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Artículo especial

Results of aortic valve replacement with the pulmonary autograft-A critical appraisal of the Ross operation

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Resultados de la sustitución de la válvula aórtica con autoinjerto pulmonar: análisis crítico de la intervención de Ross

La sustitución de la válvula aórtica utilizando la propia válvula pulmonar del paciente, el autoinjerto pulmonar, conocida como intervención de Ross, ha visto aumentada su popularidad después de una adopción inicial lenta. Hoy día muchos cirujanos la consideran como intervención de elección en niños y pacientes jóvenes. Sin embargo, hay ciertas dudas sobre el comportamiento y resultados alejados tanto del autoinjerto como del homoinjerto utilizado para la reconstrucción del tracto de salida del ventrículo izquierdo.

En esta revisión se efectúa un análisis critico de los aspectos técnicos de la intervención y de sus modificaciones, se repasan los resultados disponibles de series amplias sobre niños y adultos incluyendo nuestros propios resultados y se discuten los problemas clave del procedimiento, el potencial de dilatación del autoinjerto en la circulación sistémica y la durabilidad del homoinjerto en el tracto de salida del ventrículo derecho.

Concluimos que la intervención de Ross ofrece una reparación duradera y eficaz en niños y adultos jóvenes.

Palabras clave: **Válvulas. Aorta. Operación de Ross. Autoinjerto. Congénito.**

Replacement of the aortic valve with the patients own pulmonary valve, the pulmonary autograft also know as the Ross operation is after initial slow adoption increasingly used. It is today seen by many surgeons as the procedure of choice in children and young adults. However several concerns exist in regard to the long-term fate of the autograft and the homograft used for reconstruction of the right ventricular outflow tract.

In this review we critically assess technical aspects of the operation and modifications, review outcome date available from larger series for both adults and children including our own and discuss the key problems of the procedure, the potential for dilatation of the pulmonary autograft in the systemic circulation and durability of the homograft in the right ventricular outflow tract.

We conclude that the Ross operation offers children and young adults with aortic valve disease a long lasting, effective treatment.

Key words: **Valves. Aorta. Ross operation. Autograft. Congenital.**

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In the early, pioneering days of cardiac surgery there was only a limited choice of prostheses available to replace the diseased aortic valve. In addition the hemodynamic and clinical performance were considerably worse compared to modern devices. In 1967 Sir Donald N. Ross described a technique to replace the aortic valve with the patients own healthy, living pulmonary valve, the pulmonary autograft[1]. The right ventricular outflow tract is reconstructed mostly with homografts more infrequently with xenografts. The technical complexity of the procedure, extended aortic cross clamp time and imperfect techniques of myocardial protection prevented most surgeons from adopting the new operation. The increasing appreciation of the complications associated with lifelong anticoagulation needed even with the most current mechanical prostheses[2-4], the limited durability of biological prostheses in particular in children and young adults[5,6] and the advances of cardiopulmonary bypass and myocardial protection techniques rekindled interest in the Ross operation only more recently.

SURGICAL TECHNIQUES

The technique initially described by Ross was the subcoronary implantation of the autograft[1]. This technique has the advantage that excision and reimplantation of the coronary ostia is not required. However positioning of the commissures, annular dilatation as well as ectasia of the aortic root are all critically important for leaflet coaptation and valve competence. Hence Ross modified his technique and introduced the root replacement technique in 1974[7] which has become the preferred technique for most surgeons. The full free standing pulmonary root is implanted with reimplantation of the coronary ostia. The geometry of the root and the commissures are preserved minimizing technical errors. However the pulmonary root is exposed immediately to the increased pressure of the systemic circulation and there is concern about early and late dilatation[8]. Subsequently the importance of annular adjustment and fixation to prevent late dilatation, consideration of the relationship of the sino-tubular junction of the ascending aorta which is frequently enlarged in these patients and geometrical considerations in patients with bicuspid aortic valves were recognized to prevent autograft valve incompetence[9]. Techniques to address these problems include the cylinder inclusion technique of implantation, wrapping of the autograft with vicryl net and support of the non-coronary sinus of the autograft with the native aortic wall, annular fixation, ascending aortic replacement[9,10].

