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Intraoperative Imaging in Aortic Valve Surgery as a Safety Net

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1. Introduction

In the modern era, the morbidity and mortality of aortic valve surgeries has been markedly reduced. These improvement have been seen in: 1) aortic valve replacement or repair; 2) aortic root replacement or valve-sparing operations; 3) surgery on aortic dissections complicated by aortic regurgitation; and 4) recently introduced transcatheter aortic valve implantations. However, the goal of consistent success without complication is hampered by a number of pitfalls listed in Table 1.

While some of these complications are preventable if essential and timely information is obtained, others are rare and unpredictable. For the latter, early diagnosis and the institution of appropriate measures without delay is important in minimizing serious sequelae. For this purpose, intraoperative imaging plays an important role in recognizing the events behind the scenes. This author has exclusively applied transesophageal echocardiography (TEE) and direct echo to aortic valve surgery. The aim of this chapter is to describe the details of echo imaging in aortic valve surgery with a number of tips and case presentations.

Difficulty in implanting prosthetic valve
inadequate annular size
small sino-tubular junction
Myocardial damage
inadequate cardioplegia (antegrade and retrograde)
obstruction of coronary artery by prosthetic valve
air embolism of coronary artery
dissection in coronary artery
Aorta
calcified aorta: aortic route, clamp, aortotomy
new dissection
Dysfunction of prosthetic valve
malfunction of prosthesis
perivalvular or transvalvular leakage
Systolic anterior motion of mitral leaflet

Table 1. Pitfalls and complications in aortic valve surgery

2. Visualization of aortic valve

The aortic valve is most clearly visualized in midesophageal aortic valve long- and short-axis view through the left atrium as an acoustic window (Fig. 1a,b). Aortic regurgitation is readily assessed in the former, and every cusp and the sinus of Valsalva are visualized in the latter. Because the direction of blood flow is nearly perpendicular to the ultrasound beam in both views, Doppler measurements as an assessment of the pressure gradient in aortic stenosis cases are done in transgastric long-axis view (Fig. 1c) with minimal incident angle.

Due to the bulbar shape of the cusps and the sinus of Valsalva, visualization is limited in two-dimensional imaging of the aortic valve. 3D TEE is useful for visualizing all three cusps in a single view as well as surrounding structures such as the coronary artery and the sinus of Valsalva (Fig. 1d).

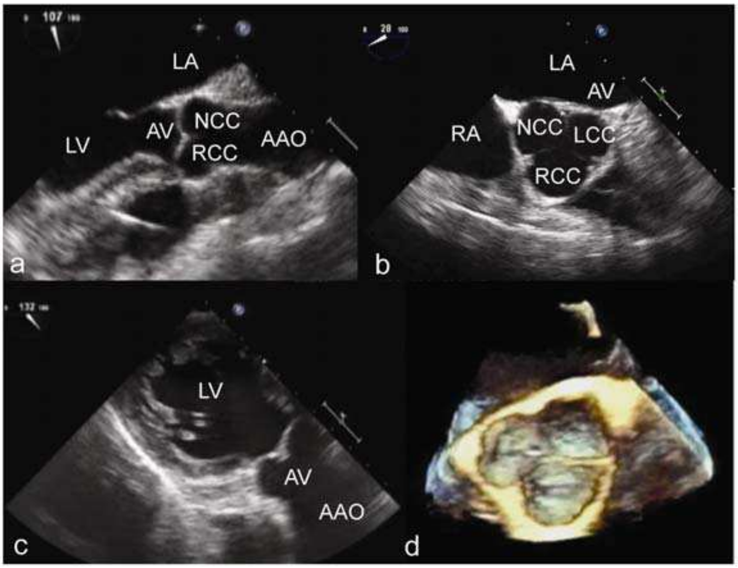

Fig. 1. Basic imaging of aortic valve. a: midesophageal aortic valve (AV) long-axis view; b: midesophageal aortic valve short-axis view; c: transgastritic long-axis view, d: 3D TEE view from the aortic side. AAO: ascending aorta, LA: left atrium, LCC: left coronary cusp, LV: left ventricle, NCC: noncoronary cusp, RCC: right coronary cusp

3. Sizing of annulus and sinotubular junction

In aortic valve replacement, the bioprosthetic valve has gained in popularity because of its long-term durability as well as its lack of dependence on anticoagulation. However, the annular size limits the use of bioprostheses in patients with small stature. Calcifications in the annulus also limit the size of the implanted valve.

In addition to preoperative transthoracic echocardiography, the annular size is measured with TEE following induction of anesthesia. In midesophageal aortic valve long-axis view, the aortic annulus is best visualized with the hinge points of the right coronary and non-coronary cusps identified as the intersection of the cusp and the sinus of Valsalva. The internal dimension of these points can then be measured (Fig. 2). In those patients with a calcified annulus, the external margin of calcium is calipered in order to assess the largest implantable valve size that would accommodate a single interrupted or non-everting mattress suture after the calcium is meticulously removed. When intraannular placement with everting mattress sutures is considered, a prosthesis one size smaller is chosen.

The internal diameter at the sinotubular junction level is important. When it is equal to or smaller than the annular dimension as in Fig. 2b, it is difficult to insert the prosthetic valve down to the annular level and a very narrow space for ligation is anticipated.

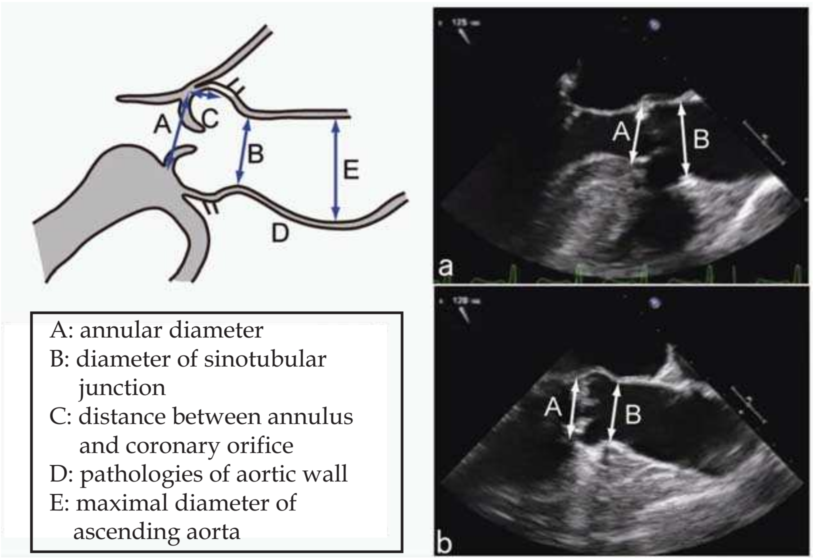

Fig. 2. Assessment of aortic valve and ascending aorta. Left: check points. a: measurement of annular dimension and sinotubular junction; b: small sinotubular junction

