Review

What the cardiac surgeon needs to know prior to aortic valve surgery: impact of echocardiography

Alfried Germing *, Andreas Mügge

Medical Clinic II, Cardiology and Angiology, Berufsgenossenschaftliches Universitätsklinikum Bergmannsheil, Bürkle-de-la-Camp Platz 1, 44789 Bochum, Germany

Received 14 December 2008; received in revised form 2 February 2009; accepted 9 February 2009; Available online 26 March 2009

Summary

Echocardiographic assessment prior to valve surgery is crucial for clinical decision making, timing of surgery, planning the adequate surgical therapy and predicting the patient’s outcome. Description of transvalvular velocities is not enough for sending a patient to the operating room. There are specific functional and morphological characteristics of each valve dysfunction that have to be addressed by the echocardiographer prior to surgery. Evaluation of the aortic valve, annulus, root, ascending aorta, left ventricular outflow tract and left ventricular function are important. In knowing these characteristics the surgeon may choose the appropriate valve and operation techniques and assess the need for additional surgical procedures. A detailed evaluation of valve morphology and function in context with cardiac hemodynamics should be achieved during echocardiography. This step-by-step evaluation allows the correct diagnosis and classification of patient’s outcome. In conclusion, an echohemodynamic approach enables the cardiac surgeon to plan and perform the adequate surgical procedure.

#2009 European Association for Cardio-Thoracic Surgery. Published by Elsevier B.V. All rights reserved.

Keywords: Aortic valve disease; Echocardiography; Aortic valve surgery

1. Introduction

Echocardiographic assessment prior to valve surgery is crucial for clinical decision making, timing of surgery, planning the adequate surgical therapy and predicting the patient’s outcome [1,2]. However, the description of transvalvular velocities is not enough for sending a patient to the operating room. There are specific functional and morphological characteristics of each valve dysfunction that have to be addressed by the echocardiographer prior to surgery. For assessment of aortic valve disease evaluation of the valve, annulus, root, ascending aorta, left ventricular outflow tract and left ventricular function are important. In knowing these characteristics the surgeon may choose the appropriate valve and operation techniques and assess the need for additional surgical procedures. A false diagnosis of aortic valve stenosis in outflow tract obstruction or a false diagnosis of prosthetic valve obstruction due to disregarded pressure recovery phenomenon may be a problem in clinical routine. Therefore, a variety of anatomic and hemodynamic aspects have to be considered during echocardiographic evaluation (Table 1).

These aspects are highlighted in context of the echocardiographic impact on the diagnosis of aortic valve dysfunction, the surgical procedure and patient outcome.

2. Valve cusps

Morphologic assessment of the aortic valve should address the number and function of the cusps [3]. Usually there are three cusps involved in the closing process of the valve. However, bicuspid, unicuspid and quadricuspid valves may occur. Unicuspid or quadricuspid valves are very rare findings. Bicuspid valves may be congenital or acquired [4]. Anatomical and functional bicuspid valves are differentiated. In the pure or anatomical type there are only two cusps of the valve genetically determined and developed. Functional bicuspid valve types show a raphe between two cusps representing the genetic disposition of a third cusp that is not developed properly. Acquired bicuspid aortic valves often correspond to rheumatic valve disease. Morphologic findings leading to regurgitation are classified as type I (enlargement of the aortic root with normal cusps), type II (cusp prolapse or perforation) and type III (restrictive coaptation) [5].

Why should the cardiac surgeon be interested in the cusp morphology? In the presence of a bicuspid valve, concomitant congenital dysfunctions that occur in up to 20% have to be ruled out prior to surgery. Patients with bicuspid aortic valves...
tend to develop enlargement of the aortic root or the ascending aorta as well as aortic dissection irrespective of altered hemodynamics [6,7]. In these cases, aortic root reconstruction or replacement of the ascending aorta would be the proper therapy [8]. However, a bicuspid aortic valve does not rule out reconstructive surgical procedures. Even in the presence of a bicuspid valve surgical techniques for root and valve reconstruction are applicable [9]. Severity and localization of valve calcification are important information for the surgeon. Asymmetric or extended calcification of annulus and cusps restrain or preclude reconstructive techniques. All three cusps usually move synchronously, in case of asymmetric calcification or cusp prolapse a valve regurgitation may occur. However, echocardiography may predict surgical repairability and postoperative outcome [5].

3. Aortic annulus and root

The echocardiographic description of the aortic annulus and aortic root is important for assessment of the valvular function and the prediction of the postoperative hemodynamic valve behavior.

Measurement of the aortic annulus is essential to calculate aortic valve orifice area by the continuity equation. Repetitive measurements are required for adequate calculation. When transhrocatheter echocardiography does not permit sufficient visualization a transesophageal approach is helpful in nearly all cases.

