Imaging techniques in aortic valve and root surgery

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Summary and future perspectives

Summary

The present thesis described the additional value of cardiac imaging in the selection and evaluation of patients with aortic regurgitation and/or aortopathy undergoing aortic valve and root surgery. In the general introduction (Chapter 1), an overview was provided on aortic valve and root pathology, the indications for surgery, different valve-sparing surgical techniques and the role of multimodality imaging in the selection of patients for valve-sparing aortic root replacement.

Part I: preoperative evaluation of patients with aortic regurgitation and/or aortopathy

Part I focused on imaging performed in the preoperative period to evaluate the progression of disease and to identify patients who may be candidates for valve-sparing procedures. Chapter 2 evaluated the effect of aortic root dilation on the aortic valve geometry using 3-dimensional transesophageal echocardiography. There was an increase in aortic valve leaflet size in patients with aortic root dilation compared to patients with normal aortic roots. However, this adaptive mechanism seemed insufficient to compensate for the increased aortic root area, especially in patients with central aortic regurgitation. In addition, in eccentric aortic regurgitation, there was relative excessive leaflet tissue in relation to the aortic root area resulting in prolapse. In Chapter 3, the effect of aortic regurgitation on the mitral valve geometry was discussed. Aortic regurgitation is associated with left ventricular volume overload and thereby left ventricular dilation and eventually reduction in left ventricular ejection fraction. This may lead to an increased tethering of the mitral leaflets due to papillary muscle displacement on one hand and a decrease in closing forces on the other hand. The mitral valve adapts to the left ventricular dilation by increased leaflet length. However, when compensatory mechanisms fail, significant mitral regurgitation can develop, which occurred in 23% of aortic regurgitation patients. Factors independently associated with significant mitral regurgitation in patients with aortic regurgitation were a larger left atrial volume and a lower left ventricular ejection fraction. Chapter 4 investigated the effect of statin therapy in reducing the progression of aortopathy in bicuspid aortic valve patients. Patients on statin therapy were compared to non-users of this medication. Patients who used statins had smaller aortic root diameters at baseline and after a median follow-up period of 4.7 years even after adjusting for coronary artery disease, age and medication use compared with non-users. The average annual aortic root dilation rates were 0.08 mm/year for aortoventricular junction, 0.16 mm/year for the sinus of Valsalva, 0.12 mm/year for the sinotubular junction, 0.45 mm/year for the ascending aorta. The use of statins had no effect on the aortic root dilation rate. Chapter 5 described the use of multidetector row computed tomography of the aortic valve and thoracic aorta in 61 patients considered for valve-sparing root replacement. The aortic valve was successfully repaired in 36 patients whereas repair was not feasible or not successful in 25 patients. Patients with a reparable aortic valve had less often bicuspid aortic valve anatomy, less annular calcification and less commissural calcification compared to their non-reparable counterparts. The information provided by multidetector row computed tomography on valve morphology and calcification grade may be helpful in the preoperative assessment of aortic valve reparability. In Chapter 6, the additional value of transthoracic echocardiography in determining the right graft size used during the David reimplantation technique was evaluated. In 30 patients, undergoing valve-sparing root replacement with the reimplantation technique without additional leaflet repair, the average leaflet height, leaflet length and the total leaflet area were measured on echocardiography. Leaflet height (diameter = 1.1 • ((2 • 2/3 • leaflet height) + 2)), length (diameter = (2 • 2/3 • length) + 2) and area (diameter = 0.8 • ((2 • √(total leaflet area / π)) + 2)) were calculated based on transthoracic echocardiography formulas. Patients who received a smaller graft size than calculated with the formulas (undersized), had less often residual mild aortic regurgitation compared to patients who received an oversized graft. However, prospective validation of the formulas is needed before application in daily clinical practice.

Part II: postoperative evaluation of patients after aortic valve and root surgery
Part II focused on the role of imaging after aortic valve and root surgery. In Chapters 7 and 8 the postoperative left ventricular reverse remodeling after aortic valve and root surgery was evaluated. Chapter 7 evaluated the differences in postoperative left ventricular reverse remodeling in patients with acute and chronic aortic regurgitation. Both in patients with acute and chronic aortic regurgitation, there was significant left ventricular reverse remodeling. However, after aortic valve and root surgery for acute aortic regurgitation, the left ventricular end-diastolic volume was more reduced and global longitudinal strain indexed for the left ventricular end-diastolic volume was more preserved in comparison to those observed in patients with chronic aortic regurgitation. Furthermore, patients who underwent a valve-sparing procedure were compared to patients who underwent aortic valve and root replacement with a biological prosthesis in Chapter 8. Patients undergoing aortic valve and root replacement had significant larger left ventricular volumes before surgery as compared with their counterparts. Postoperatively, after a median follow-up of 46 months, both groups of patients showed a significant and sustained reduction in LV volumes, with a larger reduction in patients undergoing aortic valve and root replacement. The recurrence of significant aortic regurgitation during follow up was about 7-8% and not significantly different between repair and replacement techniques. Chapter 9 evaluated the postoperative change in left ventricular volumes and function in 97 patients with acute type A aortic dissection who survived the initial surgery. In this chapter, 3 different procedures were compared; valve-sparing root replacement (with the remodeling or reimplantation technique), supracoronary ascending

