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Radiography of thoracic intravascular stents in children with congenital heart disease

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Abstract. Seventeen balloon expandable stents were placed in thoracic vessels in eleven children with vascular stenoses related to congenital heart lesions. We describe the normal radiographic appearance of three types of balloon expandable stents implanted in pulmonary arteries, pulmonary veins, and the superior vena cava of these children as well as the appearance of the complications we encountered. Knowledge of the radiographic appearance of these devices is important as chest radiography is a primary method of follow-up in children with balloon expandable stents placed to treat stenoses of intrathoracic vessels related to congenital heart disease.

Hemodynamically significant stenosis of the pulmonary arterial, pulmonary venous, and intrathoracic systemic venous circulation can occur in children as isolated findings or in association with complex congenital heart lesions. These lesions have previously been treated with surgery or balloon angioplasty with mixed results. Surgery may involve significant morbidity and is often technically difficult depending on the location of the lesions. Many severely stenotic or hypoplastic vessels are resistant to simple balloon angioplasty. The balloon expandable intravascular stent developed by Palmaz and coworkers provides a new alternative in the treatment of thoracic vascular stenoses in children. These devices are designed to support the vessel walls after balloon dilatation, thus preventing vessel recoil and recurrence of stenoses. The stents can be placed intraoperatively or percutaneously in the cardiac catheterization laboratory. The purpose of this report is to describe the normal radiographic appearance of these devices in several different vessels in the thorax of children with congenital heart disease as well as the acute complications we have observed.

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Material and methods

The radiographs and medical records of the eleven children who underwent placement of balloon expandable thoracic intravascular stents at our institution from August 1991 to September 1992 were retrospectively reviewed. The age, gender, clinical diagnosis, method of stent placement (percutaneous or intraoperative), stent location, type of stent used, and any acute complications are presented in Table 1.

Stents were placed either percutaneously by the pediatric cardiologist or intraoperatively by the pediatric cardiovascular surgeon and the pediatric cardiologist. The protocol was approved by the medical center Institutional Review Board, and informed consent was obtained for each procedure. Three types of stents were used: the Palmaz stent (PS 30, Johnson & Johnson), the Palmaz-Schatz stent (PS 20, Johnson & Johnson), and the Palmaz-Schatz coronary stent (PS 15, Johnson & Johnson). These stents are made of stainless steel and have a mesh-like design (Fig. 1). The stents increase in diameter and shorten in length with balloon expansion. Each stent has a range of diameters after inflation (2.5–5.0 mm for PS 15, 4.0–7.0 mm for PS 20, 8.0–18.0 mm for PS 30). Prior to stent placement, vessel size and distensibility of the stenosis were determined using balloon catheters of varying sizes percutaneously or vascular sounds intraoperatively. If the stenosis was not distensible by either of these methods, stenting was not attempted. Once stenting capability was confirmed, the stents were loaded onto an appropriate size angioplasty balloon. Through a 7 to 11 French sheath (percutaneous placement) or by direct catheter passage into the stenotic vessel (intraoperative placement), the stent was advanced so as to traverse the stenosis and the balloon inflated for 10–60 s. The balloon was then deflated and the catheter removed leaving the stent in place as an endovascular prosthesis.

All post-procedural and post-operative chest radiographs of the eleven patients were reviewed by a pediatric radiologist (AES) and a pediatric cardiologist (RHB). The visibility and position of the stents or any evidence of migration, fracture, or change in configuration of the stents were determined.

Results

Seventeen balloon-expandable stents were placed in eleven children. The mean age was 6 years (range 2 months to 22 years). Five stents were placed percutaneously in five patients. Twelve stents were placed intraoperatively in seven patients (one patient had both per-

Table 1. Demographic data and results for patients with balloon expandable stents

Patient	Age at time of procedure	Gender	Weight	Congenital heart lesion[a]	Method of stent placement	Type of stens(s)[b]	Location of stent(s)[c]	Procedural complications	Length of follow-up
1	12 mo.	F	6.5 kg	Pulmonary vein stenosis SVC obstruction	Intra-operative	PS 15 PS 15 PS 30 PS 20	LUPV LLPV SVC RLPV	No	6 months
2	19 mo.	F	7.5 kg	Cardiomyopathy Pulmonary vein stenosis	Percutaneous	PS 20	LLPV	No	5 months
3	8 mo.	F	3.9 kg	ASD, VSD Postoperative pulmonary vein stenosis	Intra-operative	PS 15 PS 15 PS 15	LUPV RUPV RLPV	No	11 months
4	10.5 yr	F	33.4 kg	Pulmonary atresia with VSD	Percutaneous	PS 30	RPA	No	13 months
5	16.3 yr	F	59.0 kg	Pulmonary artery stenosis	Percutaneous	PS 30	RPA	No	5 months
6	2 mo	F	4.3 kg	Pulmonary atresia with VSD	Intra-operative	PS 30	LPA	Yes[d]	6 months
7	2.4 yr	F	8.9 kg	Hypoplastic left heart syndrome	Intra-operative	PS 30	LPA	No	8 months
8	3 yr	M	12.8 kg	Hypoplastic left heart syndrome	Intra-operative	PS 30	LPA	No	6 months
9	13.2 yr	M	62 kg	Pulmonary atresia with VSD	Intra-operative	PS 30	RPA	No	10 months
10	22 yr	M	69.7 kg	Pulmonary atresia with VSD	Percutaneous Intra-operative	PS 30 PS 30	RPA LPA	Yes[e]	3 months
11	12 yr	M	34.8 kg	Alagille syndrome with isolated pulmonary artery hypoplasia	Percutaneous	PS 30	LPA	No	1 month

