Replacement of the mitral valve, aortic valve, and ascending aorta with coronary transplantation in a child with the Marfan syndrome

P. K. CAVES¹ and M. PANETH²

Brompton Hospital, London S.W.3

A girl with the Marfan syndrome is described who developed mitral regurgitation, an aneurysm of the ascending aorta, and severe aortic regurgitation. Complete surgical correction required mitral valve, aortic valve, and ascending aorta replacement with transplantation of the origin of the coronary arteries.

The cardiovascular complications of the Marfan syndrome are discussed and the previously described surgical techniques for dealing with aortic or mitral involvement are briefly reviewed. A simpler and safer method for replacement of the complete ascending aorta with coronary artery transplantation is described.

Replacement of the ascending aorta and aortic valve in the Marfan syndrome is well established (Groves, Effler, Hawk, and Gulati, 1964; Chapman et al., 1965; Bloodwell, Hallman, and Cooley, 1966) and there have also been reports of successful surgical treatment for isolated mitral valve involvement (Dietzman, Peter, Wang, and Lillehei, 1967; Sirak and Ressallat, 1968; Shahin, Eshkol, and Levy, 1969; Simpson, Nora, and McNamara, 1969; Kiser, Martin, and Kiser, 1970). Aortic and mitral valve replacement in an adult with some features of the Marfan syndrome has also been described (Nelson and Vaughn, 1969) but replacement of the mitral and aortic valves and ascending aorta with coronary artery transplantation has not previously been described. This paper reports such an operation in an 11-year-old girl with the Marfan syndrome.

CASE REPORT

The patient was born in September 1959 following a normal pregnancy. There was no family history of congenital abnormalities. Bilateral talipes calcaneo-varus was noted at birth and she was seen by an orthopaedic surgeon who diagnosed the Marfan syndrome on the basis of her skeletal deformities. No cardiovascular defect was found at birth but a cardiac murmur was noted when she was 1½ years old. She continued to attend hospital for treatment of the feet and of a progressive kyphoscoliosis. In 1965 her eye-sight deteriorated and she was found to have bilateral lenticular dislocation. Despite these disabilities she made good progress at school and was able to participate in active sports, such as swimming.

She was admitted to the Brompton Hospital in April 1968 for further investigations, although at that time she was still asymptomatic. Examination revealed an intelligent girl, very tall and thin with bilateral talipes calcaneo-varus, severe dorsolumbar kyphoscoliosis, arachnoidactyly, hyper-extensible joints, dolichocephaly with a long sad face, a high arched palate, and bilateral ectopia lentis. The pulse was jerky in sinus rhythm and the blood pressure was 120/70 mmHg. The jugular venous pressure was not raised. The cardiac impulse was left ventricular in type. On auscultation there was a grade 4/6 apical pan-systolic murmur, a quiet aortic ejection systolic murmur, and a grade 3/6 long diminuendo diastolic murmur to the left of the sternum.

The chest radiograph (Fig. 1) showed a dorsolumbar kyphoscoliosis, convex to the right, and some cardiac enlargement. The pulmonary vessels were normal. Radiographs of the hands showed a metacarpal index of 9½.

The electrocardiogram confirmed sinus rhythm with an axis of +15 degrees and voltage criteria for left ventricular hypertrophy. The ST segments were normal, but the T waves were inverted in leads II and aVF.

At cardiac catheterization normal right and left heart pressures were recorded. No shunts were demonstrated and left ventriculography showed severe mitral regurgitation into an enlarged left atrium. The left ventricle was also enlarged. Aorto-
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**FIG. 1.** Chest radiograph in April 1968 showing cardiac enlargement and prominence of the ascending aorta. The dorsolumbar kyphoscoliosis is well seen.

**FIG. 2.** Chest radiograph in May 1970 showing further cardiac enlargement and obvious dilatation of the ascending aorta and pulmonary artery.
graphy showed gross dilatation of the sinuses of Valsalva but there was only a small regurgitant jet of contrast medium into the left ventricle.

She was re-admitted in May 1970 following the onset of some shortness of breath on exertion. Her height was then 62 in (157-5 cm) and span 62-5 in (158-7 cm). The chest radiograph (Fig. 2) showed further enlargement of the heart and of the ascending aorta with obvious dilatation of the main pulmonary artery. The upper lobe pulmonary veins were dilated. Pulmonary function tests were performed in view of her kyphoscoliosis but were within normal limits.

Four months later she had deteriorated further and had obviously developed gross aortic regurgitation. The pulse was now frankly waterhammer in quality, the blood pressure was 130/0 mmHg and there was a full-length loud diminuendo diastolic murmur to the left of the sternum. The chest radiograph (Fig. 3) showed that the size of the heart and ascending aorta had again increased considerably. The electrocardiogram still showed left ventricular hypertrophy but the ST segments and the T waves were now normal.