4. Assessment of aorta

The ascending aorta is exposed to various surgical procedures such as arterial cannulation, cross clamping, root cannula insertion and aortotomy, which is potentially responsible for intraoperative stroke and dissection. While the aorta is assessed for calcification or atheromatous changes in preoperative CT in most cases, TEE or direct echo facilitates a surgeon's ability to exactly locate these pathologies intraoperatively.

TEE assessment is beneficial in minimizing interruptions in the surgical procedure. The aorta is visualized with TEE in midesophageal ascending aorta long- or short-axis view. Although the distal portion of ascending aorta used for cannulation has been deemed to be a blind zone, this can be minimized by two tips. One is the *look-up method* (Fig. 3a,b). Instead of withdrawing the probe to visualize the distal portion, the probe is rather advanced and anteflexion is applied. Improved visualization is obtained through the left atrium and right pulmonary artery as an acoustic window. Another is the *xPlane mode* (Fig. 3c,d). In the midesophageal ascending aorta long-axis view with the probe tip anteflexed, the orthogonal scanning plane is tilted upward. Not only is the distal portion of ascending aorta seen, but the aortic arch is often visualized through the left atrium and left pulmonary artery as an acoustic window. From the upper esophageal arch long- and short-axis views, the ascending aorta can be visualized by tilting the orthogonal scanning plane downward.

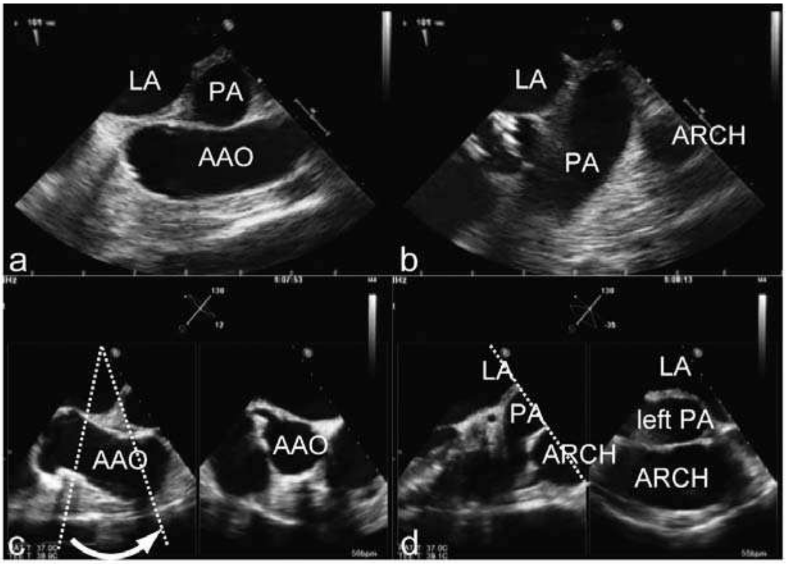

Fig. 3. Tips for visualizing the distal portion of ascending aorta (AAO). In the look-up method, the probe is rather advanced from the midesophageal ascending aorta long-axis view (a), and anteflexed. b: The arch is visualized via the left atrium (LA) and pulmonary artery (PA). In xPlane mode, the scanning plane is tilted upward (c). d: The arch is visualized through the LA and left PA

The ascending aorta is assessed for calcification and atheromatous plaque. The former is depicted as a strong echo accompanied by an acoustic shadow. When the aorta is severely calcified, it may be necessary to change the perfusion routes to the axillary artery or femoral artery. In the former, pathologies in the arch branches are checked (Orihashi, 2000). When femoral arterial perfusion is chosen, the atheromatous lesion in the descending aorta should be assessed. If the calcified aorta is clamped, it is checked for a new dissection immediately following declamping to minimize a delay in recognition and treatment.

5. Myocardial damage

Myocardial damage following aortic valve surgery can be permanent and is caused by several mechanisms. Even if the left ventricular function is transiently depressed by these mechanisms, it considerably prolongs the pump time and leads to sustained heart failure in the postoperative period. Prevention is important in avoiding these complications and can be done so through efficient and timely use of intraoperative imaging.

5.1 Visualization of the coronary arteries

Unfavorable events related to aortic valve surgeries mainly take place in the ostium and/or the proximal portion of the coronary arteries, which can be visualized with TEE.
The ostium of the right coronary artery is found in the right coronary sinus (Fig. 4a,b). Although only a few centimeters of right coronary artery can be visualized due to the large distance from the transducer, the posterior descending artery can be visualized in the posterior interventricular groove in the transgastric mid-short-axis view.
The left coronary ostium is visualized in the left sinus of Valsalva by rotating the TEE probe counterclockwise from the midesophageal aortic valve short- or long-axis view (Fig. 4c,d).