aorta replacement, and aortic valve and root replacement (with a biological or mechanical prosthesis). During follow-up, aortic regurgitation grade ≥2 was significantly more often observed in supracoronary ascending aorta replacement and valve-sparing root replacement compared to aortic valve and root replacement. Left ventricular volumes remained stable in valve-sparing root replacement and aortic valve and root replacement whereas in supracoronary ascending aorta replacement, left ventricular volumes significantly increased over time. In addition, among patients with recurrent aortic regurgitation grade ≥2 at follow-up, left ventricular volumes increased significantly over time whereas patients without recurrent aortic regurgitation did not show significant left ventricular dilation. In Chapter 10, the effect of aortic valve replacement on the conduction system was evaluated. Patients who underwent sutureless, transcatheter and conventional stented biological aortic valve replacement were compared. Patients who underwent sutureless and transcatheter aortic valve replacement developed more often new-onset complete left bundle branch block directly after aortic valve replacement in comparison to conventional aortic valve replacement.

Chapters 11 and 12 focused on the postoperative changes in aortic diameter. In bicuspid aortic valves, the aortic root growth rate has been described to be faster compared to that of patients with tricuspid aortic valves due to an underlying genetic substrate and/or altered hemodynamics. In Chapter 11 the aortic root dilation rate in patients with bicuspid aortic valve anatomy was compared to patients with tricuspid aortic valve anatomy before and after aortic valve replacement to obtain better insight in the mechanisms of aortic root dilation in bicuspid aortopathy. The preoperative aortic root dilation rate was significantly faster in patients with bicuspid valve compared to patients with tricuspid valve whereas after surgery, the aortic root dilation rate was comparable between groups, indicating that hemodynamics play an important role in the increased aortic dilation in bicuspid aortopathy.

Chapter 12 investigated the growth rate of the descending thoracic aorta in patients operated for acute type A aortic dissection. The growth rate was assessed using a volumetric measurement of the descending thoracic aorta on multidetector row computed tomography. Increased growth of the complete lumen and in particular of the false lumen of the descending thoracic aorta after aortic dissection was associated with higher risk on secondary intervention on the descending thoracic aorta.

Conclusion and future perspectives

Alongside with increasing life expectancy in the general population, the prevalence of aortic valve disease increases; hence there is a need for aortic valve surgery with long durability and low complication rate. Mechanical and biological (including transcatheter) prosthesis and aortic valve repair are the available approaches for patients with aortic valve disease. The need for reoperation (aortic valve repair and biological valves) should be balanced against the risk on thromboembolic and bleeding complications (mechanical valves that need lifelong anticoagulation). In addition, patient's preference in this era of shared decision making is an important factor. Aortic valve preservation has shown promising results, however at present there are many different surgical techniques and modifications and the success of these techniques are largely operator-dependent. In the coming years, we may witness standardization of surgical repair techniques and development of durable and less invasive prostheses and these may be possible with the help of developments in 3-dimensional imaging techniques and postprocessing softwares that allow 3-dimensional printing and simulation. Currently, thorough evaluation of the aortic root dimensions and mechanism of aortic regurgitation with echocardiography is mandatory prior to surgery. Transesophageal echocardiography provides better visualization of the aortic root and characteristics of the aortic cusps than transthoracic echocardiography. In addition, 3-dimensional echocardiographic techniques have shown to be more accurate in grading aortic regurgitation than 2-dimensional echocardiography. The ascending aorta is better visualized with multidetector row computed tomography or cardiac magnetic resonance. These 3-dimensional imaging techniques permit reconstruction of the aortic root complex and with specific software, the structure can be printed out in three dimensions allowing the surgeon to tailor the surgical approach. Ongoing research has led to important advances in finite element analyses that provide cardiac models and simulations of the aortic root reproducing the mechanism of aortic regurgitation and evaluating the effects of the surgical technique on the wall stress. This cardiac modelling will permit in the near future personalization of the aortic valve repair, probably resulting in better durability of the repair and competence of the aortic valve. In addition, patients should be discussed at the heart team meeting preparatory to surgery taking into account all information obtained by preoperative cardiac imaging to determine the most appropriate surgical technique for that particular patient. This may require centralization of care with valve-preserving procedures only executed in high volume centers with dedicated surgeons and dedicated cardiologists working together to provide the optimal care. At present, the aortic valve insufficiency and ascending aorta aneurysm international registry (AVIATOR) is ongoing, chaired by Dr. Lansac. The aims of the AVIATOR registry comprise optimized multidisciplinary patient care, uniform scientific reporting and assessment of quality of care. This international multicenter study will play a key role in the coming years to establish the place of repair in aortic valve and root surgery which might impact on guidelines.