aortic dissection in the ascending aorta where M mode helps establish a correct diagnosis. A linear image of echoes parallel to the wall suggests a false diagnosis.

its main virtues are the power to easily detect the site of dissection, to tell whether the arterial branches are involved, and to any confirm so-called "emergency symptoms" e.g., blood in the mediastinum (revealing the need for urgent surgery). Its main limitations are the inability to perform cardiac functional studies (that would permit the evaluation of associated complications such as aortic insufficiency) or to allow the evaluation of the segmentary systolic function of the left ventricle. It is recommended that this test be initially performed without contrast to allow the detection of active bleeding (a hyperlucid symptom) and to establish a diagnosis of IH. A contrast medium can then be administered intravenously to detect aortic dilation, clotting that might move from the calcified intima towards the interior (in cases of coagulated hematoma), and to detect the intimal flap separating the true and false lumens (which would allow the passage of blood between the lumens in non-clotted dissections).

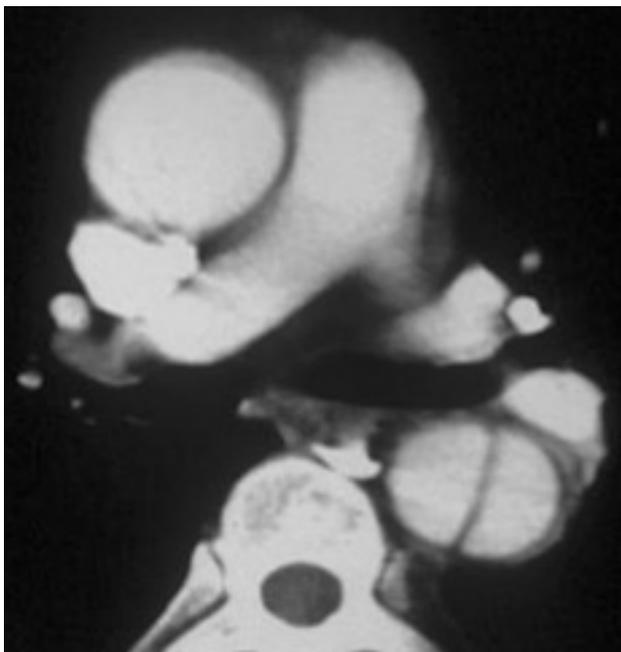


Fig. 3. Computerized tomography image of an aortic dissection. The intimal flap is visible.

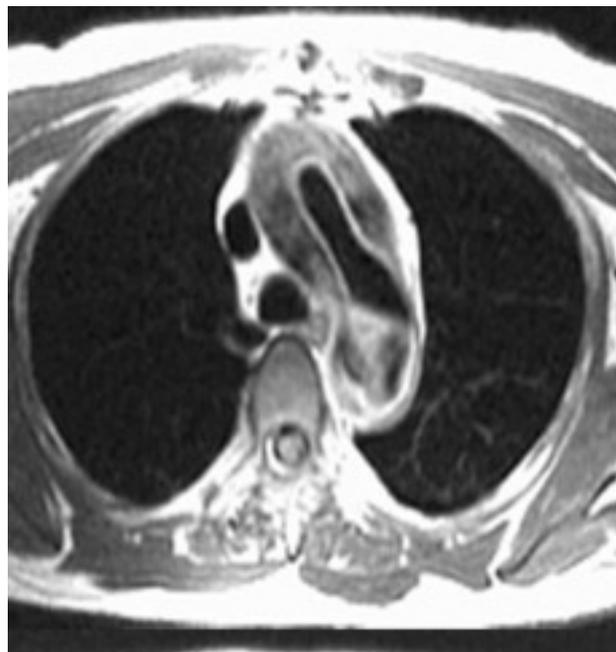


Fig. 4. Image of an aortic dissection obtained with MR.

Magnetic resonance

This technique involves taking a multitude of tomographic slices which allow the anatomy of the aorta to be observed in different spatial planes (Figure 4). The precision of MR allows a very reliable analysis to be made of the aorta's size. Since it is a noninvasive technique it can be used to monitor the progress of the disease in patients with chronic aortic dissection. If not available, CT or TEE might be used.

In classic aortic dissection, it is quite easy to analyze the direction of blood flow, distinguish between the true and false lumen, and to evaluate turbulences, clotting and communications. The entry of blood into the layers of the aortic wall causes a progressive increase in the size of the false lumen. In the most distal aorta, communications may appear between the two aortic lumens—diagnosed by the visualization of flaps in these regions.

The sensitivity and specificity of MR are close to 100%^{10,11} for all types of dissection except the most localized. Its main drawback is experienced at the moment of actually performing the study when the patient, who is often unstable, must be transferred from intensive care—with the consequent risks and delays in diagnosis that this implies. In addition, the technique places the patient in a position in which he/she is not immediately accessible to attending personnel. MR should therefore only be used with patients who are clinically stable.