[a] *Abbreviations:*
ASD-atrial septal defect
VSD-ventricular septal defect

[b] *Abbreviations:*
PS 15 – Palmaz-Schatz Coronary Stent
PS 20 – Palmaz-Schatz Stent
PS 30 – Palmaz Stent

[c] *Abbreviations:*
LPA-left pulmonary artery
RPA-right pulmonary artery
LLPV-left lower pulmonary vein
LUPV-left upper pulmonary vein
RLPV-right lower pulmonary vein
RUPV-right upper pulmonary vein
SVC-superior vena cava

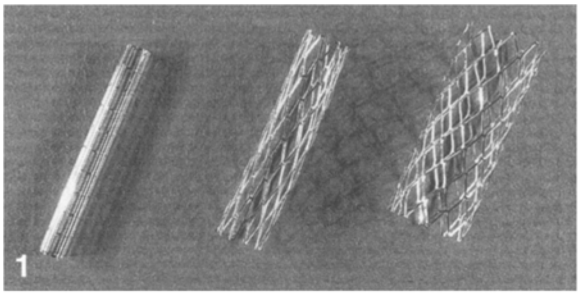
[d] Fragmentation of stent with retained metallic foreign body after stent removal

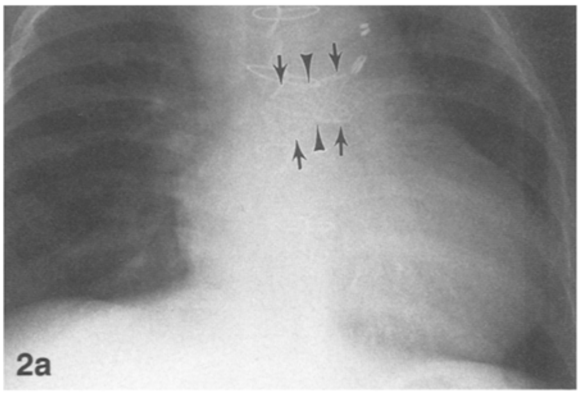
[e] Rupture and entanglement of angioplasty balloon on the RPA stent

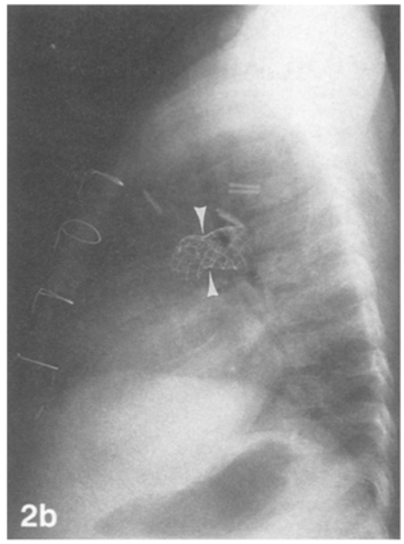
cutaneous and intraoperative placement of stents). Seven stents were placed in the pulmonary veins (four on the left and three on the right). Nine stents were placed in the pulmonary arteries (five on the left and four on the right). One stent was placed in the superior vena cava.

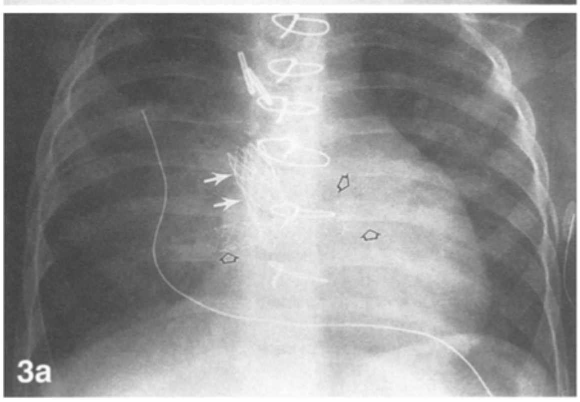
Radiographically, all three types of stents were generally well visualized and easily located in their appropriate vessels. The devices were more difficult to visualize when placed in the pulmonary veins due to their smaller diameter (all pulmonary vein stents were PS 15 or PS 20 stents). In one patient (Case 1 in Table 1), one stent placed in the left lower pulmonary vein (a PS 15 stent) was not seen immediately after placement but was seen on a follow-up radiograph after repeat dilation of the stent to a larger diameter. In all other cases, the stents were readily identified on all radiographs. In the right pulmonary arteries, the stents had a relatively horizontal orientation of their long axes on the posteroanterior (PA) chest radiographs with their mesh-like design well delineated. On the lateral view, the right pulmonary artery stents were seen on-end or in a slight oblique configuration, depending upon which portion of the pulmonary artery the stent was placed and the patient's vascular anatomy. In the left pulmonary artery, the stents had a generally horizontal orientation on the PA chest radiograph, but were somewhat foreshortened due to the oblique course of the left pulmonary artery out of the coronal plane. Likewise, the left pulmonary artery stents tended to follow an oblique course on the lateral chest radiographs (Fig. 2). Within the superior vena cava, the long axis of the stent was seen in a vertical orientation on both the PA and lateral views (Fig. 3). Within the pulmonary veins, the stents followed a more oblique course radiating from the posterior left atrium on both PA and lateral views (Fig. 3).

