Echocardiography in the emergency assessment of acute aortic syndromes

E. Louise Meredith and Navroz D. Masani*

Department of Cardiology, University Hospital of Wales, Heath Park, Cardiff CF14 4XW, UK

Acute aortic syndrome (AAS) is a collective term for several life-threatening acute aortic conditions: aortic dissection, intramural haematoma (IMH), penetrating atherosclerotic ulcer, and traumatic transection. Mortality from acute ascending aortic (type A) dissection increases rapidly immediately after presentation, reaching 1–2% per hour for the first 48 h. Early surgical intervention is recommended for type A aortic dissection and has been shown to improve outcome. Transthoracic echocardiography is an extremely valuable, often overlooked, clinical tool in diagnosing and assessing AAS in the emergency setting. Although diagnostic sensitivity is suboptimal, it is very useful in assessing potential high risk features or complications, such as pericardial effusion, and diagnosing potential differential conditions. A negative transthoracic echocardiography (TTE), however, does not exclude AAS. In patients with a high risk of type A dissection or IMH (identified clinically or by TTE), the safest and most rapid ‘gold standard’ investigation is transoesophageal echocardiography, ideally performed with the cardiac surgical team standing by. This is of particular importance in the haemodynamically unstable patient. Transoesophageal echocardiography, helical CT, and MRI have similar diagnostic accuracy and, when there is diagnostic uncertainty or no indication for immediate intervention, should be used according to clinical need, local availability, and expertise.

KEYWORDS
Acute aortic syndromes; Acute aortic dissection; Intramural haematoma; Transthoracic echocardiography; Transoesophageal echocardiography

Introduction

In this article, we review the role of echocardiography in the emergency management of acute aortic syndromes (AAS). We focus on the importance of echocardiography in the early assessment of patients with suspected AAS in the emergency and critical care settings. In particular, the value of transthoracic echocardiography (TTE), often overlooked, in the immediate management of such patients is explored. The pivotal role of transoesophageal echocardiography (TEE) is reviewed, with particular emphasis on its value in patients requiring cardiac surgery. Finally, we describe a locally developed approach that optimizes the strengths of TTE, TEE, and other imaging modalities.

Acute aortic syndrome (AAS) is a collective term for several life-threatening acute aortic conditions: aortic dissection, intramural haematoma (IMH), penetrating atherosclerotic ulcer (PAU), and traumatic transection. Traumatic transection does not share pathophysiological or clinical features with the other conditions and will not be considered in this article.

Acute aortic syndrome (AAS) is a collective term for several life-threatening acute aortic conditions: aortic dissection, intramural haematoma (IMH), penetrating atherosclerotic ulcer (PAU), and traumatic transection. Traumatic transection does not share pathophysiological or clinical features with the other conditions and will not be considered in this article.

Acute aortic syndrome (AAS) is a collective term for several life-threatening acute aortic conditions: aortic dissection, intramural haematoma (IMH), penetrating atherosclerotic ulcer (PAU), and traumatic transection. Traumatic transection does not share pathophysiological or clinical features with the other conditions and will not be considered in this article.

Patients with AAS may have similar presenting symptoms, clinical features, and co-morbid disease. Classically, AAS patients present with severe acute chest pain which can radiate to the neck in ascending aortic disease or the back in descending aortic disease. The chest pain may have a pleuritic or pericarditic nature. In type A dissection or IMH, there may be acute aortic regurgitation (AR) and associated cardiac failure. There may be differences in upper limb blood pressure, pulse deficits, and evidence of end-organ ischaemia. Transient loss of consciousness is an important presenting feature of type A dissection. Well-recognized risk factors include longstanding hypertension and atherosclerosis as well as collagen disorders such as Marfan’s syndrome (Table 1). These patients often have significant co-morbid disease such as hypertension, coronary artery disease, and renal impairment.

Pathophysiology, classification, and implications for management

Aortic dissection

Aortic dissection occurs as a result of a tear in the intimal lining of the aorta resulting in intimal exposure to elevated aortic pressures. The intima separates from the aortic wall forming a false lumen, which runs alongside the true lumen (Figure 1). The elevated pressures lead to propagation of the dissection proximally, distally or in both directions. A re-entrant tear may allow blood to circulate through the false lumen.