MR provides an excellent view of the site of the tear, it is able to detect and determine aortic regurgita-

tion, and can evaluate the involvement of the arterial branches and other complications associated with the dissection.

MR is very useful for diagnosing breakage of the aortic adventitia (a very serious complication) since the loss of blood to the mediastinum, the pleural space and the pericardium can be visualized. Sometimes, in the early stages of a dissection, only the enlarged aortic wall can be visualized owing to a region of hematoma that incipiently dissects the wall before intimal breakage and the appearance of the flap. As with angiography, this can lead to a false negative result. It is important that these atypical forms be known if a correct diagnosis is to be made.

In the case of pseudoaneurysm associated with a history of trauma, the tear is found in the aortic isthmus, distal to the subclavian artery. MR shows a dilated structure with a narrow neck in the vicinity of the ligamentum arteriosum and joined to the aorta. PUs are normally located in the descending thoracic aorta at the site of an atherosclerotic lesion and can cause IH, saccular aneurysm, pseudoaneurysm and transmural dissection. MR images show how a pathognomonic cavity extends from the aortic lumen to an area that looks like a hematoma on the vessel wall.

Intravascular ultrasonography

This is a new technique that can be used in the diagnosis of aortic dissection. However, since it is available in very few hospitals, its use is very restricted. This technique allows the architecture of the aorta wall to be

visualized from the interior of the vessel. Its sensitivity and specificity have been reported close to 100%.¹²

Angiography

This technique allows direct visualization of the lumen of the arterial system. However, in the diagnosis of acute aortic disease, it has a series of limitations such as the length of time required to perform the study, false negatives in cases of intramural hematoma, the passage of the contrast medium through both lumens at the same time, and possible complications caused by entry of the contrast into the false lumen. Further, it should be remembered that this type of contrast medium is nephrotoxic. Given these drawbacks, and the availability of alternative diagnostic techniques, angiography should not be a first choice. However, it can be helpful when diagnosis is inconclusive, in the study of primary aortic branches, in patients who have undergone previous aortic surgery, and for the diagnosis of post-surgical complications. When angiography is used to diagnose a dissection, the patent lumens are separated by a fine radiopaque line representing the lifted intima. The density of contrast is greater and the blood flow greater in the true lumen than in the false lumen.

Chest X-ray

This technique also helps establish a diagnosis and should be performed on every patient with suspected aortic disease. The most characteristic radiological symptom is the widening of the mediastinum. This can be monitored over time by taking successive radiographs. Other diagnostic symptoms are the separation between the calcification of the intima (in the case of dissection) and the external border of the aorta, the displacement of the trachea towards the right, of the esophagus forward and to the right, and the widening of the paraspinal line. Signs suggestive of bleeding outside the arterial wall are pleural effusion and the appearance of an extrapleural lesion at the vertices of the thorax.

EXPLORATION AIMS OF THE DIFFERENT IMAGING TECHNIQUES IN AORTIC DISSECTION

Confirmation of diagnosis

The diagnosis of aortic dissection is based upon the detection of an intimal flap that separates the true and false lumens. If the false lumen is completely clotted, then the central displacement of the calcification of the intima, or a separation between the layers of the intima and the clot, allow a positive diagnosis (Figure 5).

The sensitivity of TTE in the detection of intimal flaps oscillates between 77 and 80%, while its speci-



Fig. 5. Transesophageal ultrasound image showing clotting in the false lumen and the flap separating the two lumens.

city ranges from 93% to 96%.¹³ These good results are owed mainly to the detection of dissections in the ascending aorta. The detection of distal dissections in the thoracic aorta by TTE is only successful in about 70% of patients. These results have improved with TEE. In the European Cooperative Study, a sensitivity of 98% and a specificity of 88% was achieved, with a positive predictive power of 97% and a negative predictive power of 93% (confirmed during surgery or post mortem). For 164 patients, a sensitivity of 99% and a specificity of 98% was achieved. These results could not be improved with CT or angiography – an important datum with respect to the negative predictive power of TEE. Two false positives and one false negative were recorded. The false positive diagnoses were due to reverberation in the ascending aorta, something that TEE finds difficult to deal with. Similar artifacts have been described for TTE and TEE.¹⁴⁻¹⁶ Diagnoses of dissections affecting the aortic arch also have their limitations. However, dissections limited to the distal part of the ascending aorta are rather uncommon. In these patients, parasternal or right suprasternal TTE can provide information on the ascending part of the aortic arch. The use of multiplanar transesophageal probes has improved the diagnostic performance of the technique.

The sensitivity of CT in establishing a diagnosis of aortic dissection is between 83 and 94%; its specificity is between 87 and 100%.^{10,11} In the case of MR, both values are very close to 100%. False negatives with CT, MR or TEE are rare.