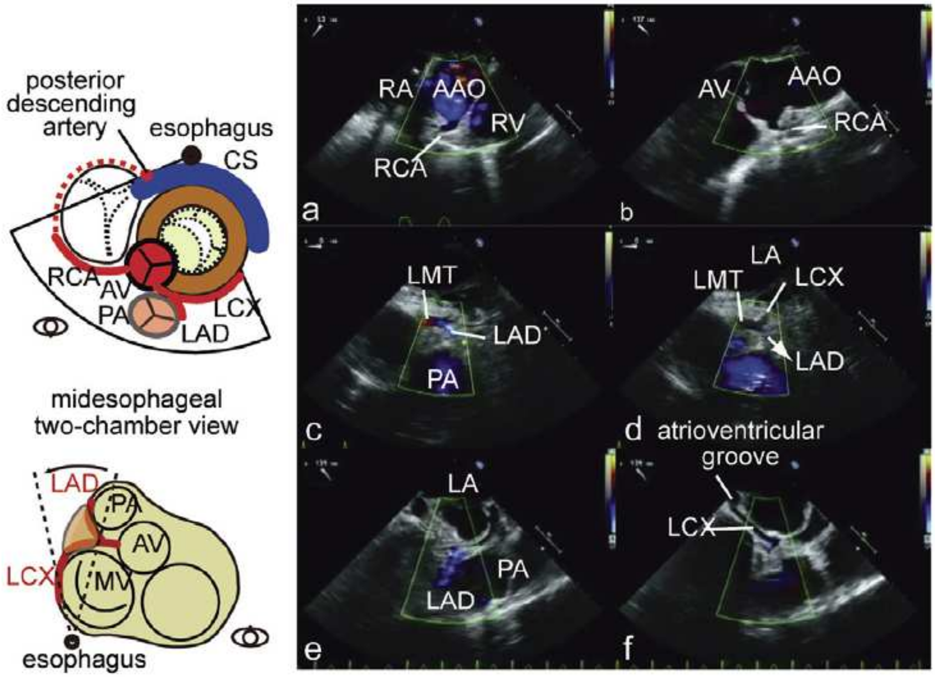

Fig. 4. Visualization of coronary arteries. Left top: diagram showing visualization of coronary arteries. The right coronary artery (RCA) is depicted in midesophageal ascending aorta (AAO) short- and long-axis view (a,b). c,d: The left main truncus (LMT) to the division to left anterior descending (LAD) and left circumflex arteries (LCX) is shown. Left bottom: method of visualizing the distal portion of LCX. e: LAD flow, f: LCX in the atrioventricular groove. AV: aortic valve, CS: coronary sinus, PA: pulmonary artery, RA: right atrium, RV: right ventricle

Further rotation visualizes the division of the left main truncus to left anterior descending artery and left circumflex artery. A few centimeters of left anterior descending artery is often visualized. The distal portion of the left circumflex artery is visualized in the left posterior atrioventricular groove in the 90° to 120° scanning plane (Fig. 4e,f) (Ender et al., 2010; Karthik et al., 2007).
3D TEE provides unique information of the coronary ostium (Fig. 5). This perspective view is helpful for recognizing the distance of the coronary orifice from the annulus.

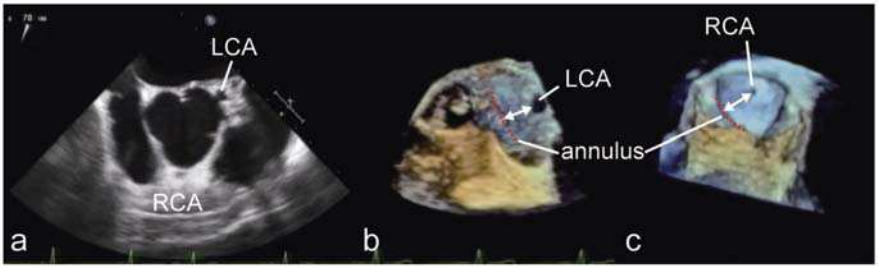

Fig. 5. 3D images of coronary ostia. a: Right and left coronary arteries (RCA, LCA) in midesophageal aortic valve short-axis view, b: 3D image of left coronary ostium, c: 3D image of right coronary ostium

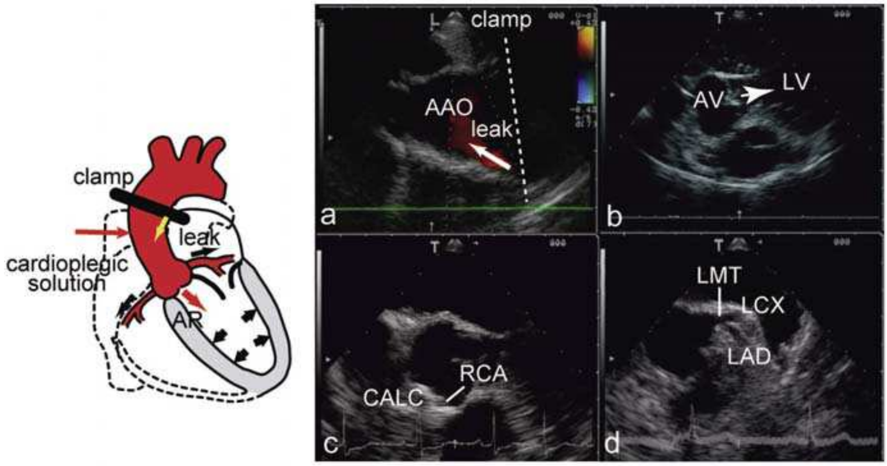

Fig. 6. Pitfalls in antegrade cardioplegia. a: incomplete aortic cross-clamp, b: Aortic regurgitation (AR) shown in B mode, c: calcification at the right coronary ostium, d: short left main truncus (LMT). AAO: ascending aorta, AV: aortic valve, LAD: left anterior descending artery, LCX: left circumflex artery, LV: left ventricle

5.2 Troubles in antegrade cardioplegia

There are two pitfalls in antegrade cardioplegia via a root cannula. In cases with a calcified aorta, the aorta may be incompletely clamped (Fig. 6a). As a result, cardioplegic solution can be washed out by leaking blood. When a patient goes into ventricular fibrillation soon after cardiac arrest, this pitfall needs to be checked. Furthermore, mild aortic reguritation may be responsible for regurgitation of cardioplegic solution, leading to distension of the left ventricle. Regurgitation is noted in the B mode as echo contrast below the aortic valve (Fig. 6b) as well as in color flow imaging.

Calcification at the coronary ostium is not uncommon in cases of aortic stenosis. This is seen as a highly echogenic area accompanied by an acoustic shadow (Fig. 6c). In such cases, the selective cannula occasionally fails to fit the ostium. Thus, infusion of cardioplegic solution is unintendedly delayed and myocardial protection becomes inadequate. Although the myocardium in the left coronary artery regions can be protected by retrograde cardioplegia, that in the right coronary artery region cannot be protected unless the right atrium is opened and coronary perfusion cannula is inserted with coronary sinus ostium tourniqueted. Otherwise, antegrade cardioplegia is essential in this region. Having TEE information on hand during these situations can help guide the surgeon in the choice of cannulas and prevent delays in the case.