* Corresponding author. Tel: +44 2920744086; fax: +44 2920743916.
E-mail address: navroz.masani@cardiffandvale.wales.nhs.uk
The entry tear occurs at sites of greatest wall stress. This is most commonly within a few centimetres of the aortic valve on the right lateral wall of the ascending aorta or close to the ligamentum arteriosum in the descending aorta. Sixty-five per cent of the cases occur within 3 cm of the coronary ostia, 10% occur within the arch, and 10% in the descending thoracic aorta.

Classification systems have been developed to describe the anatomic location of aortic dissection, which are useful in determining prognosis and guiding management. The Stanford classification was developed from a functional approach based on whether the ascending aorta was involved. Type A refers to dissections involving the ascending aorta and type B the remainder.

In the DeBakey classification, type 1 originates in the ascending aorta and extends to the arch or beyond. Type 2 is confined to the ascending aorta. Type 3 originated distal to the left subclavian and propagates to the distal descending thoracic (3A) or abdominal (3B) aorta. We will use the Stanford system in this article.

More recently, a classification based on the pathophysiologic features of the aortic lesion rather than its location has been proposed. Class 1: classic aortic dissection with true and false lumen without communication of the two lumina; class 2: intramural haemorrhage or haematoma; class 3: ulceration of aortic plaque following plaque rupture; class 4: subtle or discrete aortic dissection with bulging of the aortic wall; class 5: iatrogenic or traumatic aortic dissection, illustrated by a catheter induced separation of the intima.

Thus, it is recommended that AAS be classified according to both lesion type and location.

**Intramural haematoma**

Intramural haematoma accounts for 3–5% of the cases of aortic dissection that occur without apparent intimal disruption. Blood collects within the aortic media without the presence of a tear in the intimal lining and is caused by rupture of the vasa vasorum or possibly atherosclerotic plaque. Intramural haematoma has a higher rate of rupture (35%) than dissection due to its closer relationship to the adventitia. Extension towards the lumen may result in dissection in up to 33% of the cases and therefore surgical management is usually required in cases involving the ascending aorta.

**Penetrating aortic ulcer**

Penetrating atherosclerotic ulcer is caused by erosion of an intimal atherosclerotic plaque into the media. Erosion into the vasa vasorum may lead to IMH formation and possibly dissection. Adventitial erosion may cause aneurysm formation or rupture. Rupture has been reported in up to 42% of cases.

**Life-threatening effects of acute aortic syndrome**

Mortality from acute ascending aortic (type A) dissection increases rapidly immediately after presentation, reaching...
In the emergency setting, the clinical presentation of patients with AAS may include chest pain, dyspnoea, hypertension, and signs of heart failure. The chest X-ray may or may not reveal a widened mediastinal contour. ECG changes (non-specific, pericarditic, ischaemic, or infarction) are common. Thus, there is an important differential diagnosis, which includes acute coronary syndrome, acute myocardial infarction (MI), pericarditis, and pulmonary embolism (PE). Not only may consideration of these conditions result in crucial delay in the diagnosis of type A AAS, but also their initial management (in three of the above) includes anti-platelet, anticoagulant, and thrombotic therapies, with potential disastrous results.

Therefore, a high index of clinical suspicion and the rapid availability of diagnostic tests that are safe, sensitive, and specific are required to make the correct diagnosis and identify those patients who need early surgery.

**Emergency assessment of suspected aortic dissection: the role of transthoracic echocardiography**

Transthoracic echocardiography is safe, rapid, and readily available in the emergency department. It should be performed without delay in patients with suspected AAS, to evaluate the presence or absence of several important features. An ascending aortic dissection flap may be visible: TTE has a reported sensitivity of 59–83% and a specificity of 63–93% for the diagnosis of aortic dissection. However, there are no recent studies, using modern ultrasound technology, assessing the diagnostic accuracy of TTE in AAS. It is important to note that its sensitivity is 78-100% in type A dissection (in which the diagnosis needs to be made most rapidly) but is only 31–55% in dissection of the descending aorta (in which there is less urgency, since there is a lower early mortality and no indication for early surgery). Regardless of the visualization of a dissection flap, TTE is useful in almost all such patients: the presence of a bicuspid aortic valve (particularly in a young patient with chest pain), AR, a dilated aortic root with associated pericardial effusion, or regional wall motion abnormality (particularly inferior hypokinesia) is suggestive of acute type A dissection, whereas their absence is reassuring (but cannot definitely exclude AAS).