Differentiation between the true and false lumen

It is important to distinguish between the true and false lumens when trying to tell whether the blood

TABLE 3. Differences between the true and false lumens

	True lumen	False lumen
Size	Reduced	Greater
Pulsatility	>Systole	>Diastole
Echocontrast	Rare	Frequent
Clotting	Rare	Frequent
Communication	TL to FL systole	FL to TL diastole

TL indicates true lumen; FL, false lumen.

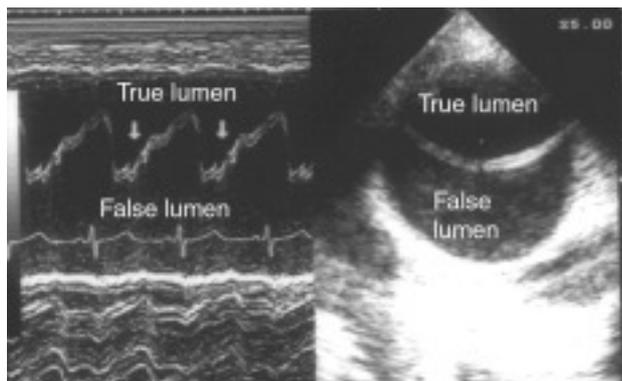


Fig. 6. Transesophageal ultrasound image which allows the true and false lumens to be distinguished.

flow compromises the branches of the aorta. Table 3 shows their differentiating characteristics. In the false lumen, spontaneous ultrasound contrast is usually seen. This is related to a slow, altered or even inverted blood flow often combined with clot formations¹⁷ (Figure 6). If the formation of clots in the false lumen is complete, it is a good idea to check the structure of the aorta in different scanning planes, and to visualize the central displacement of the calcified deposits (Figure 7). The true lumen dilates during systole and collapses during diastole owing to changes in pressure. All of these differences are much easier to see with TEE and MR.

Localizing entry and communication points

Tears in the intima can be seen directly by two-dimensional ultrasound in 22% of patients. CT is the worst technique of all for localizing intimal tears.

In the European Cooperative Study, intimal tears were seen with TEE in 61% of patients with Type I dissection and in 32% of those with Type III. With color Doppler ultrasound, tears can be picked up in about 78% of patients. Pulsed Doppler analysis has shown that the blood flow through the tears is not unidirectional but generally bidirectional. Bidirectional flow is seen in 75% of patients. In 28% of patients unidirectional flow is seen with classic entry from the true to

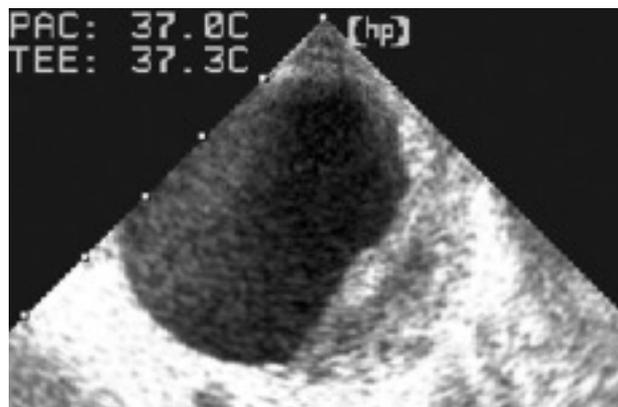


Fig. 7. Intimal calcification helps identify an intramural hematoma and to differentiate it from mural clot.

the false lumen. In 6% of cases, classic re-entry from the false to the true lumen is seen. Multiple communications between the lumens are often seen (as shown by angiography). The evaluation of intravascular flow is also possible with MR. CT, however, is very limited in this respect.

Though some authors suggest that a high pressure gradient at a tear (when detected by pulsed Doppler) is a poor prognostic sign, others have not been able to confirm this, possibly because the pressure gradient is too small to significantly reduce the pressure in the false lumen and diminish the pressure on the wall.^{18,19} The pressure gradients found were only in the range of 10-25 mm Hg, meaning that the pressure in the false lumen remains high.

Differentiation between communicating and noncommunicating dissection. New classifications

According to how the flow is visualized in the false lumen and to how tears are detected in the intimal flap, one can differentiate between communicating and noncommunicating dissections. When communication exists, the intimal flap shows strong movements during the cardiac cycle – movements that are very reduced or absent in noncommunicating dissections. In the latter, no tear can be detected nor blood flow observed with color Doppler ultrasound (Figure 8). An indicator of the reduction or absence of blood flow, and of the tendency to form clots, is the spontaneous echocardiographic contrast described by some authors.²⁰ This corresponds to reflecting bodies and the aggregation of erythrocytes (Figure 9).