In the case of a short left main truncus, the tip of the infusion cannula can be inserted into either the left anterior descending or left circumflex artery and cause inadequate myocardial protection (Fig. 6d). Therefore, a larger cannula is recommended. Adequate perfusion into both arteries is confirmed by either color flow imaging or checking blood flow in the myocardium (anterior wall for the left anterior descending artery, posterior wall for the left circumflex artery) by pulsed-wave Doppler mode with the sample volume placed on the myocardium.

5.3 Difficult cannulation of the coronary sinus

Retrograde cardioplegia is used as an adjunct method of cardioplegia in aortic valve or aortic surgery, especially in cases of coronary artery stenosis or difficult cannulation of the left coronary artery. While a coronary sinus cannula is placed with digital guidance in many institutions, it is difficult in minimally invasive cardiac surgery or in cases with an aneurysmal or angulated ascending aorta or in redo cardiac cases with marked adhesions around the heart. The author routinely uses TEE guidance in such instances.

The coronary sinus is visualized in the 0° and 90° scanning plane (Fig. 7 left). Since this image orientation is rather difficult for guidance, the view is rotated by 180° (flipped upside-down then right-left: Fig. 7 center). The upper image is oriented as viewed from the atrial side. The cannula enters the right atrium from the 1 o'clock position and is directed to the coronary sinus which is depicted in the 6 o'clock position. The cannula is often found to press the posterior wall of the right atrium near the orifice of the coronary sinus. As the

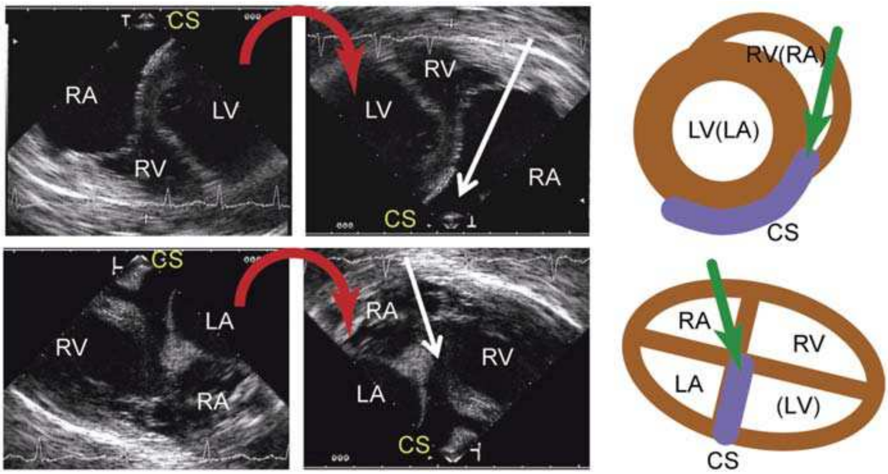

Fig. 7. TEE guided placement of coronary sinus cannula. The 0° and 90° images of coronary sinus (CS) are rotated by 180°. These images are oriented as shown in the right column, which is surgeon-friendly. LA: left atrium, LV: left ventricle, RA: right atrium, RV: right ventricle

cannula tip is tilted toward the left or the two-stage venous cannula is pulled forward to tighten the right atrial wall, cannulation is facilitated. The bottom view is oriented as viewed from the lateral side: the right atrium is depicted on the left and the right ventricle is on the right.

Once the cannula enters the coronary sinus, the location of the cannula tip is assessed with TEE. When it reaches the vicinity of the left atrial appendage, balloon inflation may interfere with the infusion of cardioplegic solution into the posterior branch of the great coronary vein. TEE assessment is helpful when palpation is not feasible in minimally invasive cardiac surgery or redo surgeries.

When the perfusion pressure of retrograde cardioplegia is low, there are two possible causes: 1) migration of the cannula to the right atrium and 2) an unusually large coronary sinus compared to the balloon. If the flow is undetectable in the coronary sinus and a flow signal is found in the right atrium, the former is probable. The coronary sinus should be checked beforehand to rule out the presence of a persistent left superior vena cava. It is diagnosed by the findings of: 1) a large coronary sinus; 2) a lumen between the left atrial appendage and left upper pulmonary vein; and 3) caudal blood flow in the lumen. However, the coronary sinus can be unusually large without such an anomaly. In this case, a cannula with a larger balloon size is used instead.

5.4 Injury of coronary artery

The coronary artery may be injured during selective infusion of cardioplegic solution by the cannula tip or the jet stream. Fig. 8 shows the echo views in a case of coronary artery damage during aortic valve replacement.

Before cardiopulmonary bypass, the TEE showed that the left coronary artery was rather small and calcification was present adjacent to the ostium (Fig. 8a). The surgeon needed to press the cannula to the ostium during perfusion. As the patient was weaned from cardiopulmonary bypass, TEE showed akinesis in the anterior and lateral left ventricular wall in the territory of the left coronary artery. Blood flow in the left coronary artery was undetectable (Fig. 8b) and there was another unusual echo-free space adjacent to it (Fig. 8c). Diagnosis of coronary artery occlusion was made and coronary revascularization to the left anterior descending artery was immediately performed. After reperfusion, direct echo was applied to clarify the mechanism of occlusion. A flap was found in the left main truncus which interrupted the flow in the left main truncus (Fig. 8d). Retrograde blood flow from the left anterior descending artery and continuous flow into the left circumflex artery was seen (Fig. 8e,f). The echo-free space adjacent to the coronary artery was the false lumen which developed due to dissection of the coronary artery.

5.5 Occlusion of coronary ostium

Aortic valve replacement can be complicated by occlusion of the coronary ostium. Although one should be aware of the potential risk of this event in cases with a low take off of the coronary artery, it is rather difficult to predict in preoperative coronary arteriography or transthoracic echocardiography.

In midesophageal aortic valve long-axis view, the ostium is located and placement of prosthetic valve is simulated (Fig. 9a). During weaning from cardiopulmonary bypass, the coronary ostium is checked for obstruction. While there is no obstruction in Fig. 9b, acceleration of flow is noted in Fig. 9c. In the latter case, even a small pannus formation can occlude the left coronary artery ostium. This intraoperative TEE assessment would be the last chance for confirming the exact spatial relationship between the coronary ostium and valve prosthesis.

