Valve-Sparing Aortic Root Replacement: Current State of the Art and Where Are We Headed?

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Since Sir Magdi Yacoub pioneered aortic root "remodeling" in 1979 [1, 2] and Tirone David [3] followed in 1988 with the "reimplantation" method to preserve the patient's native aortic valve when replacing an aortic root aneurysm with a graft, both procedures have been demonstrated to be applicable to many patients with aortic root pathology and aortic regurgitation (AR), including those with the Marfan syndrome (MFS) [4]. The hope has been that cumulative valve-related morbidity and mortality would be lower after a valve-sparing operation compared with after composite valve grafting utilizing a mechanical prosthesis and indefinite warfarin anticoagulation, which represents the surgical "gold standard." While preserving the native aortic valve liberates the patient from the need for life-long anticoagulation, the unanswered question has been valve durability after a Yacoub or David procedure. The popularity of valve-sparing aortic root replacement has escalated rapidly recently owing in no small part to patient demand, but the key question remains [4]: How many years without warfarin will the valve last before a second operation might become necessary? This also is the rationale for the ongoing international registry in 22 North American and European centers sponsored by the National Marfans Foundation comparing composite valve grafting with various types of valve-sparing aortic root replacement procedures in MFS patients. In the interim, what do we know with any modicum of certainty? Based on currently available knowledge, valve durability unfortunately has not been universally satisfactory, prompting some well-known centers to argue that valve-sparing aortic root replacement should be abandoned or limited just to those patients who cannot safely receive anticoagulation therapy [5, 6]. Further, the mortality rate for valve-sparing aortic root replacement has been excessive in other centers [7]. These problems are related in part to surgeon inexperience in aortic root surgery, surgeon unfamiliarity with the pathological anatomy, lack of conceptual understanding of the procedure by surgeons (eg, unnecessarily using pledgeted sutures inside the left ventricular outflow tract tied firmly to the graft), and false surgical pride.

First, the 15- to 20-year results after composite valve grafting in patients with MFS were shown by Gott and colleagues [8] to be outstanding if operation was performed electively before acute aortic dissection or aortic rupture. Morbidity attributed to anticoagulant-related complications was rare, and the thromboembolic and prosthetic valve endocarditis rates were low. Thus, the clinical performance bar has been set very high: the incidence of valve-related morbidity and mortality after valve-sparing aortic root replacement must equal or exceed these standards [4]. Either type of valve-sparing aortic root replacement is safe, fairly reproducible, and associated with reasonable results in selected patients, at least in the hands of certain surgeons. The surgical learning curve, however, is very steep and unforgiving. If the aortic valve cusps are not pathologically damaged, the vast majority of these valves can be conserved; relative contraindications in the past (eg, very large aortic annulus, severe AR or eccentric AR jet due to cusp prolapse, or both, and so forth) have been overcome with new surgical techniques.

The outcomes at 10 years and beyond notwithstanding excellent survival statistics, however, are not ideal. Even in the best surgical centers, 25% to 30% of MFS patients undergoing valve-sparing aortic root replacement have 3+/4+ recurrent AR at 10 years, and small numbers have required aortic valve replacement (AVR) [9]. The long-term durability data are still scanty and follow-up is limited, but most surgical authorities today use the David reimplantation method (including creation of Dacron pseudosinuses) since one can adjust annulus size to whatever is ideal for that individual patient and the annulus cannot dilate postoperatively [4]. The incidence of postoperative bleeding is higher after a Yacoub procedure [9]. Professor Sir Magdi Yacoub's personal results in 82 MFS patients showed that 17% required reoperation by 10 years, and an additional 22% had moderate AR at the time of last follow-up (mean, 5.5 years; median, 3) [10]. Discouraging results at Johns Hopkins in children and young adults after Yacoub procedures prompted

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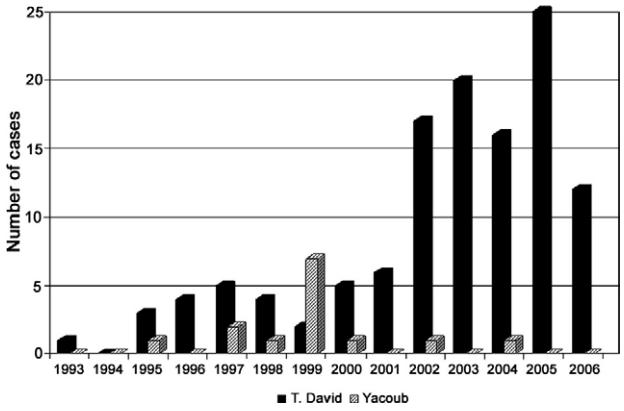

Fig 1. Distribution of valve-sparing aortic root replacements over 13-year experience at Stanford according to procedure type. Note that the 2006 data column reflects only 4 months (January through April). (Black bars = T. David; shaded bars = M. Yacoub.)