Mohr-Kahaly et al¹⁹ used TTE combined with TEE to follow 18 patients that survived acute aortic dissection (seven received surgical and 11 received medical treatment). In agreement with published data, they ob-

served a high prevalence (78%) of persistence of the false lumen. An association was demonstrated between the presence of large intramural communications, laminar flow and the absence of blood clots in the false lumen. This finding could be of important prognostic value; clotting in the false lumen is associated with better prognosis.^{20,21} From a technical point of view, this kind of study demonstrates the value of Doppler ultrasound for visualizing intimal tears and characterizing the flow. These results are complemented by those of the European Cooperative Study Group for Echocardiography published by Erbel et al.³ This group used TEE during the acute phase and during a mean follow-up of 10 months with 168 patients suffering acute dissection of the ascending (86 patients) and descending (82 patients) aorta. Based on the observations of blood flow in the false lumen obtained with TEE, these authors suggested a modification to the classification of DeBakey to take into account the communication between the false and true lumens and the anterograde and retrograde propagation of the dissection process (Figure 10). These subtypes correlated with later clotting in the false lumen which, in turn, was related to prognosis and recovery rate.

Involvement of lateral branches

In emergency surgery, the need to know whether the lateral branches are affected is not so important since the ascending aorta can be restored with or without repositioning the valve. The lateral branches of the aortic arch – the innominate and carotid arteries – can be seen by Duplex scanning. TEE allows 70% of the innominate artery and 30% of the left carotid to be visualized. Ultrasound and color Doppler allow one to visualize the intimal flap and the abdomen, as well as the involvement of the mesenteric and renal arteries. CT and MR are also good techniques for detecting the involvement of the arterial branches of the aorta.

Involvement of the coronary arteries

Alterations in the parietal motility of the left ventricle suggest myocardial ischemia due to the dissecting membrane occluding the orifices of the coronary arteries, or to diastolic collapse of the true lumen into the ascending aorta.

TEE can show the proximal part of the coronary arteries in a high percentage of patients. In the European Cooperative Study, alterations in wall motility were detected in 4% of patients. This figure coincides with those recorded in other studies that describe myocardial infarction in 1%-2% of patients with a dissection. Alterations in wall motility can be recent or old (related to a history of coronary cardiopathy). Such a distinction cannot be made with ultrasound, but the clinical history of the patient may help.

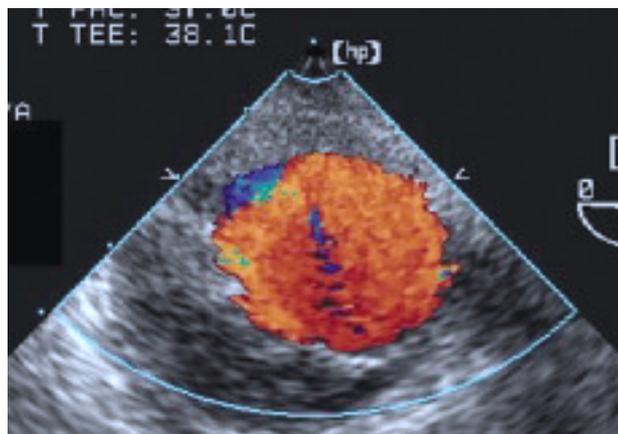


Fig. 8. A non-communicating aortic dissection. Total clotting of the false lumen can be appreciated, as well as the intimo-medial flap.



Fig. 9. Partial clotting of the false lumen. Different layers of clot formation are visible.

Currently, only coronary angiography can provide information about other coronary cardiopathies in patients with aortic dissection. Stable patients, especially those with a Type III aortic dissection, can undergo peri-operative angiography without risk (Figure 11). On some occasions, given the degree of emergency, surgeons may decide that coronary angiography is unnecessary.

Associated aortic insufficiency

Color Doppler offers high sensitivity and specificity in the detection of aortic regurgitation. This alteration is seen in 52% of patients with Type I dissection, in 64% of those with Type II, and in 8% of those with Type III.²⁴ The technique used to detect aortic insufficiency should also facilitate information on the degree of this insufficiency, its etiology, and the size of the left ventricle. Aortic insufficiency can be provoked by dilation of the aortic annulus and by prolapse of the aortic intima towards the ventricular cavity (Figure 12).

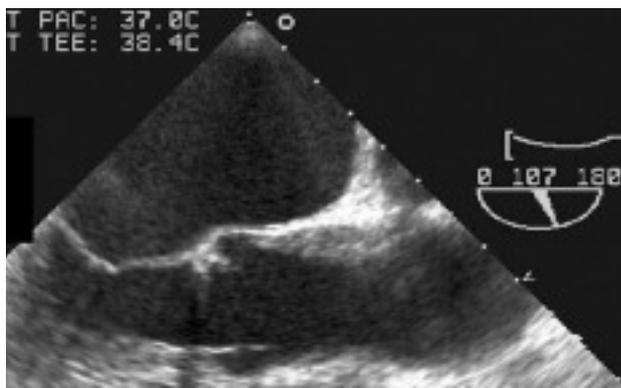


Fig. 10. Transesophageal echocardiogram showing an intramural hematoma in the ascending aorta. According to the new proposal of Erbel et al, this should be treated as a Type A dissection.