Transthoracic echocardiography is also useful in establishing or excluding the differential diagnosis in the acutely unwell patient, particularly in the absence of aortic root dilatation: MI (large regional wall motion abnormality), pericardial effusion, and PE (right heart dilatation, etc.).

Finally, in those patients in whom a dissection flap can be seen, TTE can identify those features of type A dissection that indicate high risk—severe proximal aortic dilatation or pericardial effusion (suggestive of impending rupture), associated regional wall motion abnormality (coronary occlusion), and AR—facilitating immediate surgical referral and appropriate emergency management. If there is high clinical suspicion and the TTE provides direct or corroborative evidence for type A dissection, we recommend transfer of the patient immediately to a cardiothoracic unit, where further pre- and intra-operative echocardiographic (TEE) imaging (or alternatively CT or MRI) can take place. This approach minimizes any delays, particularly while the patient is in an environment in which potentially life-saving cardiac surgery
cannot take place, and ensures that emergency management is undertaken by appropriate experts—cardiologists, cardiac anaesthetists, and surgeons.

Therefore, despite its relatively poor diagnostic accuracy, TTE is an extremely valuable clinical tool in diagnosing and assessing AAS in the emergency setting, identifying its related complications and diagnosing potential differential conditions. Most importantly, it has a vital role in identifying patients at high risk and directing their referral to the relevant cardiac surgical department promptly.

Performing transthoracic echocardiography in suspected acute aortic syndrome

Where the clinical situation allows, a full TTE study should be performed, as soon as possible, using standard and off-axis views (Figure 4). Standard two-dimensional and colour flow imaging in parasternal long axis (Figure 4A), apical five- (Figure 4B) and three-chamber views are used to image the aortic valve and root. In the parasternal and modified apical two-chamber views, parts of the descending aorta (behind the left atrium) can be visualized (Figure 4A). Right parasternal or high left parasternal views allows visualization of the ascending aorta in some patients. Using the suprasternal view, the arch, origin of the head and neck vessels, and proximal descending aorta can be imaged. The subcostal view allows imaging of the abdominal aorta in most patients (Figure 4C).

Transthoracic echocardiography should also be used to assess the presence of pericardial or pleural effusions. Assessment of any AR should be made, assessing the severity and mechanism of AR. This may provide valuable information to the surgeon about the need for aortic valve repair or replacement. Left and right ventricular function should be assessed. Regional wall abnormalities may represent coronary involvement in the dissection flap or pre-existing coronary disease.

Definitive imaging in acute aortic syndromes: the role of transoesophageal echocardiography

The ideal diagnostic technique in AAS should be safe, relatively rapid, and have high sensitivity and specificity. The primary objectives are to immediately identify an intimal tear (or haematoma) and delineate the extent of thoracic dissection. Important secondary objectives are to evaluate complications and, in type A dissection or IMH, provide important information to cardiac surgeons: the presence and mechanism of AR; branch occlusion, coronary/head and neck; extravasation of blood, pericardial/pleural effusions.

Transoesophageal echocardiography, helical CT, and MRI are all excellent imaging modalities in AAS.16 Transoesophageal echocardiography is reported to have a sensitivity of 94–100% and specificity of 77–100% for identifying an intimal flap.16,17 The reduced specificity in early studies relates to the false-positive interpretation of reverberation artefacts in the aortic root (discussed later),13 particularly with the use of mono- or bi-plane TEE. In a comprehensive meta-analysis16 of all three modalities, the most recent studies reported 100% sensitivity and 100% specificity for TEE,18 helical CT, and MRI, whereas conventional CT (probably the most widely used technique) is less accurate (sensitivity 83–94%, specificity 87–100%).16 In various reports, the 'TEE blindspot' caused by the interposition of the trachea between oesophagus and upper ascending
aorta is mentioned as a potential disadvantage of TEE. In our experience, this has not been a problem, given the extremely low probability of dissection of IMH confined to this precise location only. A detailed discussion of the relative merits of each of these imaging modalities is beyond the remit of this article and has been performed elsewhere, but is considered in brief in the final section.

