International Journal of Cardiology 284 (2019) 82–83

Contents lists available at ScienceDirect

International Journal of Cardiology

journal homepage: www.elsevier.com/locate/ijcard

Editorial

Custom tailoring of medical implants for pulmonary artery bifurcation stenosis

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ARTICLE INFO

Article history:
Received 21 May 2018
Received in revised form 21 November 2018
Accepted 27 November 2018
Available online 29 November 2018

Despite considerable evolution in stent technology and implantation techniques pulmonary bifurcation stenosis (PBS) remains one of the complex lesion subsets challenging the interventional cardiologist.

So far the intrapericardial type 1 and 2 pulmonary artery stenosis (PaS) have been considered classical surgical indications and in experienced hands also multilocular peripheral PaS were addressed by surgery alone [1]. Nevertheless, the percutaneous approach is favored in most institutions. Equivalent to coronary interventions, techniques for bifurcation stenosis in the pulmonary artery tree were developed over the years [2–4] favoring stent implantation rather than ballooning alone.

In this issue of the JIC, Krings and colleagues present midterm follow up on one further step in addressing PBS percutaneously that has recently been introduced by Narayan [5]. They suggest to move from an entirely surgical battle field to construction of a completely metal supported y-shaped pulmonary artery bifurcation/trifurcation.

In their series of eleven patients, all but one had postoperative PBS. Pre-procedural imaging using 3D-rotational angiography was applied and used to guide stent implantation.

Effectiveness of y-stenting was assessed by measuring the increase in vessel diameter and pressure unloading of the RV (for the 8 patients with central PBS). The substantial acute mean increase in vessel size for 33 stenoses addressed with 22 stents was 116.4% and the RV/LV pressure ratio declined from 0.9 to 0.5 on average. The follow up time ranged from 4 to 94 months. The patient cohort was divided according the stenting technique into those with overlap of the second stent (connected y-stenting) and those without anchoring within the first stent (non-connected y-stenting). A high incidence of restenosis in practically all central PBS was found in non-connected y-stents. Need for reintervention (all transcatheter) at the stented vessels was 50% after a median time of 26 months. More than half of the patients were below 25 kg bodyweight.

Given the high rate of instantaneous procedural success of pulmonary artery stenting of 75%–98%, re-intervention rate is remarkable predominantly in the younger patients and some of the risk factors have been elucidated [6].

In the light of reducing the burden of re-do-procedures either surgically or by catheterization, emerging techniques and technologies must be evaluated and more questions should be answered.

1.) Retrospective studies rarely include defined follow up measurements:
Indication for PBS might be recruitment of peripheral lung vasculature, lowering RV-pressure, redistribution of flow to either lung. Having said this, success of treating PBS has a multi-facet appearance.

2.) Pre-interventional 3D-imaging for PBS:
Understanding the anatomy by adding 3D-datasets is undoubtedly advantageous and an important tool to know about the proximity of coronaries or airways when placing stents within the pulmonary circulation. Whether automatic computerized segmentation is accurate enough and how movements of the heart and the patient, respiration, stiff guide wires among others may alter the anatomy during the intervention and make those overlays meaningless are all issues that are still debated.

3.) Only what you look at, you will find:
Segmental PBS cannot be evaluated by echocardiography, while post-interventional RV-pressure can be easily acquired by Doppler measurements, but without information about the exact region of obstruction. CT-scans, either conventional or based on rotational angiography, or MRI have different spatial resolutions and require sophisticated corrections [7] to be interpreted. Angiography outside a clinical trial in asymptomatic patients is rarely justified to detect some degree of restenosis. Additionally, techniques like IVUS or OCT are superior to discriminate remodeling and detection of malapposition of the stent struts – a comparable standard might be developed for pulmonary stenting as well.

DOI of original article: https://doi.org/10.1016/j.ijcard.2018.03.100.

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https://doi.org/10.1016/j.ijcard.2018.11.120
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4.) Substrate of stenosis – are all lesions eligible?:
Intrinsic anomalies of the vessel architecture in Alagille or Williams syndrome are at higher risk for endothelial inflammation and flap formation. A squeezed right pulmonary artery competing for space with a huge right sided aorta or a steep angled PBS after arterial switch operation (ASO) are amenable for stenting, but continuous rubbing of a stented pulmonary artery may cause damage and induce aortopulmonary fistula [8]. Especially the adherence of aorta and pulmonary arteries after the Lecompte maneuver in the context of ASO represents a region of increased vulnerability. Even after balloon pulmonary arterioplasty alone as well as in RVOT enlargement by stents or percutaneously inserted transcatheter valves, dissection through the extravascular tissue and subsequent creation of an aortopulmonary window can occur either immediately or years after surgery and must therefore be encountered and thoroughly ruled out in follow up [9,10]. In patients with a dilated ascending aorta as in Tetralogy of Fallot or in common arterial trunk (TAC) stents in PBS may impinge and distort the aortic wall inducing progressive regurgitation of the valve. Postoperative central PBS can include rigid calcified patches that per se do not allow complete apposition of stents thereby increasing endothelial shear stress. Stent fractures in peripheral PaS are rare (1–2%), a higher incidence has to be expected in central PBS. The greater the movement of implants with the heartbeat, the higher the forces on the material and the more likely stent fractures will occur.

5.) Stent technology and alignment – know your material!:
Open and closed cell stents with different specifications of crowns, radial force, shortening etc. have been used in PBS. It is obvious that the results of the study of Krings et al. cannot automatically be translated to other stents with different characteristics. Interlocking stents with only a small area of overlap are known to induce heavy vascular inflammation and this is supported by the actual study with a higher rate of restenosis in the non-connected y-stents giving way for friction. Computational flow analysis eventually allows further individualized patient specific stent arrangements. After the first stent is implanted, the angle at which the side branch originates, determines the circumferential size of the offspring. Tailoring of stents requires exact knowledge about the maximum circumferential size of the created “side hole” which varies considerably with the stent design, to allow full expansion of the second interlocking stent [11]. Especially in view of secondary PPVI or breaking the stents for outgrowth of the patients from the initial stent diameter this must already be encountered when y-stenting is done.

Intentional jailing of side branches and secondary re-opening is a conceptional U-turn compared to the former standard to avoid even partial covering. At the same time the approach expands the indications of PPVI. Other techniques especially drug eluting balloons are on the horizon also for in-stent stenosis in congenital PaS [12]. Krings et al. can be congratulated for their willingness to report also on complications and failure in midterm follow up that should lead to technical refinements of the y-stenting technique which basically is suitable and effective to save reoperations in individual patients.

But still, at least for the younger patients, the procedure remains a bridging tool between surgeries, which can be either another pulmonary arterioplasty, insertion of a new RVOT-conduit or even heart transplantation. Close collaboration and partnership of cardiologists and heart surgeons is mandatory. Although there is increasing surgical experience for post-stent patients with congenital heart disease, sequelae of prolonged surgeries, eventually requiring hypothermic circulatory arrest to trim, partially remove or completely retrieve the stents must be weighed prospectively [13].

Including innovative approaches in clinical decision making is a need in order to improve and develop medical care especially in the fragile population of the young with CHD – at the moment we should be careful in patient selection for y-stenting the central pulmonary arteries - feasibility has been proven, freedom from intervention must be enhanced to promote this approach being superior to the standard and in the best interest for the patient.

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