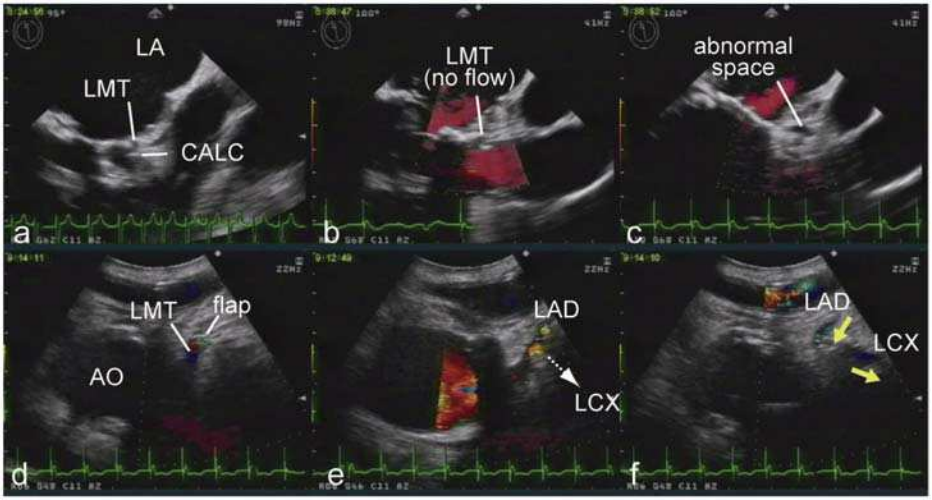

Fig. 8. A case of coronary artery damage. a: preoperative image showing small and calcified left coronary ostium, b: at weaning from bypass without flow in the left main truncus (LMT). c: abnormal space adjacent to the LMT. Direct echo following additional coronary revascularization, flap was noted in the LMT (c) with retrograde flow from the left anterior descending artery (LAD) (e) direct toward left circumflex artery (LCX) (f). AO: aorta, CALC: calcification, LA: left atrium

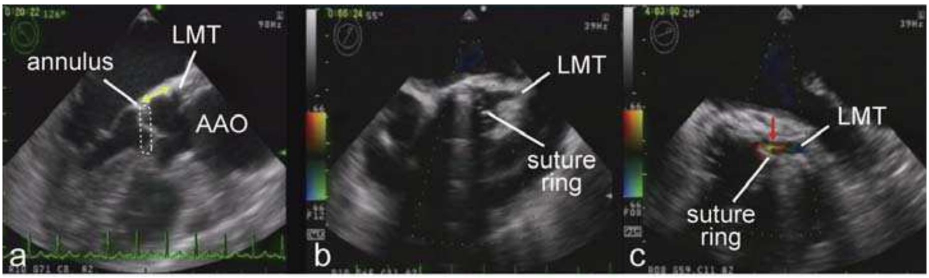

Fig. 9. Aortic valve replacement and coronary artery. a: Distance between the annulus and left coronary orifice is measured. b: no obstruction of left coronary orifice. c: accelerated flow in front of the left coronary orifice, suggesting the presence of narrowed space. AAO: ascending aorta, LMT: left main truncus

In aortic root repair procedures, the coronary anastomosis is routinely checked for stenosis immediately following declamping of the aorta. When there is significant stenosis, one should not proceed to weaning from bypass because it prolongs the duration of ischemic insults on the myocardium.

5.6 Air embolism of coronary artery

Air embolism in the coronary artery can occur in aortic valve surgery. Air not only enters the left ventricle during aortotomy, but also reaches the left atrium and even pulmonary veins. It moves to the left ventricular outflow tract during weaning from bypass and enters the coronary artery (predominantly the right coronary artery because of its buoyancy) (Orihashi et al, 1993, 1996).

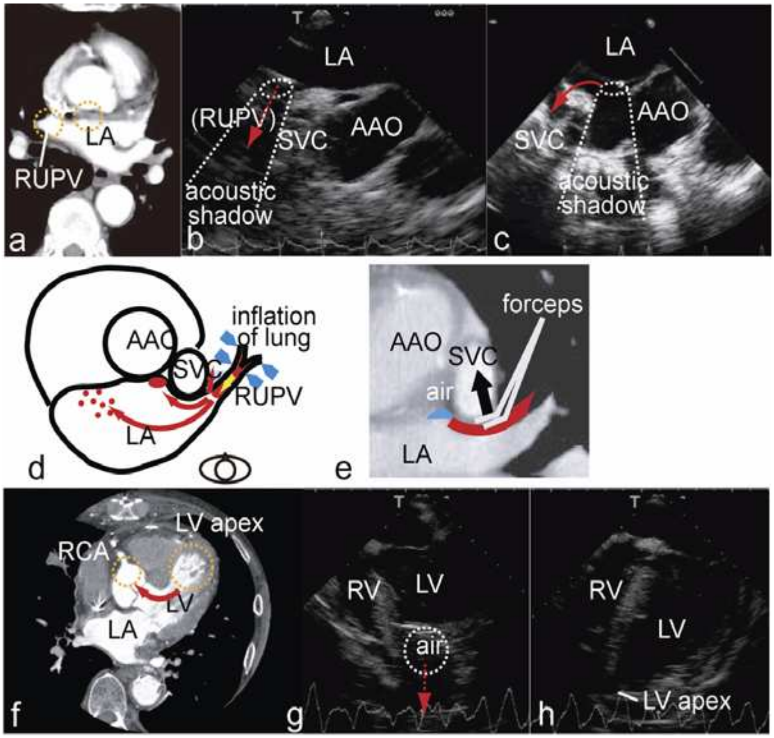

Fig. 10. Retained air visualized with TEE. a: Air retention in the right upper pulmonary vein (RUPV) and left atrium (LA), which is visualized with TEE (b: RUPV, c: LA). d: removal of air in the RUPV, e: removal of air in the LA. f: air in the left ventricular (LV) apex, which is depicted with TEE (g). h: after aspiration of air. AAO: ascending aorta, RCA: right coronary artery, RV: right ventricle, SVC: superior vena cava

Air embolism causes regional myocardial ischemia manifesting as a conduction disturbance and/or regional wall motion abnormality mainly in the inferior wall. Although the air is washed out within 10 to 30 minutes with gradual improvement of the ischemia, it prolongs the pump time and occasionally results in myocardial infarction. Despite the use of carbon dioxide gas inflation in the pericardial sac during cardiopulmonary bypass, wall suction easily removes the gas.