Transoesophageal echocardiography is rapid and safe. It may be performed at the bedside in a critical care environment: this is of particular importance in the haemodynamically unstable patient and avoids the need to transfer the patient to another department for imaging. When there is a high degree of suspicion for type A dissection or IMH, TEE can be performed in the operating room, with anaesthetists and surgeons standing by. In such cases, unnecessary and dangerous delays can be incurred by transferring patients to CT or MRI scanners; expert TEE can provide all of the required diagnostic and pre-surgical information.

There are anecdotal reports of deterioration of patients with aortic dissection, during TEE, possibly related to discomfort, gagging or distress. However, no mortality has been reported in larger studies. Moreover, given the mortality rate of 1–2% per hour, there is a high risk of fatal deterioration while transferring patients for, or during, CT or MRI. Nevertheless, it is vital that TEE is performed by suitably trained and experienced operators in this setting.

Performing transoesophageal echocardiography in suspected acute aortic syndrome

Scrupulous attention must be paid to the medical and supportive treatment of the patient with AAS during TEE (and during CT, MRI, etc.). Careful and continuous monitoring of heart rate, blood pressure, and oxygen saturation is necessary. Adequate opioid analgesia should be given. Intravenous beta-blockers, nitroprusside, or nitrates should be used to maintain a low blood pressure (we avoid beta-blockers in the presence of severe AR). We recommend careful conscious sedation during TEE, using intravenous midazolam. The aim is to introduce the TEE probe with maximal patient cooperation and minimal agitation, following which further sedation may be given if needed.

Assessing the aorta

Intimal flap

The classic sign of aortic dissection is the intimal flap. This is seen as a mobile linear echo separating the true from the false lumen with flow on either side. The false lumen is often much larger than the true lumen. The intimal flap moves throughout the cardiac cycle. With chronic dissections, there is a decrease in mobility. It is important to be able to identify the proximal extension of the dissection as this determines whether an urgent surgical approach is used. It is not important to identify the distal extent of the flap, if this extends below the diaphragm, during the emergency presentation of AAS since this will not alter management unless there is evidence of an intra-abdominal complication or end-organ ischaemia.

When the aorta is dilated, linear artefacts are common and may appear in the transverse or longitudinal plane.

False lumen

It is important to be able to distinguish the true from the false lumen. This has particular (surgical) relevance when the dissection extends to the origins of the coronaries and/or head and neck vessels, which may originate from the false lumen. In dissections of the descending aorta, visceral arteries may be involved having surgical or endovascular implications. The false lumen is often much larger than the true lumen. Flow in the true lumen is usually greater than in the false lumen, antegrade during systole, with the flap moving toward the false lumen. However, in cases where the proximal entry tear is large, flow in the false lumen may be similar to that in the true lumen with systolic forward flow similar in velocity and timing along with diastolic reversal. With small or more distal entry tears, flow in the false lumen is much slower and spontaneous echo contrast or thrombus may be identified. An aortic wall thickness of greater than 15 mm suggests dissection with thrombosis in the false lumen (Figure 6). In this situation, an aortic flap may not be identified—this is unusual in the emergency setting. Thrombus formation is dependent on the flow within and location of the tear: it is more common in the descending aorta and infrequent in the ascending aorta, being described in only 7% of dissections.

They may be difficult to distinguish from intimal flaps and account for some of the false-positive diagnoses of aortic dissection. Reverberation artefacts in the aortic root can occur from the walls of the left atrium and in the ascending aorta from the right pulmonary artery. Using M-mode, the artefact can be seen to be double the distance from the probe as the original structure with movement, which is in time but twice the amplitude of the original structure (Figure 5). Colour flow mapping, which shows differential flow between true and false lumens in true dissection, is also useful in recognizing reverberation artefacts.

False lumen

It is important to be able to distinguish the true from the false lumen. This has particular (surgical) relevance when the dissection extends to the origins of the coronaries and/or head and neck vessels, which may originate from the false lumen. In dissections of the descending aorta, visceral arteries may be involved having surgical or endovascular implications. The false lumen is often much larger than the true lumen. Flow in the true lumen is usually greater than in the false lumen, antegrade during systole, with the flap moving toward the false lumen. However, in cases where the proximal entry tear is large, flow in the false lumen may be similar to that in the true lumen with systolic forward flow similar in velocity and timing along with diastolic reversal. With small or more distal entry tears, flow in the false lumen is much slower and spontaneous echo contrast or thrombus may be identified. An aortic wall thickness of greater than 15 mm suggests dissection with thrombosis in the false lumen (Figure 6). In this situation, an aortic flap may not be identified—this is unusual in the emergency setting. Thrombus formation is dependent on the flow within and location of the tear: it is more common in the descending aorta and infrequent in the ascending aorta, being described in only 7% of dissections.
Entry tears

