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Arterial Duct Stenting in Duct-Dependent Pulmonary Circulation: is Surgical Shunt Still Worthwhile?

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Introduction

It has long been realized that patients with congenital heart malformations resulting in duct-dependent pulmonary circulation would greatly benefit from stabilized pulmonary blood flow in view of spontaneous improvement or later lower-risk surgical repair. Although this aim may be achieved for a short period by continuous intravenous prostaglandin E infusion, a longer time stable pulmonary blood flow source must be provided in the vast majority of cases. Over time, different surgical systemic-to-pulmonary artery shunt techniques were proposed [1-4], with the main advantage of providing significant pulmonary blood flow increase for long time. However, size and angulations of the prosthetic conduit used to make either Blalock-Taussig or "central" shunts often resulted in pulmonary artery distortion and hypertension [5,6].

Maintaining arterial duct patency has long been proposed as an effective alternative to surgical systemic-to-pulmonary artery shunt in neonates who are unsuitable for primary repair or in whom there is anticipated spontaneous improvement of oxygen saturation as pulmonary vascular resistance decreases. Using arterial duct as a native systemic-to-pulmonary communication was first reported in lambs submitted to surgical duct formaldehyde infiltration [7]. Rudolph et al. [8] extended this concept to newborns with cyanotic congenital heart disease, whose arterial duct was surgically exposed and infiltrated with 10% buffered formaldehyde with resulting significant and long-lasting clinical improvement. Further evolution of this idea was trans-catheter stabilization of arterial duct by balloon angioplasty, although the initial experimental studies were disappointing and hampered a wide clinical application of this approach [9-11]. Arterial duct stabilization by stent implantation to achieve a durable patency was then considered as the "Columbus egg" in clinical setting of duct-dependent congenital heart malformations. Indeed, this option makes possible to finely tailor shunt magnitude to individual patient. In addition, in the case of very low-weight neonates, stent diameter might be progressively increased by serial balloon dilatations to adapt the shunt flow to the patient growth. Finally, allowing the stent to conform to the pulmonary artery anatomy might have favourable effects on development of the pulmonary vascular tree due to even distribution of pulmonary blood flow. Following the early experiences in animal models [12,13], this approach was then performed in cyanotic neonates with conflicting results in terms of failure rate, early complications and mid-term outcome [14-18]. Over time, technical improvement of stents and delivery systems made percutaneous duct stenting safer and more feasible as short-term palliation of duct-dependent neonates and young infants, with success rate around 90%, morbidity rate less than 10% and no procedural mortality [19-22]. Procedural failures and complications were mainly due to ductal tortuosity and in-stent hyperplasia/thrombosis, respectively. In addition, this approach was cost-effective either in low-risk patients or in clinical and/or anatomical high-risk ones [22-29]. In addition, arterial duct stenting revealed more "physiologic" with respect to surgical shunt since resulted in a better distribution of pulmonary blood flow with consequent more balanced pulmonary artery growth [30-32]. Effective and balanced pulmonary artery growth was shown either in standard or in challenging anatomic settings [33-35].

Inclusion criteria to arterial duct stenting program could be roughly set as follows:

a) Patients with high-risk profile for conventional surgical palliation due to significant co-morbidities or with unusual anatomic arrangement of the pulmonary arteries (for example, with the arterial duct serving a discontinuous pulmonary artery or with bilateral ducts serving isolated pulmonary arteries.

b) Patients with anticipated need for a short-term support to pulmonary circulation as in pulmonary atresia with intact ventricular septum after successful radio-frequency pulmonary valve perforation or in critically cyanosed neonates due to Ebstein's anomaly of the tricuspid valve and functional pulmonary atresia.

c) Patients with complex cardiac malformations with uni-ventricular physiology destined to the Fontan operation as a bridge toward an early cavo-pulmonary an astomosis.

d) Elective alternative to systemic-to-pulmonary artery shunt in low-risk neonates in whom early surgical repair may be planned.

The main aims to pursue in the next future should be to increase feasibility rate of duct stabilization in patients with very tortuous arterial ducts and to prolong life-span of the stented duct. Both these advances might universally extend this approach also to include patients with planned surgical repair in late childhood. Newer technologies should give significant answers to these questions. The former goal might be attained with the use of new, very pliable, self-expandable stents that can be deployed using smaller and more easily trackable delivery sheaths. The latter goal might be based on the use of drug-eluting stents, provided evidence-based safety of the released drug, or more flexible covered stents that can be deployed through smaller delivery sheaths. Clinical trial restricted to single centres with special expertise and experience might give final answers to these questions.

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