Cameron to switch to the David technique in 2002 [11]. The Hannover (Germany) 1993 to 2005 experience (exclusively T. David-I reimplantation using a cylindrical graft) totals 325 patients, 59 of whom had MFS [12]. Freedom from AVR was 80% ± 9% at 10 years, but MFS was a risk factor for late AVR. David's most recent updated experience in 220 patients (40% with MFS; mean age, 46 years; average follow-up, 5.2 ± 4 years) revealed an operative mortality of 1% (3 of 220) and overall freedom estimate from 3+ or 4+ AR of 85% ± 5% at 10 years (94% ± 4% after David reimplantation versus 75% ± 10% after Yacoub remodeling, $p = 0.04$) [13]. Late AVR was necessary in 5 patients (freedom from AVR at 10 years was 95% ± 3%). David and colleagues [13] concluded that the reimplantation method proffers better durability; however, it should be noted that multivariable analysis using propensity score matching or case control statistical techniques were not employed to test this hypothesis rigorously, as the Yacoub and David patient cohorts differed.

The basis for my opinion and prejudices rests on our 13-year experience at Stanford, where we have performed 134 valve-sparing aortic root replacement procedures between July 1993 and April 2006. Seventy-two patients had MFS. There were a total of 120 T. David reimplantations and 14 Yacoub remodeling procedures (Fig 1). We started with the T. David-I operation and then tried the Yacoub technique in the late 1990s; even though the remodeling approach is quicker and saves one suture line, one reoperation due to annular dilatation and recurrent AR prompted abandoning the Yacoub approach after 12 adult cases. We then reverted to the T. David-IV technique, and in May 2001 (the same month Dr David independently but similarly began using a larger graft necked down both proximally at the annulus and distally at the sinotubular junction) adopted the T. David-V method.

In December 2002, we developed our simplified T. David-V technique ("Stanford modification") using one large graft and one small graft, which creates large, billowing Dacron pseudosinuses [14]. Twenty-five cases were performed in 2005 and 12 in the first 4 months of this year, which extrapolates to a total of 30 to 40 cases in 2006. I continue to prefer fabricating a custom-designed "sinus prosthesis" using two grafts because every important dimension (ie, new annular diameter, sinus diameter, sinus and commissure height, and sinotubular junction diameter) can be individualized for each patient; the commercially available sinus graft developed by De Paulis does not provide this unlimited degree of flexibility. The difference in sizes between the large and small grafts has varied from 8 to 12 mm, with the large graft diameter ranging from 30 to 36 mm (one was 38 mm).

On the other hand, one can oversize the proximal graft excessively; I do not concur with Aybek and colleagues [15] or Gleason [16] who use a "$2 \cdot h + 2$" (h = average cusp height in mm) formula to select the proper proximal graft size, nor does David [17]. In many patients, reducing the size of a dilated aortic annulus is an essential element of the operation to restore valvular competency; this is easily accomplished by necking down the proximal end of the large graft with several small plicating sutures [14], taking care to calculate that this will be the external diameter of the aortic annulus, not the internal diameter. Being able to cut off the large graft above the top of the commissures facilitates visualizing the sinus rim reimplantation suture line (instead of sewing inside a long, small caliber "chimney" graft as in the T. David-I technique) and allows recreation of more optimal three-dimensional geometry of the sinuses and cusp hinge lines, especially in patients with MFS who have very tall commissures (upward of 5 cm in length) and a relatively bulky rim of aortic tissue contiguous with the hinge of the cusps [14]. In recent years, I have shortened the free margin of one or more aortic cusps in more than 75% of cases; this is done using a 6-0 Gore-Tex (W.L. Gore & Assoc, Flagstaff, Arizona) suture to imbricate the central portion of the cusp (the nodulus of Aranti) to correct preexistent cusp prolapse (associated with eccentric AR) or to craft an equal and high coaptation level for all three cusps (striving to create greater than 5 mm of cusp coaptation zone) or when making a large annulus much smaller inadvertently creates prolapse, usually involving the right or noncoronary cusp.

There has been only 1 operative death (secondary to complications arising from a nondominant right coronary artery anastomosis in a teenager who also required concomitant total arch replacement) among the first-time cases, and 1 late death (suicide). Two patients have required reoperation owing to recurrent AR: a woman, 7 years after a T. David-I (cusp edges thickened and retracted), and a very young man with MFS who had marked annular dilatation 2 years after a Yacoub remodeling procedure. Progressive mitral regurgitation prompted reoperation in a third patient. At 10 years, we are very satisfied with the durability of the David reimplantation method; all patients have zero or 1+, nonprogressive AR on serial follow-up echocardiograms. Conversely, some of the adult Yacoub patients do have 2+ AR, but it is not yet progressing. Postoperatively, we assessed aortic root and downstream