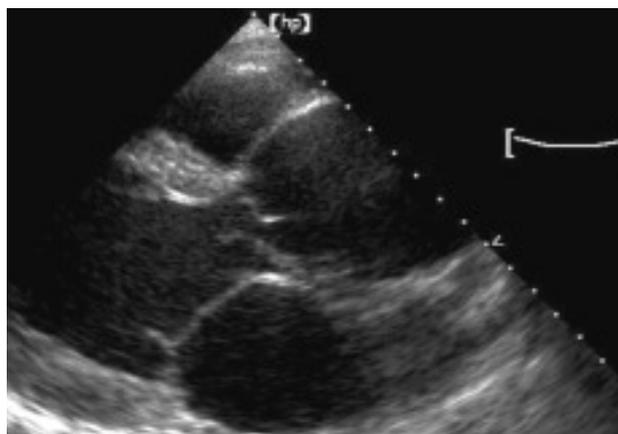


Fig. 12. Transthoracic echocardiogram (parasternal plane) showing a flap prolapsing into the ventricular cavity, the etiology of the patient's aortic regurgitation.

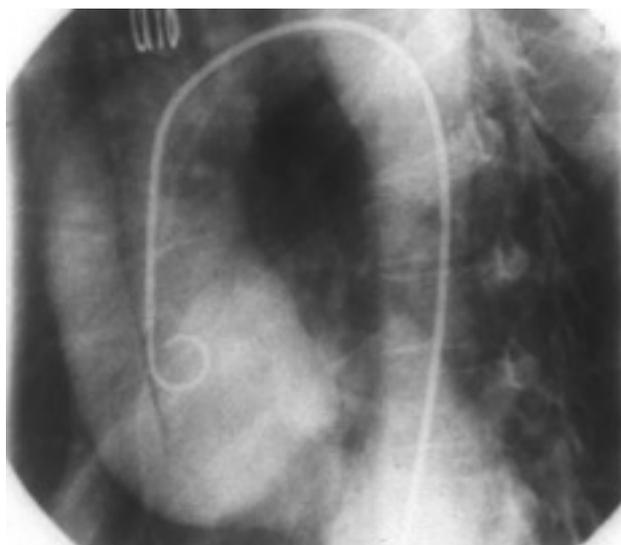


Fig. 11. Angiography showing a dissection of the ascending aorta.

Fluid effusions

The effusion of fluid into the pericardium, the pleural space and/or the mediastinum are signs of emergency and of poor prognosis.²² Echo-free spaces between the epicardium and pericardium represent pericardial effusion. Echo-free spaces around the aorta are signs that penetration or perforation is underway, often combined with intramural hemorrhage.²³ Anechoic areas in the pleural space are detected with TTE and TEE, and can be found close to the descending aorta. The symptoms of mediastinal hematoma are a widening of the distance between the esophagus and the wall of the descending aorta, and between the former and the wall of the right atrium. These can be increased by compression of the left atrium in cases of acute hemorrhage. Ultrasound offers greater precision than CT in the detection of peri-

cardial effusion, which is seen in 33% of patients with Type I dissection, in 45% with Type II, and in 6% with Type III.

INTRAMURAL HEMATOMA AND INTRAMURAL HEMORRHAGE

The pathogenesis of aortic dissection has now been described. The high resolution offered by TEE allows intramural hematomas and hemorrhages to be detected as the first events in aortic dissection.²³⁻²⁵ The diagnostic characteristics of IH are multiple layers of aorta wall divided by the hemorrhage (anechogenic area), thickening of the wall (>0.5 cm), an increased distance between the lumen and the esophagus, and a peri-aortic area with no echo (a sign of bleeding).

IH typically shows a localized thickening of the aorta wall (Figure 13) with echo-free central intramural spaces limited to one or two scanning planes. The calcification of the intima helps considerably in the differential diagnosis of IH and intraluminal thrombus.

Intramural hematomas or hemorrhages can cause typical dissection in 30% of patients²⁴ or scar spontaneously, as demonstrated by CT and ultrasound. In these patients, no false lumen is detected. The literature reports that the histology associated with aortic dissection is the same as that associated with IH.²⁰

One of the main characteristics of IH is its dynamic nature, with the possibility of its developing into a classic aortic dissection (provoked by an intimal tear [28%-47% of cases]) or an aortic rupture (21%-47% of cases). Reabsorption may even occur (10% of cases).