The intimal tear is usually >5 mm and is situated in the proximal ascending aorta (Figure 1A) or in the descending aorta just distal to the left subclavian artery. A principal aim of cardiac surgery in type A dissection is to obliterate the entry tear in the ascending aorta, thereby preventing flow into the false lumen, encouraging thrombosis of the false lumen and healing of the aorta.25

Transoesophageal echocardiography identifies the intimal tear in 78–100% of the cases.26,27 In cases where it is not visualized by two-dimensional echocardiography, colour Doppler may show a turbulent jet directed toward the false lumen. Using pulsed Doppler, flow velocity is usually <1.5 m/s in systole. Secondary tears, in up to 20% of the cases,26,27 may be identified with TEE using colour Doppler. These are small communications between the true and false lumen and occur more commonly in the descending aorta.

Intramural haematoma (Figure 2)

Echocardiography reveals an aortic wall thickness of over 7 mm, with no dissection flap, entry tear, or false lumen. The thickened aorta in transverse section may have a crescentic shape with distortion of the circular contour. Intramural echo-free spaces are seen. Intramural haematoma is more common in the descending aorta and there may be signs of more widespread atherosclerosis. Intramural haematoma may regress or progress to dissection or rupture. Supplementary imaging in the form of MRI or CT is often required and is used for serial imaging of these lesions.

Penetrating aortic ulcer

Penetrating aortic ulcers occur predominantly in the descending thoracic and abdominal aorta (Figure 3). They occur more commonly in the elderly and there is often widespread atheromatous disease. Penetrating atherosclerotic ulcer is usually a focal lesion appearing as an outpouching of the aortic wall with jagged edges. Concomitant aneurysms of the descending aorta may be found. If a PAU extends to dissection, the dissection is usually shorter, limited by neighbouring fibrosis and calcification. The flap is usually thicker, may be calcified, and is less mobile than in a true dissection.

Pericardial and pleural effusions

Pericardial effusions occur in 20–30% of ascending aorta and 6% of descending aorta dissections.17,21,28 Pericardial effusions may occur due to rupture of the false lumen into the pericardium or due to irritation of the pericardium secondary to aortic haematoma. The presence of a pericardial effusion with an ascending aortic dissection is a sign of poor prognosis.

Aortic regurgitation

Both TTE and TEE are able to accurately assess the severity of AR. Transoesophageal echocardiography often gives greater information about the mechanism of the AR. There are several mechanisms that may contribute to the AR.

1. Dilatation of the annulus, leading to incomplete valve closure and resultant AR.

2. Aortic leaflet prolapse occurs when the dissection extends into the root and disrupts the suspension of one of the cusps. Abnormal leaflet coaptation occurs and there is eccentric AR. This is best seen in a long-axis view when the cusp is seen to prolapse back onto the left ventricular outflow tract.

3. Dissection flap prolapse can occur through the aortic valve, during diastole, distorting the valve and causing regurgitant flow (Figure 7). Prolapse of redundant intimal flap tissue and the resultant AR may be intermittent. This unusual mechanism of severe AR, in which the valve itself may be inherently normal, is particularly well visualized by TEE.29

4. Pre-existing valvular disease, for example, a bicuspid valve (Figure 1B), annular dilatation secondary to Marfan’s syndrome, or degenerative valve disease may cause significant AR. In these cases, the dissection may be of the descending or ascending aorta.
It is critically important to provide accurate information about the severity and mechanism of the aortic valve regurgitation, as this will influence the surgical decision to repair or replace the valve: in the first three mechanisms above, it is usually possible to surgically 're-suspend' the native valve.

Arterial involvement

In 10–20% cases of dissection, the intimal flap propagates retrogradely to involve the origin of one or both coronary arteries, thereby obstructing flow. Coronary involvement is suggested by left ventricular regional wall abnormalities, although these may represent pre-existing coronary disease. Transoesophageal echocardiography allows direct visualization of the coronary ostia and their spatial relationship to the proximal extent of the dissection flap; proximal flow can be seen with colour Doppler. This is achieved in the mid-oesophageal short- and long-axis views. It is possible to identify whether the coronaries originate from the true or false lumen or whether the dissection extends into the coronary (Figure 8). It should be remembered that coronary angiography is hazardous, and therefore frequently not performed, in patients with aortic dissection.