Operation was performed on 22 October 1970 through a vertical median sternotomy. There was a flask-shaped aneurysm involving the aortic sinuses and proximal ascending aorta of a maximum diameter of 9 cm just above the level of the coronary ostia (Fig. 4). The right coronary artery was dilated and slightly tortuous. The pulmonary artery was also dilated with enormous saccular sinuses. The left atrium and left ventricle were considerably enlarged.

Cardiopulmonary bypass was instituted with systemic return to the left femoral artery and the aorta was occluded immediately proximal to the innominate artery. The aneurysm was opened longitudinally to establish coronary perfusion. The coronary canulae were held in place by tourniquet ligatures placed around the origin of the vessels immediately outside the aorta. At this stage an assistant sutured a No. 12 Starr-Edwards aortic prosthesis into one end of a 30-mm crimped Dacron tube graft in preparation for replacement of the aortic valve and ascending aorta.

Exposure of the mitral valve revealed dilatation of its annulus to a diameter of 6 cm. The valve leaflets were thin, large, and floppy, with thickened nodular margins, and the chordae tendineae were very long, rendering the valve grossly regurgitant. A No. 3 Starr-Edwards prosthesis was inserted, rolling up the mitral leaflets with the over-and-over mattress sutures to form a firm edge for the sewing ring.

**FIG. 3.** Chest radiograph in September 1970. The heart and ascending aorta have enlarged considerably over the intervening four-month period.
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The aortic valve cusps were thin and stretched and obviously incapable of occluding the enormously dilated valve orifice. The cusps were excised and the previously prepared prosthesis and graft were inserted into the subcoronary position with multiple interrupted mattress sutures. The first 2 cm of the coronary arteries were mobilized and detached from the aorta with a 'collar' of aortic wall surrounding each ostium. The coronary cannulae were temporarily removed, while the coronary arteries with their 'collars' of aortic wall were drawn inside the tube graft through appropriately placed openings. Coronary perfusion was re-established and the aortic 'collars' around the coronary ostia were sutured to the inside of the Dacron tube. Splitting the tube longitudinally from above downwards towards the prosthesis made these manoeuvres simple (Fig. 5). The cephalic end of the graft was sutured to the distal ascending aorta where it had been divided above the aneurysm, the slit in the graft was closed, and the coronary cannulae were removed. The aortic clamp was released and after control of some haemorrhage from the region of the aortic valve ring the remains of the ascending aorta were wrapped around the Dacron tube graft. The total perfusion time was four hours.

The patient was returned to the theatre during the early postoperative period for relief of the tamponade and control of the haemorrhage. Tracheostomy was performed and artificial ventilation was maintained for 10 days when she was readily weaned off the ventilator. Anticoagulation with Warfarin was started on the fourth postoperative day and was regulated to a prothrombin ratio of 2·0. She was discharged from hospital one month after the operation.

Seven weeks later she suddenly collapsed at home and was admitted to another hospital in cardiac arrest. Resuscitation was unsuccessful. Necropsy showed that the mitral valve prosthesis was well healed in position (Fig. 6). There was a considerable amount of antemortem thrombus around the ring and frame of the aortic valve prosthesis. The Dacron graft was well incorporated, the coronary ostia were both patent, and the coronary 'collars' looked healthy. Death was due to thrombus formation interfering with the normal function of the aortic ball-valve prosthesis.

Histological examination of the aorta showed mucinous spaces in the media and disappearance of many muscle fibres with fibrous tissue replacement. The elastic fibres showed patchy disruption and were widely separated.

The collagen and fibrous tissue in the mitral leaflets and chordae appeared normal.
DISCUSSION