Although the matching of the prosthesis size is made intraoperatively the dimensions of the aortic annulus are an important preoperative marker for choosing the appropriate size and type. When there is an annulus of 20 mm or less, a relatively high transvalvular velocity has to be expected after valve replacement. Therefore, prosthetic material with the lowest flow resistance would be adequate. In these cases, a stentless bioprosthesis would provide the best postoperative hemodynamic results [10]. Alternatively, surgical annulus remodeling can be performed to enlarge the orifice area [11]. Imaging of the aortic root should include measurements of aortic annulus, aortic sinus, sinotubular junction and ascending aorta (Fig. 1) [12]. This allows the correct assessment of the origin and cause of aortic regurgitation. A restricted leaflet motion with regurgitation would probably be followed by valve replacement. The surgical approach for valve regurgitation due to aortic root enlargement would be reconstructive. Therefore, demonstration of the aortic root geometry is helpful in clinical decision-making [8,13–16]. When there is an isolated sinus dilatation reconstructive techniques are feasible. However, when there is a severe root distortion with cusp prolapse, a valve reconstruction is much more difficult [17]. In case of a concomitant aneurysm of the ascending aorta a simultaneous replacement would be the proper therapy [18].

Before sending a patient with severe aortic stenosis to surgery the severity and localization of calcification should be assessed in detail. In few cases, the degree of calcification of aortic root and the ascending aorta is extreme. The so-called porcelain aorta may render a surgical approach impossible [19]. Occasionally, minimally invasive surgery or percutaneous valve implantation may be alternative techniques. Echocardiography has limitations in imaging the ascending aorta. In case of a heavy calcification computed tomography may be the correct imaging modality to decide the best invasive approach.

Annulus and root dimensions are characteristics that may identify patients for a percutaneous aortic valve implantation. For percutaneous approach annulus size should be between 16 mm and 27 mm and aortic root size should not go below about 30 mm. An ascending aorta of more than 45 mm in diameter, congenital valve dysfunction, presence of subaortic stenosis or intracardiac masses exclude percutaneous techniques. However, these data depend on the valve type and are not yet evaluated scientifically.

4. Left ventricular outflow tract

The left ventricular outflow tract is of importance in hemodynamic evaluation of aortic valve dysfunction, parti-
cularly in aortic valve stenosis [20]. Echocardiography should differentiate between Doppler profiles generated within the narrowest point of the stenotic valve and the outflow tract. There are characteristic Doppler profiles, which help differentiate valve stenosis from a subvalvular outflow tract obstruction. Valvular derived Doppler profiles are symmetric (Fig. 2), whereas profiles of subvalvular obstruction show a velocity maximum at late systole (Fig. 3). Profiles of a fixed outflow tract obstruction, for example in a subvalvular membranous stenosis, are often very similar to profiles of a valvular obstruction, although fluttering of the membrane results in a rough velocity curve. It may be distinguished by two-dimensional and color flow imaging. An aortic valve replacement does not treat an outflow tract stenosis and after surgery high-flow velocities persist. When there is aortic valve and outflow tract stenosis valve replacement should be accompanied by a left ventricular myectomy [21]. When there is a suspicious outflow tract morphology with severe septal hypertrophy in addition to a valve stenosis, a stress test should be performed to uncover a dynamic outflow tract obstruction [22].

5. Left ventricle

Left ventricular function determines prognosis and postoperative survival in patients with aortic regurgitation and stenosis [23]. Therefore, documentation of left ventricular geometry, systolic and diastolic performance is important. Severity and treatment options in aortic regurgitation are mainly linked to left ventricular dimensions and function. When the end systolic diameter exceeds 55 mm and ejection fraction is below 55% surgical treatment of severe aortic valve regurgitation has to be considered. When left ventricular systolic function is severely reduced, valve surgery will probably not increase survival or lower symptoms of the patient.

Quantification of aortic valve stenosis is influenced by stroke volume. Because pressure gradients are stroke-dependent the situation of an ejection fraction of 30% and a mean pressure gradient of 20 mmHg within a heavily calcified aortic valve may occur. This so-called low-flow, low-gradient constellation does not rule out a hemodynamic relevant valve stenosis [24]. Low-dose dobutamine echocardiography may uncover a severe aortic valve stenosis with left ventricular dysfunction [25]. Furthermore, stress tests may be used to identify patients with aortic valve stenosis and left ventricular dysfunction, who will not benefit from valve surgery. If the patient has severe aortic valve stenosis, but stroke volume does not increase by more than 20% during low-dose dobutamine stress, surgical risk is high and long-term outcome after valve replacement is poor [24].

