Masters of Cardiothoracic Surgery

Root remodeling for aortic root dilatation

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Introduction

Dilatation of the ascending aorta has been found to be the most frequent pathogenic mechanism in aortic regurgitation (1,2). Root remodeling was first proposed by Sarsam and Yacoub as an operation for patients with aortic regurgitation and aortic aneurysm (3), with the assumption that regurgitation was solely due to aortic dilatation. The initial results were good, demonstrating that aortic valve function could be improved or even normalized. The concept of root remodeling was then challenged by aortic valve reimplantation within a vascular graft, as proposed by David (4). A complementary (rather than competitive) role of these two procedures was hypothesized (5). Experimental data investigating cusp mobility after application of these two techniques showed essentially normal cusp motion after root remodeling, which was strikingly different from the abrupt opening and closing movements after valve reimplantation (6).

Subsequent studies indicated that the initial results proved difficult to reproduce. The degree of preoperative aortic regurgitation (7) or root dilatation (8), or the presence of acute aortic dissection (9) were observed as risk factors for postoperative aortic regurgitation. None of the authors, however, proposed a plausible mechanism of valve failure and it remains unclear whether failure was induced by the operation per se or the actual conduct of the operation.

We have previously found that cusp prolapse can be induced by root replacement, which was for our institution the most frequent reason for secondary valve failure (10). Concomitant repair of cusp prolapse with root remodeling proved to be safe, and it did not compromise the late results (11). Based on the analysis of our failures and investigations in normal cusps, we introduced the effective height concept into aortic valve repair and valve-preserving surgery (12). Intraoperative determination of the effective height of aortic cusps allowed for more objective assessment of cusp configuration and reproducible correction of cusp prolapse (12,13). Furthermore, we have recently showed that the guided combination of prolapse repair with root remodeling has led to significantly better long-term aortic valve function compared to the isolated root procedure (14).

In comparison to valve reimplantation, root remodeling consistently takes less time to perform and is applicable in acute dissection as well as in the presence of the usual cardiovascular comorbidities seen in proximal aortic dilatation. Root remodeling thus has become our preferred approach to dilatation of the aortic root. In light of the frequent existence of cusp prolapse it has become an aortic valve repair procedure rather than an aortic operation.

Operative technique (*Video 1*)

Exposure is essential for the assessment and correction of the aortic valve after root replacement. We perform this operation through a median sternotomy. Aortic and right atrial cannulation are performed in typical fashion; if aneurysmatic dilatation extends into the arch we prefer direct cannulation of the distal arch over other cannulation sites.

Following aortic cross-clamping the aorta is incised longitudinally and cardioplegia is given by antegrade infusion into the coronary ostia. The aorta is transected 5 to 10 mm above the commissures, and stay sutures are placed through the commissural tissue for later exposure. The valve must be carefully assessed before making a decision in favor of valve preservation. Calcification, cusp retraction, or the presence of extensive fenestrations make the aortic valve an uncertain substrate for preservation or repair. We usually proceed with

repair if geometric height exceeds 18 to 19 mm (15).

Mobilization of the root involves the commissural areas. The sinuses are excised, leaving approximately 5 mm of aortic wall adjacent to the cusp insertion. The coronary ostia are mobilized just sufficiently to allow for later anastomosis into the graft. We choose a tubular graft correspondent to patient size, taking geometric cusp height into consideration. In most instances a 26 mm graft will be adequate; in the presence of a small patient or limited cusp height we choose a 24 mm size. The graft is tailored to create 3 symmetric tongues.

The graft is then sutured into the excised sinuses using a 4-0 polypropylene suture, taking care to place the sutures close to the cusp insertion lines. We begin in the nadir of a sinus and move towards the respective commissures. Initially we space the stitches 2 to 3 mm apart both on the graft and the aorta. When approaching the commissures the distance between stitches is widened to 4 to 5 mm in order to bring extra graft material into the sinus. If necessary the incision in the graft is extended as appears appropriate. This will allow the commissure to extend maximally when the graft is pressurized, an effect that has been identified as crucial for adequate valve configuration. The suturing is continued through the remaining 2 sinuses, and then are tied.