To prevent air embolism, it is important to detect air retention and remove it before it moves to the coronary artery. Common sites of air retention include the right upper pulmonary vein, left atrium, and left ventricle (Fig. 10a,f). TEE is useful for detecting and guiding aspiration of retained air.

Visualization of air in the right upper pulmonary vein is often tricky. The pooled air which fills it up to its ostium is hard to see, but a strong echo accompanied by side lobes and acoustic shadowing with a swinging motion indicates the presence of air at the orifice of the right upper pulmonary vein. As venous return resumes, the air pops up as bubbles in the left atrium or scrolls along the left atrial wall. The air in the left atrium often stays in a shallow pocket formed by the superior vena cava and ascending aorta (Fig. 10c). It can be aspirated directly with a needle or led to the vent port by lifting the superior vena cava with a forceps (Fig. 10d,e, c: red arrow). The adequacy of air removal can be immediately assessed by TEE.

The air in the left ventricle is visualized as a strong echo at the apex to the anteroseptal region. The air masks the image of the apex by acoustic shadowing (Fig. 10g). Aspiration by a needle often produces several milliliters of air. If the amount of air is small, it may be agitated to let the bubble out while the right coronary artery is pressed to avoid new air entry. Again, the outcome can be assessed by TEE (Fig. 10h).

When depressed ventricular contraction is associated with echogenic dots, especially in the inferior wall, air embolism is likely to be responsible and circulatory assist at a rather high perfusion pressure is advised. If such findings are not present, other causes are probable. Thus, TEE is helpful for differentiating the reasons for undesirable hemodynamics.

6. Assessment of prosthetic valve

The function of implanted prosthetic valves is assessed during weaning from cardiopulmonary bypass and is focused on transvalvular and perivalvular leakage. The former originates from inside of the suture ring and the leakage is usually directed inward. This type of leak is allowed to persist unless the regurgitant volume is high. The latter originates from the outside of the sewing ring and is directed outward. This is abnormal and should be addressed by the surgeon.

Unfortunately, the discs of the mechanical valve are hard to visualize by TEE. Instead, the ejected blood just above the valve prosthesis is checked. When the color signal fills the aortic lumen, an immobilized disc is unlikely.

A case of an everted leaflet of a bioprosthetic valve is demonstrated (Orihashi et al., 2010). This patient underwent aortic valve replacement with a Magna valve [TM] due to severe aortic regurgitation. Following aortic declamping, however, TEE showed an unusual transvalvular regurgitant flow in the left ventricular outflow tract. The noncoronary leaflet was fixed in an open position (Fig. 11). The 3D view from the aorta showed that the left ventricular outflow tract was visible in diastole on the noncoronary side. An attempt at weaning failed due to severe aortic regurgitation. Based on the TEE finding and the hemodynamic data, we decided to perform a second aortotomy.

There was no jammed thread or captured leaflet, but the noncoronary leaflet was everted. After it was manually corrected, the leaflet did not spontaneously evert. No needle hole or laceration on the leaflets was noted. Even if the bioprosthetic valve was replaced with another one, a similar event could have occurred. There was no reason for replacement with a mechanical valve. Reimplantation of the same valve would not have been beneficial as it would have prolonged the cardiac arrest time. Eversion of leaflet is unlikely to occur after it starts opening and closing. Thus, the aortotomy was just closed. After weaning from bypass, the leaflet was shown to close normally without significant leakage. Two years after discharge, this patient has had no recurrences of an everted leaflet.

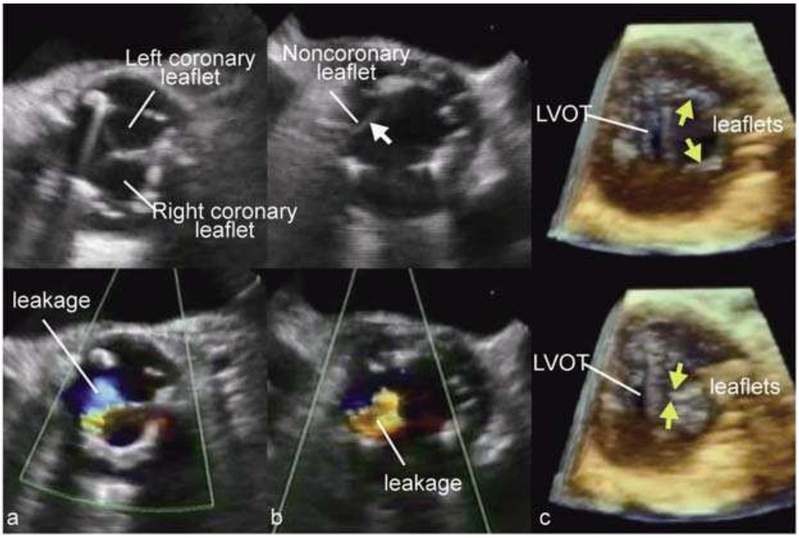

Fig. 11. A case of everted leaflet of Magna valve. a: severe aortic regurgitation in the noncoronary leaflet, b: immobilized leaflet visualized by lateral bending of the probe tip, c: 3D image of valve prosthesis. On the noncoronary side, the left ventricular outflow tract (LVOT) is seen from the aorta side

7. Echo-oriented aortic valve repair

In aortic valve repair or valve sparing surgery, aortic regurgitation is assessed by TEE. When significant regurgitation remains despite the best possible repair based on the preoperative assessment and acceptable coaptation by inspection, the mechanism of regurgitation under pressure loading needs to be identified in order to make additional repairs on the valve.

