Less Invasive Treatment of Heart Valve Disease

a report by
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After the advent of the heart–lung machine, which permitted open-heart surgery, in 1953, valve surgery was one of the most important advances in cardiac surgery. Initially, only conservative procedures were possible, but the first orthotopic human implantation of an artificial valve, by Starr in 1960, permitted the replacement of most cardiac valves not amenable to repair. Since then, more than a million and a half patients have had valve replacement using countless models of prostheses. However, the complications related to valve prostheses, often resulting in the patient’s death, led to the development of valvuloplasty techniques, especially of the mitral valve, pioneered by Carpentier1 and Duran in the early 1970s.2 The results of mitral valve conservation have been clearly superior to those of replacement, especially in degenerative mitral insufficiency. More recently, several authors have developed techniques of aortic valve repair, but these attracted less attention, mainly because aortic valve replacement is associated with significantly lower morbidity than mitral valve replacement.

Classically, valve surgery required an open-chest approach, via either mid-sternotomy or thoracotomy, which have their own specific morbidity and obliged the patient to go through a relatively long period of discomfort and restricted mobility. Hence, from the beginning there has been a search for less invasive approaches, which initially meant smaller incisions, then, more recently, endoscopic approaches. However, cardiopulmonary bypass, which remained an essential component of all these techniques, is directly associated with the morbidity and mortality associated with valve surgery. Hence, the concept of heart surgery without the use of the heart–lung machine is appealing. Off-pump cardiac surgery has been used extensively for coronary surgery,3 facilitated by the superficial location of the coronary arteries, but valves are placed well inside the heart and the complex procedures required for repair or replacement mandate an arrested heart. This has changed recently with the development of techniques and devices that permit repair of or replacement of heart valves in the beating heart.

In this article, the concept and results of less invasive techniques of valve intervention by two different approaches are discussed: minimised incisions and off-pump (beating heart) procedures.

Minimal-access Valve Surgery

Besides the advantage of diminution of the trauma associated with large incisions, initial efforts to decrease the size of incisions were based on a cosmetic necessity. This was also the reason for the return to thoracotomy rather than sternotomy access, via submammary incisions, especially in women.4 This access, which was preferred in the early days of valve surgery, is particularly useful in mitral and tricuspid valve procedures, but is not as appropriate for the aortic valve, for which many types of ministernotomy approaches were developed. These were essentially aimed at avoiding full sternal split, allegedly providing better stability of the chest wall after closure and shorter post-operative recovery time.5 The trade-off of these approaches is less space for the surgeon to work, which led to the development of special instruments and bypass cannulae. Theoretically at least, the quality of the procedures could be impaired, although many surgeons have developed skills that allow them to match the short-term results of classic approaches. However, these new techniques are technically more complex and therefore far from being universally accepted, and are certainly not within the reach of all surgeons.

Another approach to minimally invasive surgery is video-assisted surgery, which is associated with minimised skin incisions. This type of technique has been used for a long time for all sorts of abdominal surgery with excellent results and, above all, with the preference of patients, who appreciate the reduced discomfort and the cosmetic results, sometimes in detriment of the efficiency. Often it is patient demand that drives the utilisation of some techniques, and this type of technique has definitely become favoured — hence the natural extension to cardiac surgery, where this was initially used for minor procedures such as ligation of the patent ductus arteriosus, and then extended to more complex operations such as coronary artery bypass surgery, again taking advantage of the superficial anatomy of the coronary arteries. However, valves could be reached only in the arrested and open heart under cardiopulmonary bypass, which could not be instituted in the classic way — with aortic and caval cannulation. The problem was solved by using femoral or iliac artery and vein access with special cannulae that can be inserted percutaneously.6 Femoro-femoral bypass had been used in the early days of cardiac surgery but was abandoned in favour of direct aortic and caval cannulation, which
was considered a safer approach, especially concerning asepsis. Besides this peripheral cannulation, special catheters were developed to be advanced to the ascending aorta for internal occlusion and cardiopulmonary bypass in order to achieve heart arrest and thus better conditions for valve visualisation. However, this system, developed by the HeartPort Company, has had several complications, including dissection of the ascending aorta and of the arch and cerebral embolisation, and was never able to attract wide acceptance.