In most cases, the upper oesophageal views of the aortic arch can be used to identify the origin of the head and neck vessels and assess whether flow is from the true or false lumen (Figure 9).

Operative assessment: pre, intra, and post

Cardiac surgery is indicated in patients with acute type A aortic dissection (or IMH), reducing 14-day mortality from 50% to 20%. The aims of cardiac surgery are to repair or replace the aortic root/ascending aorta, to obliterate the entry site (tear) into the false lumen, to repair or replace a regurgitant aortic valve, and to secure antegrade flow to the coronary and proximal head/neck vessels.

Transthoracic echocardiography and, in particular, TEE provide the cardiac surgeon with invaluable information, as detailed in the above section (Table 2). When a diagnosis of type A dissection or IMH has already been made (by TTE, TEE, CT, or MRI) before transfer to the operating room, we recommend the use of peri-operative TEE to augment and review the available diagnostic information. Furthermore,
Suspected aortic dissection

Immediate TTE

High-risk features
- Pericardial effusion
- RWMA
- Dilated root
- AR

or confirmed dissection

Transfer to C-T unit

TEE in CCU or cardiac OR

Type A dissection or IMH

No high-risk features

No aortic dissection

TEE or CT or MRI
- Availability
- Expertise
- Haemodynamic stability
- Monitoring/critical care
- Coronary angiography
- Abdominal pathology

Figure 10 Algorithm for the use of echocardiography in acute aortic syndrome (see text for details). RWMA, regional wall motion abnormalities; AR, aortic regurgitation; C-T unit, cardiothoracic unit; CCU, coronary care unit; OR, operating room.

dissection and IMH are dynamic and rapidly progressing conditions, and contemporaneous imaging at the time of surgery frequently provides important information (such as the development of pericardial effusion, rapid expansion of the aortic root, etc.).

Post-operatively, TEE is valuable in assessing competence of the aortic valve, integrity of upper and lower anastomoses of interposition grafts, and, in haemodynamically unstable patients, ventricular function and the presence of pericardial collections. Because of the severe nature of the presenting illness, often with cardiovascular collapse, and the complexity and duration of surgery required, post-operative complications are common. The rapid availability and portability of TEE (including in the operating room or intensive care unit) are invaluable in assessing these complex patients.

Suggested approach for echocardiography in patients with suspected acute aortic syndrome

Untreated, AAS can be a rapidly fatal condition (Figure 10). For this reason, prompt and accurate assessment is required to identify high-risk patients. A high index of clinical suspicion is required, to distinguish AAS from other causes of chest pain and dyspnoea.

We recommend TTE as the first-line imaging modality. Where more definitive imaging (such as CT) is regarded as the conventional first-line investigation, TTE can be performed in the emergency department, while the preparations for the CT scan are being made. This serves to highlight complications or high-risk features (such as pericardial effusion) that may alter the management plan—this is particularly important in non-surgical centres.

If TTE identifies type A dissection or high-risk features in association with a strong clinical suspicion, we recommend performing TEE with cardiac surgeons and anaesthetists standing by. If the diagnosis is confirmed, surgery can proceed with minimal delay. Importantly, TEE (and TTE) allows the assessment of AR, its severity, mechanism, and need for replacement or repair.

In the absence of TEE, suspicion of type A dissection (or IMH) or high-risk features, there is less urgency. The definitive imaging modality will depend upon clinical circumstances, availability of facilities, and operators: helical CT, MRI, and TEE are equally accurate and have relative strengths and weaknesses. Although both allow visualization of the entire aorta including branch vessel involvement, this is less important in the first few hours. Both CT and MRI may have time delays and practical difficulties in monitoring patients whilst in the scanner. Occasionally, multiple modalities may be needed to clarify suspicious or incongruous results. The choice of modality will depend on the resources available in individual centres and the expertise available.

In patients undergoing surgery, TEE offers invaluable information for the surgeon operating on these most challenging of patients.

Conflict of interest: none declared.

References
17. Nienaber C, von Kodolitsch Y, Nicolas V, Siglow V, Piepho A, Brockhoff C