Differential diagnosis of intramural hematoma

Echocardiographically, IH is defined by a circular or semicircular thickening of the aorta wall (≥ 7 mm) with

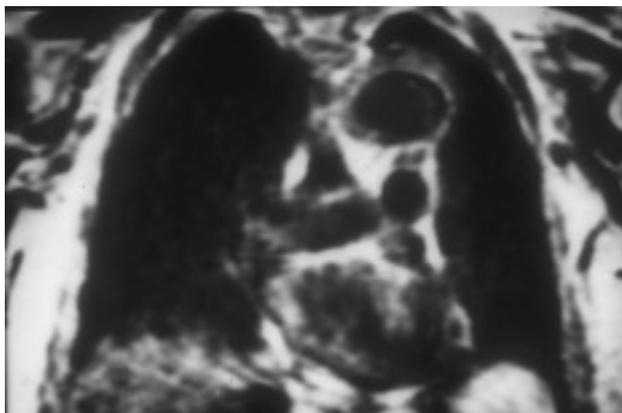


Fig. 13. MR image showing an intramural aortic hematoma.

a density similar to clots, and no evidence of internal Doppler flow or of intimal tear. This thickening provokes a central displacement of the intima (which might have calcifications), and a reduction in the diameter of the aortic lumen. It may extend longitudinally for 1-20 cm along the thoracic aorta.

In approximately two thirds of cases, echolucent zones representing fluid-filled areas (with no internal flow) are observed inside the hematoma.

When these echo-free zones are located below the intima, the image of a flap can be identified which, unlike in classic aortic dissection, remains still. Nevertheless, this frequently makes it impossible to differentiate IH from a noncommunicating dissection. Distinction from acute atherosclerosis of the aorta can also be difficult, especially when these lesions are associated with a wall clot. In such cases, unlike with IH, the aorta is usually dilated, the inner shape of the thickened wall is very irregular, and frequently there is autocontrast with the aortic lumen. Further, wall clots are almost always semicircular, their surfaces are irregular and they show no signs of echolucent zones in their interior.

AORTIC ULCER

Many atherosclerotic lesions of the aorta show a varying degree of erosion at their surface. On occasions, this erosion can invade the medial layer after passing through the internal elastic lamina, giving rise to a penetrating aortic ulcer (PU). PUs usually affect patients of advanced age, who are hypertensive, and who have diffuse atherosclerosis. They are usually located in the descending thoracic aorta, and their clinical presentation is normally very similar to classic aortic dissection or IH with sudden retrosternal or interscapular pain.

Given that the medial layer is very rich in vasa vasorum, PUs often accompany IH. They are nearly always localized since their longitudinal propagation is limi-

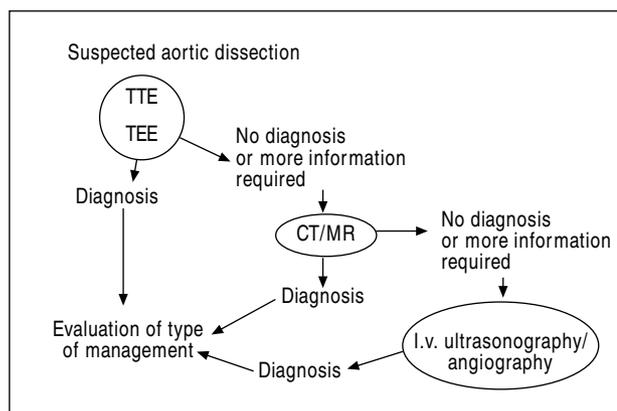


Fig. 14. Sequence of use of the different diagnostic techniques in patients with suspected acute aortic dissection.

ted by the habitual fibrosis and calcification of the aorta. This also explains why the propagation of a classic aortic dissection, although possible, is rare. A more common development is the progressive dilation of the aorta, but if ulceration continues to deepen it can cause a pseudoaneurysm or even aortic rupture.²⁶⁻²⁸

Ultrasound diagnosis is based on identifying an image that looks like a crater with irregular edges standing out from an aorta wall showing acute atherosclerosis. As a diagnostic criterion, and to differentiate it from IH, some authors include the identification of blood flow in the interior and at the edges of the ulcer by pulsed color Doppler analysis. In addition, they consider that the disappearance of this flow during follow-up can be a sign of stabilization of the plaque, especially when accompanied by an improvement in symptoms. The identification of a thickening of the wall with echolucent images in its interior and central displacement of intimal calcifications allows one to diagnose an IH associated with a PU.^{26,27}

DIAGNOSTIC STRATEGIES IN PATIENTS SUSPECTED OF SUFFERING ACUTE AORTIC DISEASE

A series of recommendations based on current techniques for obtaining images have been prepared for patients with suspected aortic dissection.⁹ However, these should be taken with care: the experience of each center and the availability of equipment will influence what is eventually done. Ultrasound combined with Duplex and color Doppler techniques can be performed in the emergency room at the bedside. These are noninvasive or semi-invasive techniques, both the associated risk and cost are low, and sensitivity and specificity are high. The proposal shown in Figure 14 was based mainly on the results of European cooperative studies.²⁸ Following TTE, TEE is performed. If the heart surgeon confirms the diagnosis, and can answer all the questions necessary for a decision to be

made on whether surgery should be performed, the patient should not be subjected to further tests: surgery should take place immediately. However, when a diagnosis of aortic dissection is not definite, or symptoms are not clearly diagnostic, it is recommended that MR or CT images be obtained. Angiography and intravascular ultrasonography are rarely necessary.