Recently, a new paradoxical hemodynamic finding of a low-flow, low-gradient aortic stenosis with preserved left ventricular function has been described [26]. Although the clinical relevance of this finding has not been studied intensively, it seems to indicate an advanced stage of the disease. However, this demonstrates the need to quantify the severity of an aortic valve stenosis by measuring the effective orifice area (EOA) and not just by measuring gradients.

In order to avoid false echocardiographic findings, evaluation of the severity of aortic valve stenosis should always be based on the valve orifice area derived from the continuity equation that is less dependent on stroke volume. Transvalvular velocity and gradients are of use only when left ventricular ejection fraction is 50% or more. As applicable for aortic regurgitation in aortic valve stenosis with severe left ventricular dysfunction patients may not benefit from surgery.

In addition, geometry and severity of left ventricular hypertrophy should be addressed during echocardiography. Regardless of age, sex or valve type a regression of left ventricular mass is achieved after aortic valve replacement [27]. Changes in left ventricular mass and function may be predicted, influencing factors are preoperative excessive hypertrophy and findings of irreversible myocardial damage [28]. However, persisting left ventricular hypertrophy after valve replacement is associated with increased morbidity and mortality [29].

6. Elevated transvalvular velocities

Occasionally, there is a high transvalvular pressure gradient without valve dysfunction postoperatively. Discre-
Table 2
Echohemodynamic concept of elevated transvalvular velocities.

<table>
<thead>
<tr>
<th>Hemodynamic concept</th>
<th>Applicable for evaluation of</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure recovery phenomenon</td>
<td>Transvalvular pressure is the lowest where the velocity is the highest. After the narrowest point a part of the jet kinetic energy is recovered in pressure drop. Net pressure gradient is lower than the maximum pressure gradient. Invasive measurements document the net pressure gradient, whereas echocardiography demonstrates the maximum pressure gradient.</td>
</tr>
<tr>
<td>Native valve</td>
<td>Prosthetic valve</td>
</tr>
<tr>
<td>Patient prosthesis mismatch</td>
<td>Elevated pressure gradients in a functional normal prosthesis that is too small in relation to the body surface area.</td>
</tr>
<tr>
<td>IEOA = EOA/BSA</td>
<td>Prosthetic valve</td>
</tr>
<tr>
<td>EOA is specific for each prosthesis type, provided by manufacturer.</td>
<td></td>
</tr>
<tr>
<td>IEOA should be 0.85 or greater</td>
<td></td>
</tr>
<tr>
<td>IEOA can be predicted prior to surgery</td>
<td></td>
</tr>
</tbody>
</table>

IEOA: Indexed effective orifice area; EOA: effective orifice area; BSA: body surface area.

Pannies between echocardiographic and invasive measurements of transvalvular gradients have been reported in native aortic valves as well [30,31]. In this regard, two different hemodynamic concepts should be considered during echocardiography (Table 2).

By assessment of native or prosthetic valves the pressure recovery phenomenon may occur. The transvalvular pressure gradient through a stenotic valve is maximal at the level of the vena contracta, the pressure is the lowest where the velocity is the highest. After the vena contracta a part of the jet kinetic energy is recovered in pressure drop, resulting in a net pressure gradient that is lower than the maximum pressure gradient. Invasive measurements document the net pressure gradient, whereas echocardiography demonstrates the maximum pressure gradient. In patients with intermediate aortic valve stenoses and small aortic roots, the pressure recovery phenomenon may occur and produces false high non-invasive measurements [32]. Therefore, by evaluating aortic annulus and root dimensions, false high pressure gradients may be avoided.

The concept of effective orifice area index is based on aortic annulus measurements. With knowledge of the valve’s effective orifice area provided by manufacturer’s instructions and patient’s body surface area (BSA) the indexed orifice area (IEOA) may be calculated preoperatively (IEOA = EOA/BSA). An index of 0.85 or greater is generally considered optimal. When there is a difference between the implanted prosthesis size and body surface area a patient prosthesis mismatch may occur [33]. This mismatch is defined as a functional normal prosthesis that is too small in relation to the body surface area. Technically it is seen in post-operative elevated transprosthetic gradients without a valve dysfunction. Patients may present less left ventricular mass regression and an unfavorable clinical outcome [34,35]. However, clinical relevance of patient prosthesis mismatch still remains under investigation.

7. Conclusion

Evaluation of the clinical anatomy of all structures involved in aortic valve dysfunction has to be addressed by echocardiography prior to surgery. The detailed evaluation of the valve function in aortic stenosis exceeds the measurements of gradients; calculation of the effective orifice area should be mandatory. All morphological and functional findings should be interpreted in context with cardiac hemodynamics. In conclusion, an echohemodynamic approach enables the cardiac surgeon to plan and perform the adequate surgical procedure.

References