Assessment of the aortic valve after completion of the actual remodeling procedure is an essential component of the operation. In order to have adequate exposure the Dacron graft is trimmed to 1 to 2 cm above the commissures. Polypropylene sutures fixed to the commissures are placed under tension, taking care to maintain the original commissural orientation. Accordingly, the commissures are pulled upward and outward, mimicking the pressurized corporeal condition. Using a commercially available caliper (MSS-1, Fehling Instruments, Karlstein, Germany), effective height is measured on all 3 cusps as an indicator of cusp configuration. Normal effective height should be 9 to 10 mm. An effective height of less than 9 mm indicates prolapse, which in most instances should be corrected. In addition, the height of the free cusp margins relative to each other is compared.

Prolapse is frequently found after valve-preserving root replacement irrespective of the preoperative degree of aortic regurgitation. We have found that it can be best corrected by plication of cusp tissue in the central portion of the free margin, possibly also extending it into the body of the cusp. This plication is continued until the respective cusp has an effective height of 9 to 10 mm upon reassessment. Ultimately all free cusp margins should be at identical level, usually with equivalent effect cusp heights.

In the past 3 years we have found that the likelihood of aortic valve competence can be improved by the addition of annuloplasty (16). This is easily done using a PTFE suture placed at the level of the basal ring. A Hegar dilator is inserted into graft and left ventricular outflow tract; we use a 25 mm Hegar in conjunction with a 26 mm graft. The annular suture is then tied firmly around the Hegar. Finally the coronary ostia are implanted into the graft in typical fashion. We place the sutures close to the orifices in order to completely eliminate diseased aortic wall. The Dacron prosthesis is then anastomosed to the distal ascending aorta. If necessary a second segment of graft can be added for more extensive aortic replacement.

The heart is deaired and coronary circulation resumed. Careful echocardiographic assessment of aortic valve function is essential by transesophageal echocardiogram.

A regurgitant leak of more than minimal severity should prompt consideration of reexploration to improve aortic valve function, particularly if the jet is eccentric.

Comments

We have used the remodeling operation in more than 700 patients for a variety of valve morphologies and lesions. We have found the concept versatile enough to be adapted to root dilatation in the presence of bicuspid (17) or even unicuspid valve anatomy. For asymmetries of the root the graft has to be tailored adequately. Probably the most important lesson we have learnt is that root remodeling can be safely combined with cusp repair (11,18). In fact, in the majority of patients it must be combined with cusp repair procedures in order to correct preexistent prolapse. Prolapse often arises from the normalization of the enlarged sinotubular dimensions that are associated with increased cusp size (19). In addition, localized cusp prolapse may already be present in the dilated root. We have found that moderate or severe aortic regurgitation is almost always associated with prolapse of at least one cusp.

We have found the application of the effective height concept with intraoperative use of the caliper an important prerequisite for reproducibly achieving near-normal valve configuration and function (12). Simple "eyeballing" compares the relative height of the free cusp margins and may detect prolapse of one cusp. It does not prevent the generation of symmetric prolapse which has been found to result in poor valve durability (10,20). Combining root repair with cusp repair has become routine in our practice;

it has changed the character of this operation from an aortic procedure to aortic valve reconstruction. With the application of these principles we have been able to obtain 10-year stability rates in the range of 90% to 95% (14).

A controversial aspect in valve-preserving root replacement has been the question of stabilization at the level of the basal ring. This is automatically included in the valve reimplantation procedure (4) but is absent in root remodeling. Interestingly we have not yet observed relevant dilatation at the basal level. Nonetheless, a recent analysis of our experience indicated a basal diameter of more than 28 mm to be a risk factor for late valve failure (14,21). Interestingly, this risk was applicable to both valve reimplantation and root remodeling, suggesting that basal diameter is not a risk per se, but is rather an indicator of larger root size and of higher likelihood of prolapse induced through normalization of root dimensions (14). The use of cusp plication guided by effective height measurement could largely obviate the negative effect of basal dilatation. Nonetheless these observations prompted us to explore the combination of basal suture stabilization with root remodeling (16). The early results up to 3 years showed no difference in valve stability, but demonstrated a higher proportion of competent valves (16).

Overall we have been satisfied with the clinical results of root remodeling. The incidence of valve-related complications has been less than 1% per patient-year, and thus lower than what has been published for composite replacement of valve and aorta. The presence of ventricular muscle in the right or left coronary sinuses has not been an obstacle to this form of valve-preserving surgery, since the graft tongues can easily be sutured to the myocardium close to the cusp insertion lines. Further follow-up will show whether the addition of the annuloplasty is able to improve valve stability in the long term even further. In summary, root remodeling leads to normalization of aortic valve function with stable long-term results if normal aortic valve configuration is achieved.

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