Comparison of different imaging techniques used in the diagnosis of aortic dissection

Although the diagnostic performance and availability of TEE are not in question, this method does have its limitations. It is less diagnostically precise in the distal part of the ascending aorta and its capacity to evaluate true cross-sectional dimensions of tortuous aortas is relatively limited. Such knowledge might be important in some cases, requiring other imaging techniques to be considered. The precision of CT in diagnosing the true and false lumen is excellent, and it is a very valid alternative for the initial evaluation of patients with suspected aortic dissection. However, it provides no hemodynamic information and is of very limited value in evaluating the complex morphology of the intimal flap or detecting the location of the initial tear. Some studies are available that compare the use of CT and TEE in the long-term follow-up of aortic dissection patients. Nienaber et al²³ offer a complete perspective of the relative diagnostic value of the three main non-invasive techniques for diagnosing acute aortic dissection. They obtained equivalent overall sensitivities for MR (98.3%), TEE (97.7%) and CT (93.8%), but a lower specificity for TEE (76.9%) than for MR or CT (97.8% and 87.1% respectively). The subanalysis of these data showed that the differences between the three methods was significant only for dissection Type A, with MR and TEE significantly more sensitive than CT (100 and 96.4% compared to 82.6% respectively). Transesophageal echography was also less specific than MR and CT (85.7% compared to 98.6% and 100% respectively). As expected, aortic regurgitation was better diagnosed with echocardiographic techniques, though MR was also exact when explorations were complemented with radiographic images. The usefulness of CT was limited to locating the site of the original tear, and TEE was less sensitive than CT or MR for the detection of clot formation in the ascending aorta and aortic arch. However, TEE was performed with monoplanar probes and color Doppler was not performed uniformly. Magnetic resonance was the most reliable method for diagnosing the involvement of the lateral branches. Based on these results, these authors recommend the use of MR with all stable patients but suggest that TEE is a better choice for those who are unstable and cannot be moved. Erbel et al²⁸ indicate higher specificities for MR: the high specificity declared for dissection Type A could be related to

the routine use of color Doppler or biplanar or multiplanar probes.

In agreement with these results and recommendations, it would appear that the main procedures of choice for patients who have survived an acute aortic dissection are MR and TEE. Comparative data for these two methods in terms of long-term follow-up of patients are still limited. Data based on the exclusive use of multiplanar probes are rare.

CONCLUSIONS

Computerized tomography, and especially TAE and TEE, are very accessible and available tools for studying patients with suspected acute aortic disease. Their diagnostic performance is excellent, although in difficult or doubtful cases they should be complemented by other imaging techniques. Transesophageal echography seems to be the technique of choice for the diagnosis of aortic dissection in its acute phase. In an ideal world, in which all patients are stable, cost is no object, and all types of medical equipment are available, MR is probably the best choice. However, at the majority of centers, TEE should be considered an equivalent alternative when repeated series of MR studies cannot be made. Some patient characteristics tip the balance in favor of using one or the other of the latter methods: complex disease in the ascending aorta or aortic arch will probably be detected more easily by MR, while information useful for establishing a prognosis (such as the situation with respect to intimal tears and blood flow communications) are better obtained with TEE. Complex cases can benefit from complementary use of these last two methods.

REFERENCES

1. Miller DC, Stinson EG, Oyer P, Rossiler S, Shumway NE. Operative treatment of aortic dissections: experiences with 125 patients over 16 year period. *Thorac Cardiovasc Surg* 1979;78:365-75.
2. DeBakey ME, Cooley DA, Creech O. Surgical considerations of dissecting aneurysm of the aorta. *Ann Surg* 1955;142:586-612.
3. Erbel R, Oelert H, Meyer J, Puth M, Haussman D, Daniel W. Influence of medical and surgical therapy on aortic dissection evaluated by echocardiography. *Circulation* 1993;87:1604-15.
4. Erbel R, Zamorano J. The aorta. Aortic aneurysm, trauma and dissection. *Critical care clinics*. 1996;12:733-66.
5. Roberts W. Aortic dissection: anatomy, consequences and causes. *Am Heart J* 1991;101:195-214.
6. Zotz R, Erbel R, Meyer J. Intrawall hematoma of the aorta as an early sign of aortic dissection. *J Am Soc Echocardiogr* 1991;4: 636-8.
7. Mügge A, Daniel W, Laas J, Grote R, Lichten P. False negative diagnosis of proximal aortic dissection by computed tomography or angiography and possible explanations based on transesophageal echocardiographic findings. *Am J Cardiol* 1990;65:527-9.
8. Evangelista A, García-del-Castillo H, González-Alujas MT, Domínguez Oronoz R, Salas A, Permanyer-Miralda G, et al. Diagnosis of ascending aortic dissection by transesophageal echocardiography: utility of M-mode in recognizing artifacts. *J*