The origin and eccentricity of the regurgitant jet is an important key to assessing the problem. The former is assessed in midesophageal short-axis view which can examine which pair of cusps is responsible for incompetency. The latter is assessed in midesophageal aortic valve long-axis view to determine the mechanism of regurgitation. If the regurgitant jet is central and originates from the center of the three cusps, coaptation of the Arantius nodule is incompetent, either by deformity of the nodule or by tethering of the three commissures. When the regurgitant jet is deviated to the anterior mitral leaflet and originates from coaptation between the right coronary cusp and noncoronary cusp (Fig. 12b), prolapse of the right coronary cusp is most likely to be causative and plication of this cusp is indicated (Fig. 12c).

Aortic regurgitation can be caused by aortic dissection by three mechanisms: 1) prolapse of the leaflet due to detachment of the commissures from the aortic wall; 2) tethering of the commissures due to an enlarged sinotubular junction; and 3) invagination of an intimal flap into the aortic valve (Fig. 13 a,b,c). These scenarios can be repaired by reuniting the dissected layers and plicating the sinotubular junction to the size which is nearly equal to the aortic annulus diameter (Fig. 13 d,e). If significant regurgitation remains, the mechanism of regurgitation needs to be explored by TEE and additional interventions performed as necessary.

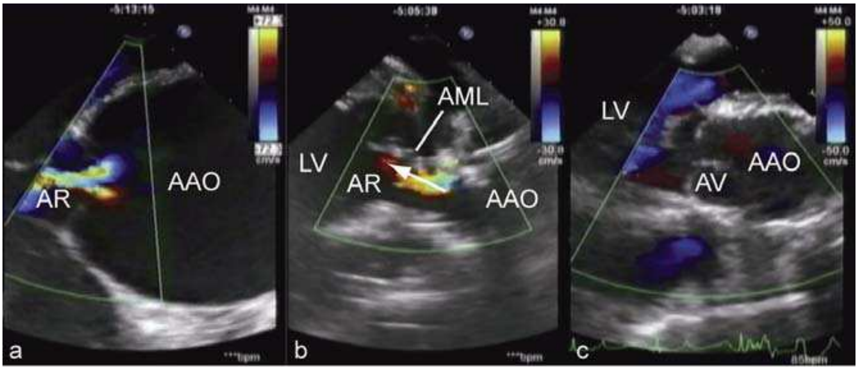

Fig. 12. Echo-oriented aortic valve repair. a: preoperative TEE image of aortic regurgitation (AR) by annuloaortic ectasia, b: residual regurgitation following initial repair with a Valsalva graft, which is directed to the anterior mitral leaflet (AML). c: no regurgitation after plication of right coronary cusp. AAO: ascending aorta, AV: aortic valve, LV: left ventricle

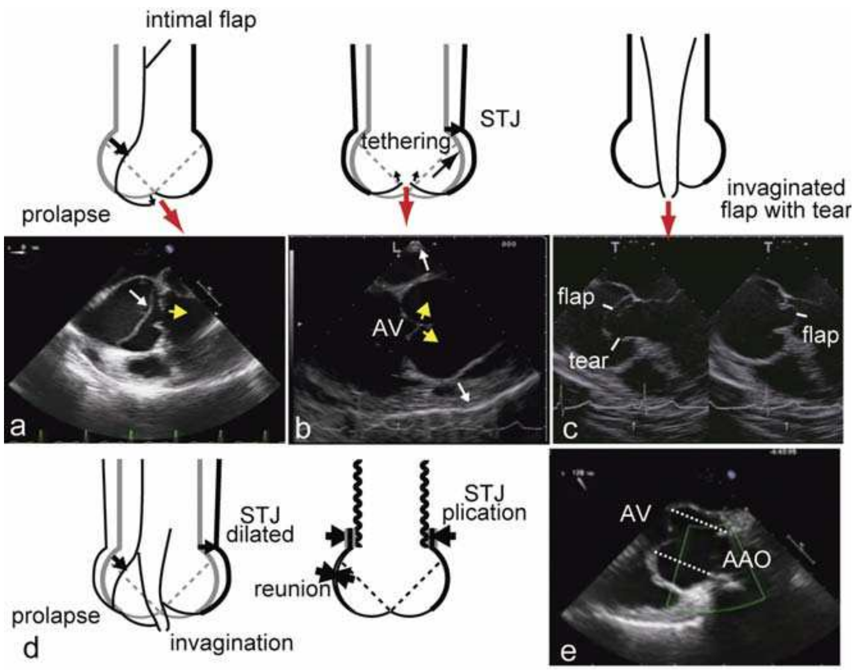

Fig. 13. Three mechanisms of aortic regurgitation in aortic dissection. a: prolapse of a leaflet due to a detached commisure, b: tethering of a leaflet due to an enlarged sinotubular junction (STJ), c: an invaginated flap with tear. d: repair of the sinus of Valsalva sinus based on these mechanisms. e: TEE view after repair. Note that the size of the aortic graft is nearly equal to the aortic valve (AV) annulus. AAO: ascending aorta

8. Systolic anterior motion of mitral leaflet

Systolic anterior motion (SAM) of the mitral leaflet occurs not only in cases with mitral valve repair but also in cases with aortic stenosis or hypertrophic cardiomyopathy. SAM may develop following aortic valve replacement and necessitates additional mitral valve replacement. The mechanism of SAM has been reported as being due to a Venturi effect or drag effect (Cape et al, 1989; Sherrid et al, 1993, 2003). There are several risk factors for developing SAM in mitral valve repair, including a short distance between the coaptation point and interventricular septum (C-Sept), a large angle between the mitral and aortic annular plane, an decreased length ratio of the anterior and posterior mitral leaflets, excess valvular tissue, and a hyperkinetic left ventricle (Maslow et al., 1999).