The Marfan syndrome (Marfan, 1896; McKusick, 1966) is the most appropriate title for the inherited disorder of connective tissue characterized clinically by dislocation of the ocular lenses, skeletal abnormalities, and cardiovascular complications. Rigid diagnostic criteria for the complete syndrome have recently been suggested (Bowers, 1969a). Degeneration of the media of the aortic wall (first recognized by Baer, Taussig, and Oppenheimer in 1943) is the cause of the most commonly seen cardiovascular defects—ascending aortic dilatation, dissection or aneurysm formation with or without aortic valve regurgitation. McKusick (1955) emphasized that the degenerative process begins at the level of the aortic ring and may cause so much sacculation of the aortic sinuses...
and dilatation of the valve ring that aortic regurgitation may appear before true aneurysm formation. He also described similar changes in the pulmonary artery with aneurysmal dilatation of the pulmonary ring and sinuses. Mitral valve wrinkling and thickening in a patient with the Marfan syndrome was first noted by Salle (1912), since which time fewer than 40 case reports of mitral valve involvement have been documented. Until recently the majority of these were based on necropsy studies, and a successful mitral valve replacement for the Marfan syndrome was not recorded until 1967 (Dietzman et al., 1967). Most commonly, mitral regurgitation has been secondary to aortic regurgitation and left ventricular enlargement with consequent dilatation of the mitral valve ring (Barrett, Helwig, Kay, and Johnson, 1964). Isolated involvement of the mitral valve structures by the inherent connective tissue defect is quite rare (Bowers, 1969b). Four of the six cases described by Bowers were infants or children, although the majority of other reported patients with involvement of the mitral valve had reached adult life. It seems likely that patients presenting in adult life with mitral regurgitation and some features of the Marfan syndrome have only a forme fruste of the complete disorder. With the fully developed syndrome mitral valve involvement, if present, is likely to present in childhood (Bowden, Favara, and Donahoe, 1965; Anderson, Grondin, and Amplatz, 1968).

This case report draws attention to the rapid deterioration which may occur in the Marfan syndrome when the cardiovascular connective tissue abnormalities are widespread. Initially this girl's dominant cardiovascular lesion was mitral regurgitation but this was fairly well tolerated until rapid dilatation of the aortic root produced increasingly severe aortic regurgitation. Her deterioration over the last four preoperative months was dramatic (Figs. 2 and 3). Keith, Rowe, and Vlad (1967) noted that the speed with which an aneurysm of the ascending aorta develops is an index of the severity of the syndrome.

The changes in her electrocardiogram are of interest in that when her dominant lesion was mitral regurgitation the T waves were inverted in leads II and aVF. Later, when severe aortic regurgitation had developed as well, the T waves returned to normal in all leads. Bowers (1969a) has shown that T-wave inversion in leads II, III, and aVF is common in the Marfan syndrome when the mitral valve is predominantly involved but is not seen with isolated aortic involvement.

Surgery for the cardiovascular manifestations of the Marfan syndrome poses many problems. Control of the ascending aorta proximal to the innominate artery may be difficult to achieve when a large ascending aortic aneurysm is present. The aortic valve ring is very dilated and may require to be tailored or plicated to fit the largest available prosthetic valves. The tissues hold stitches poorly and haemostasis is often difficult to achieve. Chapman et al. (1965) and Gerbode, Semb, Hill, and Kerth (1966) described techniques for replacement of the ascending aorta and the aortic valve in the Marfan syndrome which did not involve transplantation of the coronary arteries. It seems illogical to leave the aortic sinuses in situ when this region of the aorta is usually the most severely involved (McKusick, 1966) and is likely to dilate further and possibly rupture if left as a bridge between the prosthetic valve ring and the graft replacing the ascending aorta. The alternative is complete replacement of the ascending aorta, which involves reimplantation or transplantation of the coronary arteries but permits the total exclusion of the diseased aorta from the circulation. A technique involving reimplantation was first described by Wheat et al. (1964) and coronary...
transplantation has been described by Bentall and De Bono (1968) and Edwards and Kerr (1970). We have modified the described techniques to permit suturing of the coronary artery 'collar' to the inside of the aortic graft. Technically this is quite simple to perform if a longitudinal slit is made down the front of the aortic graft as described. The great advantage is that the intra-aortic pressure tends to make the seal between the graft and the coronary 'collar' more secure and prevents any leak at this site.

Both repair and valve replacement have been recommended for correction of mitral regurgitation in these patients. Repair seems inadvisable as further enlargement and stretching of the abnormal chordae, leaflets, and annulus can result in the redevelopment of serious regurgitation after an initially successful repair (Sirak and Ressallat, 1968; Gerbode et al., 1969). After excision of the valve Dietzman et al. (1967) found it difficult to plicate the greatly enlarged mitral annulus to fit the sewing ring of the prosthesis. In our case the leaflets were not excised but were plicated with mattress sutures to form a seat for the valve. The prosthesis seated down well, and there was no evidence of a periprosthetic leak in the postoperative period—or later at necopsy.

Thrombus formation is the most serious complication of the Starr-Edwards prosthesis and unfortunately led to this patient's sudden death three months postoperatively when she was making satisfactory progress. Necropsy of the heart showed that the operation had been technically successful. Major surgery of this degree therefore appears to be justifiable when it offers the only prospect of averting the consequences of severe aortic and mitral involvement in the disorder. However, in view of the basic underlying connective tissue abnormality, the ultimate prognosis must always be uncertain.

We are grateful to Dr. P. A. Zorab and Dr. M. Honey for their referral of this case.

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Thorax 1972 27: 58-65
doi: 10.1136/thx.27.1.58

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