- Am Coll Cardiol 1996;27:102-7.
9. Erbel R, Alfonso F, Bileau C, Dirsch O, Eber B, Haverich A, et al. Diagnosis and management of aortic dissection. Recommendations of the Task Force on Aortic Dissection, European Society of Cardiology. *Eur Heart J* 2001;22:1642-81.
 10. Sommer T, Fehske W, Holzknicht N, Smekal AV, Keller E, Lutterbey G, et al. Aortic dissection: a comparative study of diagnosis with spiral CT, multiplanar transesophageal echocardiography, and MR imaging. *Radiology* 1996;199:347-52.
 11. Nienaber CA, von Kodolitsch Y. Diagnostic imaging of aortic diseases. *Radiologe* 1997;37:402-9.
 12. Yamada E, Matsumura M, Kyo S, Omoto R. Usefulness of a prototype intravascularultrasound imaging in evaluation of aortic dissection and comparison with angiographic study, transesophageal echocardiography, computed tomography and magnetic resonant imaging. *Am J Cardiol* 1995;75:161-5.
 13. Nienaber CA, Spielmann R. Diagnosis of thoracic aortic dissection. *Circulation* 1992;85:434-47.
 14. Erbel R, Daniel W, Visser C, Roelandt J, Renollet H. Echocardiography in diagnosis of aortic dissection. *Lancet* 1989;1:457-61.
 15. Nienaber C, von Kodolitsch Y, Nicolas V. The diagnosis of thoracic aortic dissection by noninvasive imaging procedures. *N Engl J Med* 1992;85:434-47.
 16. Gorge G, Erbel R, Gerber T, Ge J, Zamorano J, Makowski T, et al. Intravasaler Ultraschall bei Patienten mit Verdacht auf Aortendissektion: Vergleich zur transesophagealen Echokardiographie. *Z Kardiol* 1992;81:437-43.
 17. Zamorano J. Enfermedades de la aorta. Aneurisma y disección. En: Ribera JM, Cruz A, editores. *Patología vascular y periférica en geriatría*. Madrid: Editorial Masson, 1998; p. 332-42.
 18. Vilacosta I, Nanda N, San Román JA. Ecocardiografía y disección aórtica. *Rev Esp Cardiol* 1996;49:13-26.
 19. Mohr-Kahaly S, Erbel R, Renolet H, Meyer J. Ambulatory follow-up of aortic dissection by transesophageal and color coded doppler echo. *Circulation* 1989;80:24-33.
 20. Zamorano J, Mayordomo J, Evangelista A, San Roman JA, Bañuelos C, Gil M. Guías de práctica clínica de la Sociedad Española de Cardiología en enfermedades de la aorta. *Rev Esp Cardiol* 2000;53:531-41.
 21. Evangelista A, Salas A, Armada E, González Alaujas MT, García del Castillo H, Soler J. Follow up of aortic dissection by transesophageal echocardiography: different evolution patterns. *Eur Heart J* 1996;17:438-40.
 22. Cigarroa JE, Isselbacher EM, De Sanctis RW, Eagle K. Diagnostic imaging in the evaluation of suspected aortic dissection. *N Engl J Med* 1993;328:35-43.
 23. Nienaber C, Kodotisch Y, Petersen B, Spielman R. Intramural haemorrhage of the thoracic aorta. Diagnostic and therapeutic implications. *Circulation* 1995;92:1465-72.
 24. Robbins RC, Mitchell R, Latter D, Moon MR, Miller CM. Management of patients with intramural haematoma of the thoracic aorta. *Circulation* 1993;88:1-10.
 25. Khandheria BJ. Aortic dissection: the last frontier. *Circulation* 1993;87:1765-8.
 26. Moskowitz HD, Lampert C, Jacobs LE, Kotler MN. Penetrating atherosclerotic aortic ulcers. *Am Heart J* 1994;128:1210-7.
 27. Atar S, Nagai T, Birnbaum Y, Harold JG, Luo H, Naqvi TZ, et al. Transesophageal echocardiography Doppler findings in patients with penetrating atherosclerotic aortic ulcers. *Am J Cardiol* 1999; 83:133-5.
 28. Montgomery DH, Ververis JJ, McGorisc G, Frohwein S, Martin RP, Taylor WR. Natural history of severe atheromatous disease of the thoracic aorta: a transesophageal echocardiography study. *J Am Coll Cardiol* 1996;27:95-101.