Video-assisted surgery usually requires three skin ports for the video camera and light source, and both left and right-hand instrumentation. In the case of valve surgery, a fourth port is often used for introduction of the aortic cross clamp. These ports are placed at different intercostal spaces, thus multiplying the number of intercostal nerves that can be injured during the procedure; this is the cause of much discomfort, which the procedure was supposed to minimise.

Another technical problem related to this type of procedure is the need for long instruments, which magnify the natural tremor of the human hand and make handling of the structures much more difficult. This was minimised by the introduction of computerised robotic arms to handle the surgical instruments and the camera. For the latter, special voice-controlled arms were developed. Robotic-assisted surgery potentially permits the operation to be performed by a surgeon located at unlimited distance, aided locally by someone who can position the robotic arms and the instruments. However, these systems have until now failed to meet expectations and are extremely expensive. Contrary to initial predictions, only a handful of cardiac surgical units remain faithful to them and only for appropriately selected cases.

**Beating-heart Valve Intervention**

A little more than a decade ago, balloon mitral commissurotomy, a new method of treatment of rheumatic mitral valve stenosis, was developed. It consists of splitting the fused commissures of the valve by a balloon-tipped catheter. This method, which followed identical use in dilatation of the aortic and pulmonary valves, especially in congenital cases, has almost replaced open surgical commissurotomy. However, the valve areas achieved are not as large as those reported by some groups.13

Much more recently, the percutaneous transcatheter approach to mitral valve regurgitation has been explored. In the last two to three decades, mitral valvuloplasty performed as an open-heart procedure has gained much popularity. The most important techniques involved in this operation are correction of leaflet prolapse and annuloplasty of the dilated/deformed annulus. Exceptionally good results have been reported, especially for degenerative disease.14 Recently, the feasibility of the edge-to-edge repair (Afieri) by a metal clip mounted in the tip of a catheter was demonstrated and is being applied by some groups.15 On the other hand, annuloplasty devices placed in the coronary sinus during cardiac catheterisation have been developed,16 but the anatomy of the coronary sinus is variable and its relationship with the mitral annulus is not constant.17

Not unexpectedly, these methods have not yet met expectations and, for the time being, patients with mitral valve regurgitation benefit the most from conventional surgery, independent of the use of the minimal-access techniques described above. In contrast to the mitral valve, the majority of the aortic valves cannot be repaired and require replacement. Recently, a new approach to heart valve intervention has arisen in the form of replacement by a valve attached to the tip of a catheter introduced from a peripheral artery or vein. This method was initially used for replacement of the pulmonary valve and good results were obtained by several authors.18 This procedure is facilitated by easy access via a peripheral vein and by the less essential nature of the pulmonary valve, as moderate dysfunction of this valve is relatively well tolerated.

The natural sequence of this experience was the extension to the aortic valve, but this valve is far less tolerant to even moderate degrees of dysfunction. Positioning of the prosthesis is here far more difficult, and peri-prosthetic leakage and the potential for coronary obstruction are the main drawbacks. This procedure is so far used only in so-called compassionate cases. However, because the concept of valve replacement without opening the heart is appealing, the percutaneous transcatheter approach is being challenged by a transapical approach, which has the advantage of a much easier and more accurate positioning because of the shorter way to the valve.19 Several types of self-expanding valves have been developed for this type of utilisation, but the procedure remains experimental.20 A similar approach is being sought for mitral valve replacement, but positioning is here even more difficult than for the aortic valve.

**Conclusion**

Until recently, the principles of valve surgery have remained mostly unchanged since the early 1960s. Valve conservation and replacement have specific indications and the results are generally good. Newer valve prostheses are more efficient and somewhat less thrombogenic and it is difficult to conceive that major advances will be around the corner. The new devices being developed for catheter-based procedures do not conform to widely accepted standards applied for over four decades with the classic prostheses. Hence, it is to be expected that it will take some time before transcatheter valve repair and replacement may reach general use. However, progress has undoubtedly been made in decreasing the invasiveness of conventional valve surgery, and it is conceivable that in the future a significant number of these procedures may be performed with the resulting diminution of surgical trauma and improved comfort to the patient.