SHORT TO MID-TERM RESULTS

Numerous reports have demonstrated excellent short and midterm results with low rates of valve related deaths and complications[11-14]. A report from the Spanish national Ross registry shows a mortality of 2,36% and low reoperation rates with freedom from reoperation at a mean follow-up of 36 months of 92,4%[15]. The recent evaluation of our 15 year experience with the Ross operation (1991-2005) showed a perioperative mortality in 194 patients of 2,6%. The hemodynamic performance at rest and during exercise is physiological and better than in any prosthesis to date[16].

LONG-TERM RESULTS

Results beyond 10 years are unfortunately still sparse. In the pioneering series operated by Ross between 1967 and 1984 survival at 10 and 20 years was 85 and 61%, respectively in the 131 hospital survivors[17]. Freedom from reoperation on the autograft was 88 and 75%. Causes of late death were mainly chronic heart failure, death from reoperation and endocarditis. Elkins, et al.[12] reported at the recent AATS meeting 2005 the 16-year results in 464 patients of which 197 were below 18 years of age. Survival at 16 years was 80%. Freedom from autograft degeneration, defined as reoperation or severe insufficiency was 81%. Important differences were noted in this series between patients who were operated for aortic stenosis and insufficiency with a freedom from autograft degeneration of 95 *vs.* 53% ($p < 0,002$), respectively[18]. There were no thromboembolic or bleeding events and freedom from endocarditis was 94%. Freedom from all valve related events was 63% at 16 years. Kouchoukos, et al.[19] reported follow-up of up to 13 years with a 94% survival at 10 years with 75% freedom from autograft reoperation and 86% from homograft reoperation. Oswalt, et al.[20] achieved an excellent 90% survival at ten years although the proportion of patients with endocarditis as the indication for the Ross operation was more than 25%. Freedom from autograft and homograft reoperation were 93 and 98%, respectively. Freedom from reinfection was 98% for both the autograft and the homograft. In our own series of 142 adult patients with follow up extending to 15 years survival was 92% at 13 years and event free survival (death, reoperation and endocarditis were the only events observed) was 85%.

ROSS OPERATION IN THE PEDIATRIC POPULATION

Even though some have reported good results with mechanical valves in children[21] many series indicate increased complication and reoperation rates[22,23]. Biological xenografts are of low durability in children[24]. The Ross operation was adopted for children[25] and allows to address even multi-stage obstructions of the left ventricular outflow tract at the subvalvular, valvular and supra-valvular level[26,27]. Although the series reported are generally much smaller in number and follow-up is shorter than in adults the Ross operation has emerged as the procedure of choice if valve replacement becomes necessary in a child. Very importantly growth of the pulmonary autograft was

demonstrated not only experimentally, but clinically as well with physiological hemodynamic performance despite considerable increase in body surface area of the patient[28,29]. This may be the most important reason excellent clinical outcomes reported and for low reoperation rates despite considerable somatic growth in this age group[29-32]. We recently updated our own series of 52 children with a mean age of 11,4 years (range: 23 days-17 years) who were operated since 1991. Patient demographics are depicted in Table I. The mean time of follow up is 5 years with a maximum of 14 years. There was 1 perioperative death in a newborn baby who had previous unsuccessful balloon dilatation of critical aortic valve stenosis and left ventricular outflow tract obstruction. Two late deaths occurred of which one was a sudden death in a child scheduled for homograft replacement for rapid degeneration and the other was non-cardiac. Echocardiography showed excellent hemodynamic results at the latest follow up (Table I). Gradients stayed within normal physiological ranges throughout with none of the children having a peak gradient above 20 mmHg. Two patients had reoperations, one for failure of both the autograft and the homograft and the other for prophylactic tissue engineered porcine xenograft replacement[33]. Elkins, et al.[18] reported again at the AATS 2005 an excellent 97% survival in 197 children at 13 years, and freedom from autograft degeneration of 83% at 16 years.

