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SPECIAL SECTION ON CORONARY ANOMALIES

WILEY Congenital Heart Disease

Coronary artery bypass grafting in infants, children, and young adults for acquired and congenital lesions

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Abstract

Coronary artery disease ranges from congenital in origin such as anomalous aortic origin of a coronary artery (AAOCA) to acquired diseases such as Kawasaki disease, and previously repaired conditions such as transposition of the great arteries. It is not uncommon, in the long run, for proximal coronary stenosis to develop following arterial switch, AAOCA repair, Ross procedure and Kawasaki disease leading to coronary artery bypass grafing (CABG). The objective of this report is to discuss the indications, challenges, and outcomes of CABG in infants, children, and young adults with acquired and congenital lesions.

KEYWORDS
ALCAPA, CABG, Kawasaki disease, neonates, pediatric

1 | INTRODUCTION

Congenital and acquired coronary artery (CA) anomalies in infants, children, and young adults have been the focus of great interest of late,[1,2] owing to newly introduced and much improved imaging techniques,[3,4] clinical detection of coronary obstructive lesions as a result of coronary manipulation during arterial switch and Ross procedures, recognition of ischemic syndromes and sudden death from anomalous aortic origin of the coronary arteries (intramural and abnormal courses), and the realization that coronary bypass can be accomplished for ischemic syndromes not amenable to proximal repair such as Kawasaki disease, left main CA atresia, and iatrogenesis.

Coronary anomalies are categorized by anomalous origin or abnormal course, lack of patency or stenosis, abnormal connections, and/or abnormal drainage.[1] Congenital and acquired coronary lesions result in significant morbidity and mortality including myocardial dysfunction and sudden death. Congenital lesions include anomalous origin of the coronary artery from the pulmonary artery (ALCAPA), critical left main stenosis/atresia, CA fistulas, anomalous aortic origin, and intramyocardial courses. Acquired lesions include Kawasaki disease, late postoperative obstructions in patients who had CA surgical manipulations, and iatrogenic injuries that can occur in the catheterization laboratory or the operating room. A comprehensive nomenclature analysis describing these lesions is documented in the Society of Thoracic Surgeons Congenital Heart Surgery Nomenclature and Database Project.[2]

2 | CORONARY BYPASS FEASIBILITY IN INFANTS, CHILDREN, AND YOUNG ADULTS

Categorization of coronary lesions in infants, children, and young adults is generally by specific diagnoses which include clinical inquiry, pathophysiology, medical treatment, and surgical treatment. This review will consider the use of coronary artery bypass grafting (CABG) as the primary focus and indication for the various diagnostic spectra for which revascularization is necessary. Perhaps the most important obstacle to performing internal thoracic artery (ITA)-CA bypass grafts in infants and children is the small caliber of corresponding vessels.[5] Accrued experience, however, has documented long-term patency rates and appropriate anastomotic growth in patients who have had ITA-CA grafting as opposed to saphenous vein grafting.[6] Retrospective angiographic measurements[5] indicate that most coronary arteries are 1 mm or larger even in the neonatal population with few exceptions measuring as low as 0.7 mm. These findings correspond to those reported by Yatsunami and associates[7] who measured CA size in neonates with transposition of the great arteries before and after arterial switch operation. These combined data and clinical experience[5] suggest that ITA-CA bypass appears feasible in most infants with vessels 1 mm or greater and possible in

vessels as small as 0.7 mm with modern day techniques using magnification and currently available microvascular suture techniques.

3 | CORONARY BYPASS FOR KAWASAKI DISEASE

Coronary artery lesions in Kawasaki disease was first described by Kato et al.[8] in 1975. Aneurysms and ectasia are present in 12.8%–25% of patients with untreated Kawasaki disease, and represent the most common cause of acquired CA disease in children.[1,8–20] The pathologic characteristics include vasculitis involving the arterioles, capillaries, and venules resulting in coronary wall segmental destruction and aneurysm formation.[1,8] The inflammatory insult to the endothelium and coronary wall may be followed by remodeling and/or revascularization, with intimal proliferation and angiogenesis, leading to accelerated atherosclerosis and stenosis.[1,9] Virtually all other cardiac structures may be involved, including the pericardium, myocardium, endocardium, and valves.[1,9] Diagnosis of cardiac lesions is generally performed by echocardiography, computed tomographic coronary imaging, and coronary angiography. The details and characteristics of the diagnostic imaging techniques are beyond the scope of this extended abstract.