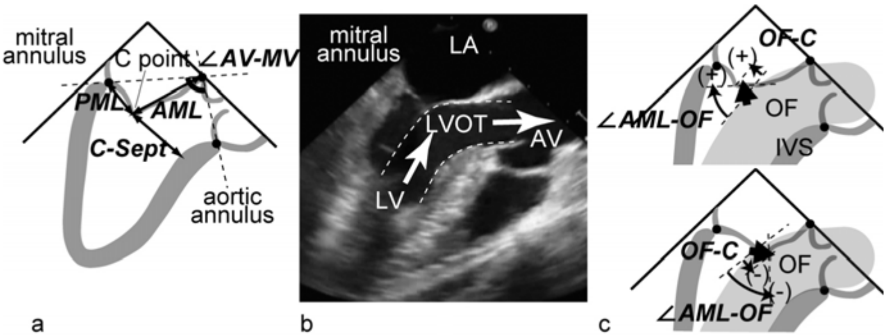

Fig. 14. Measurements for mechanisms of systolic anterior motion. a: conventional parameters, b: assumed outflow in the LV. c: newly introduced two parameters. AML: anterior mitral leaflet, ∠AML-OF: angle between AML and outflow (OF), AV: aortic valve, C-Sept: distance between coaptation and interventricular septum, LA: left atrium, LV: left ventricle, OF-C: distance between OF and coaptation, PML: posterior mitral leaflet

The author believes that there should be a common mechanism of SAM beyond the causative diseases and has analyzed the TEE images obtained in cases of mitral valve repair and septal hypertrophy. In the midesophageal long-axis view, several parameters related to SAM were examined (Fig. 14a): 1) C-Sept; 2) the ratio of lengths of anterior and posterior mitral leaflets (AL/PL ratio); and 3) the angle between the aortic and mitral annular planes (∠AV-MV). Since the LV to LVOT forms a curved but an isometric path (Fig. 14b), the virtual outflow (OF) was assumed as an isometric route along the interventricular septum with a width equal to the dimension of the aortic annulus. The angle and location of the AML tip relative to the OF (∠AML-OF, C-OF) was measured and defined as positive when the AML was away from the outflow and negative when it was within the outflow (Fig. 14c).
Measurements were done in 27 cases of mitral valve repair (before and after repair: 54 measuring points including 6 measuring points with SAM and one point of missing data) and 7 cases with septal hypertrophy which underwent mitral valve replacement. The above parameters were compared among three groups: MVP-SAM Group (valve repair without SAM: n=47), MVP+SAM Group (valve repair with SAM: n=6), and SH+SAM Group (septal hypertrophy with SAM: n=7). Among these three groups, there was no significant difference in the ∠AV-MV and AL/PL ratios. However, C-Sept, ∠AML-OF, and C-OF was significantly smaller in the SAM positive groups than in the negative group (Fig. 15).

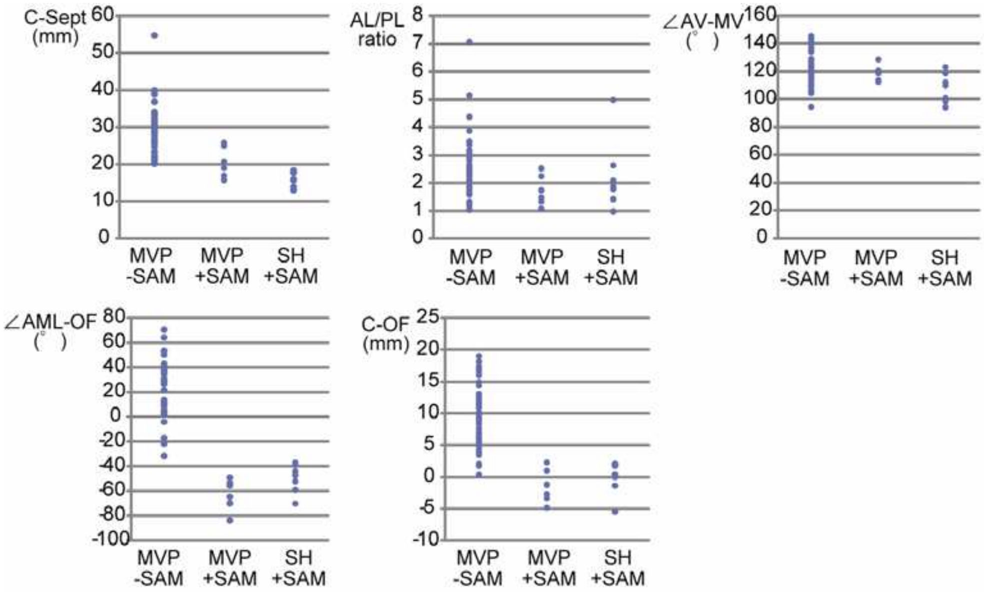

Fig. 15. Comparison between three groups. Among the three groups (mitral valve repair with or without SAM and septal hypertrophy with SAM), there was no significant difference in ∠AV-MV and AL/PL ratio, but C-Sept, ∠AML-OF, and C-OF was significantly smaller in the SAM positive groups than in the negative groups

These results indicate that a dragging effect is the common mechanism in mitral valve disease and septal hypertrophy. SAM occurs when the tip of the anterior mitral leaflet is located in the outflow with a tilted angle to be dragged toward the septum. To prevent SAM in aortic valve replacement, septal myectomy should be adequate so that the anterior mitral leaflet is located out of the new outflow after myectomy. To solve the tilting problem of anterior mitral leaflet, Alfieri's stitch, especially on the A1-P1 side, may be beneficial (Pareda et al, 2010).

In conclusion, intraoperative imaging by means of echocardiography provides a variety of data which can help guide the operation including: 1) avoiding unexpected complications; 2) enhancing the efficacy of surgical treatment; and 3) making immediate and appropriate decisions in cases of rare and unpredictable events. To take the best advantage of this capability, it is essential to efficiently and effectively utilize the modalities available with echocardiography.

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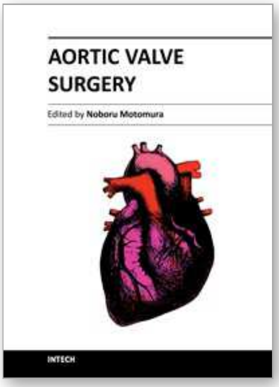

Aortic Valve Surgery

Edited by Prof. Noboru Motomura

ISBN 978-953-307-600-3
Hard cover, 246 pages
Publisher InTech
Published online 22, December, 2011
Published in print edition December, 2011

The aortic valve is located at the center of the heart. It is the core of cardiac anatomy and aortic valve surgery has led the field of cardiac surgery. This book describes all aspects of aortic valve surgery and it will help clarify daily questions regarding the clinical practice in aortic valve surgery, as well as induce inspiration and new insights into this field.