TABLE I. PEDIATRIC PATIENTS WITH ROSS OPERATION

Gender	Male	37	Female		15
Surgery	Ross	43	Previous interventions/surgery		33
	Ross-Konno	5	RVOT reconstruction	HG	47
	Ross+other	4		XG	5
Echocardiography		discharge (n = 52)		last FU (n = 49)	
	AI 0-1	49		39	
	1-2	3		9	
	2.5	0		1	
	Gradient > 20	0		0	
	PI 0-1	42		33	
	1-2	5		12	
	> 2	6		3	
	Gradient > 20	5		25	
	> 50	0		6	

RVOT: right ventricular outflow tract; HG: homograft; XG: xenograft.

CONCERNS

Autograft dilatation

The autograft was shown to retain its cellularity and viability over long implantation periods[17]. It was also shown that adaptive changes occur in the pulmonary root when transposed in the systemic circulation[34,35]. However in patients with bicuspid aortic valves there is an increased fragmentation pattern of the elastic fibers not only in the aortic root but was also observed in the pulmonary root[36]. These structural changes have been implicated in the development of progressive dilatation of the autograft root and may lead to reoperation[8]. Even aneurysm formation and dissection have been observed[37,38]. However these can be treated with a valve sparing operation i.e replacement of the diseased root and ascending aorta with a vascular prosthesis and resuspension of the pulmonary autograft valve within the prosthesis if the leaflets appear unaffected and normal. We have previously reported that in fact dilatation of the autograft occurs[39]. There is clear evidence of a time dependent dilatation of the autograft root. At one, two, five and seven years freedom from dilatation was 80, 62, 48 and 45%, respectively. The sinus increased by a mean of 7.6% from the early to the last follow-up. However the amount of dilatation was less than 25 in 90% of patients. Even though we observed dilatation of the autograft root clinically relevant aortic insufficiency did not develop. We identified as important risk factor for dilatation observed in our study was the time from surgery, with an annual rate of dilatation of 1.4% percentage points and the initial diameter of the autograft. Since we did not find that dilatation up to 25% of the initial diameter was associated with progressive aortic insufficiency considerable tolerance of the pulmonary root may be assumed. Male gender was also found to be a risk factor for dilation with an increase in diameter of 9.2 in men *vs.* 0.9% in women when they have the same underlying initial sinus. Technical considerations seem also to be of importance[9].

Right ventricular outflow tract

The Ross operation requires reconstruction of the right ventricular outflow tract and critics maintain that aortic valve disease is turned into "double valve disease". The substitute most commonly used is the pulmonary homograft. Homograft degeneration and reoperations are acceptable even in the long-term[18-20]. Freedom from homograft replacement in the pulmonary position was 80% at 20 years in the pioneer series[17]. Although in contrast to the autograft growth of the homograft does not occur durability is still satisfactory in children[28]. In our series only one homograft out of 51 implanted in children over a 15 year period had to be replaced. However many children have developed moderate pulmonary insufficiency and gradients over 20 mmHg and six even a gradient over 50 mmHg (Table I). An important risk factor for degeneration is young age and therefore all attempts towards valve preserving procedures should be made in the very young[40]. Previous use of a homograft has also been identified as a risk factor for accelerated homograft degeneration[41]. Other types of xenograft[42-44] and tissue engineered conduits[33] have been used with mixed results but do not seem to be able currently to match results of homografts.

SUMMARY

The Ross operation can be considered today the procedure of choice in children and adolescents and young women of child bearing age. The available long-term information suggest that aortic valve replacement with the pulmonary autograft may also

be superior in young adults. However at 15 to 20 years valve related events mainly reoperations are not negligible and a personalized patient oriented and informed decision has to be made in individual cases.

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