The surgical management of aneurysms owing to Kawasaki disease has been diverse. Excision or plication of coronary aneurysms have been attempted with poor results, even leading to death, and have been abandoned.[1] While not firmly established by prospective clinical trials in children, indications for CABG include severe (>75%) proximal stenosis, left main stenosis, proximal left anterior descending coronary artery (LAD) stenosis, ischemia post-percutaneous transluminal coronary angioplasty, and proximal aneurysms.[1,9,12,16,20] The rationale for CABG is based on the high rate of myocardial infarction and sudden death without surgery.[1,16] In addition, stenotic lesions occur proximal or distal to aneurysms that are at risk for rupture and/or thrombosis.[1,21] Saphenous vein bypass resulted in a 67% patency at 1-year angiographic follow-up[1,17,22] and has largely been abandoned. The ITA has a better long-term patency and growth potential (86%–100% at 1 year).[1,19,21,22] Kitamura and associates[23] advocated the use of bilateral ITA grafts to the LAD and right CA. They report no sternal infections or adverse effects on chest wall development in the pediatric population.

Patent and nonstenotic aneurysms represent challenging clinical scenarios, in that localized flow perturbation and stasis may cause acute coronary events. In some cases, CA bypass to patent aneurysms may cause postoperative thrombosis with resulting myocardial infarction and possible death. The current recommendation is therefore to perform coronary bypass to only stenotic vessels.[1,9,17] When performing arterial grafts, a high early patency can be expected.[1,5]

Indications for percutaneous transluminal coronary angioplasty in Kawasaki disease are the same as for atherosclerotic CA disease, namely, localized proximal stenosis.[24] Optimal coronary angioplasty outcomes are time related and are most successful when the time elapsed between the onset of acute illness and the procedure occurs within 6–8 years. Favorable results can be obtained with a reduction in stenosis from 84% to 33% ($P < .05$).[24]

4 | CA BYPASS FOR CONGENITAL LESIONS

In my experience, CA bypass can be performed for primary CA lesions such as left CA atresia/stenosis, single CA, and for unusual cases of ALCAPA that have been previously treated with CA ligation in infancy. Preoperative studies in patients with congenital left main CA atresia show severe left ventricular dysfunction. An aortogram can show absence of the left main CA while a pulmonary artery angiogram will reveal no origin of the artery indicating the diagnosis of left main atresia. Proximal CA pericardial patch arterioplasty can be performed.[5] Failure to wean from cardiopulmonary bypass can prompt an ITA-LAD bypass that can be life-sparing. Long-term follow-up is necessary to monitor myocardial function that may result in cardiac transplantation if there is no myocardial recovery.

Coronary bypass may be indicated in some unusual circumstances. One patient underwent cardiac transplantation for hypoplastic left heart syndrome with an excellent result for 4.9 years.[5] The successfully transplanted heart was known to have a single CA with a malignant course of the left main coronary. Owing to multiple episodes of fainting spells, the patient underwent an ITA-LAD bypass, which resulted in long-term resolution of symptoms.[5]

Predictably, some patients with obligatory coronary manipulation in association with arterial switch (including those who underwent arterial switch and the Ross operation) develop CA stenosis. Oftentimes, proximal patch coronary arterioplasty can be performed in association with coronary bypass. In patients with acquired proximal stenosis after arterial switch, I have chosen to perform concurrent proximal arterioplasty and ITA-CA bypass with the idea that this "belt and suspenders" approach will give the patient the best chance of coronary reperfusion in the event that one of the procedures yields suboptimal results. In patients with left main occlusion after arterial switch operation, proximal arterioplasty is not recommended; ITA-CA bypass is preferred and should provide excellent coronary perfusion. The best therapeutic options are dictated by clinical and anatomic circumstances.

By far, the most dangerous and highest potential for mortality are those patients who have incurred CA injury owing to catheter or surgical intervention. These injuries may require emergency coronary bypass and can occur owing to catheter induced coronary dissection, right CA occlusion/avulsion, status post truncus arteriosus and tetralogy of Fallot repair, and CA injury of an intramural artery in association with Norwood operation. An example of surgical CA injury,[5] can be caused by transatrial repair of tetralogy of Fallot with anomalous LAD origin from the right CA across the right ventricular outflow tract. The CA can be injured posteriorly resulting in a CA to right ventricular acquired fistula,[5] ischemic symptoms, and multiple premature ventricular contractions. At operation, the fistula can be ligated and a distal ITA-LAD bypass graft can be placed. Resolution of symptoms and elimination of the premature ventricular contractions can be expected. Catheter-based coronary dissection can occur and will require emergency ITA-CA bypass.

Other CA interventions for acute and chronic iatrogenic problems can be encountered and include polytetrafluoroethylene interposition

CA graft for pseudoaneurysm of the right CA after aortic root replacement for Marfan syndrome, right ventricular to pulmonary artery conduit replacement for coronary compression, CA Bovie burn requiring resection and end-to-end anastomosis, and pericardial patch arterioplasty for coronary torsion after Norwood operation.

5 | CONCLUSION

There is an increased awareness of acquired and congenital CA ischemic syndromes owing to new technology. Surgical and catheter-based iatrogenesis is rising. There are expanding indications for pediatric ITA-CA bypass. Surgical results are efficacious, long-standing, and often life-saving.

CONFLICT OF INTEREST

None.

DISCLOSURES

None.

AUTHOR CONTRIBUTIONS

The author contributed in the concept/design, drafting, critical revision and approval of the article.

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