We encountered two procedural complications with radiographic manifestations. In one case (Case 6 in Table 1), a LPA stent placed intraoperatively was noted to have a tight residual stenosis in its midportion. Therefore, the stent was immediately removed by pealing it away from the vessel wall and cutting it out in pieces. A small,









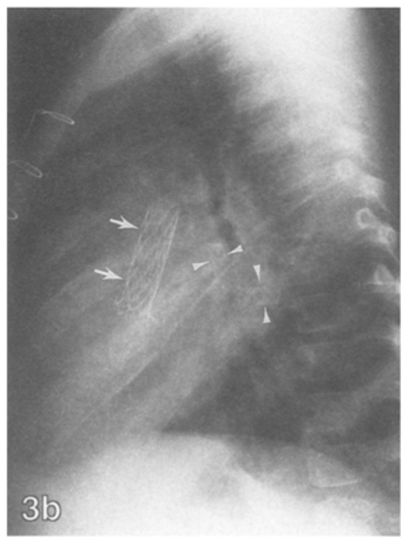


Fig. 1. Palmaz stent (PS-30) in the unexpanded state (3 mm diameter) *(left)*, partially expanded to 6 mm *(center)*, and further expanded to 11 mm *(right)*

Fig. 2. **a** PA chest radiograph in a 2-year-old girl (Case 7) demonstrates a left pulmonary artery stent (PS-30) *(arrows)* with narrowing at a site of residual stenosis *(arrowheads)*. The pulmonary artery stent has a horizontal orientation with some foreshortening corresponding to the normal course of the left pulmonary artery out of the coronal plane.
b Lateral chest radiograph of the same patient (Case 7) as in Fig. 2 a reveals the oblique orientation of the left pulmonary artery stent with a focal narrowing *(arrowheads)*

Fig. 3. **a** PA chest radiograph in a 1-year-old girl (Case 1) with one stent (PS-30) in the superior vena cava (SVC) and three pulmonary vein stents (one in the right lower pulmonary vein [PS-20], one in the left lower pulmonary vein [PS-15], and one in the left upper pulmonary vein [PS-15]). The SVC stent has a vertical orientation *(arrows)*. The pulmonary vein stents *(open arrowheads)* radiate from the expected location of the left atrium. The smaller (PS-15) left-sided pulmonary vein stents are difficult to see, whereas the larger (PS-20) right-sided pulmonary vein stent is readily identified.
b Lateral chest radiograph of the same patient as in Figure 3 A (Case 1) once again reveals the vertical orientation of the SVC stent *(arrows)* and the oblique course of the pulmonary vein stents *(arrowheads)* radiating from the posterior left atrium (only two of the pulmonary vein stents are clearly seen due to superimposition in the lateral projection)

unsuspected retained metallic fragment was first detected on follow-up radiographs. The patient has done well without clinical problems related to this small residual fragment. In another patient (Case 10 in Table 1), during percutaneous placement of a stent in the right pulmonary artery, the angioplasty balloon ruptured and caught on the stent. This entanglement of the balloon was detected on fluoroscopy and confirmed by chest radiography. Because the balloon catheter could not be disengaged from the stent, the patient was brought to the operating room to remove the balloon catheter as well as to place a separate left pulmonary artery stent. In the remaining patients, there were no acute procedural complications; specifically, no cases of stent migration or fracture, or vessel rupture or thrombosis were encountered.

Discussion

Balloon expandable tubular stents were first described by Palmaz et al. in 1985 [1]. The initial studies involved implantation of these stainless steel stents to treat stenoses in peripheral arteries [1–5] and coronary arteries [6, 7]. More recently, balloon-expandable stents have also been used on an experimental basis to relieve vascular stenoses in laboratory animals and patients with congenital heart disease [8–14]. These stents have been used to expand stenoses in pulmonary arteries, pulmonary veins, the superior vena cava, the right atrium, the descending aorta, and right ventricular outflow tract conduits.

In clinical trials, balloon-expandable stents are being used with increased frequency to treat vascular stenosis in children with congenital heart disease. Knowledge of the normal radiographic appearance of these devices in various locations (as well as the appearance of complications) is important for radiologists as chest radiography is a primary method of follow-up for change in configuration of these stents and for evaluation of stent size, position, or migration. Our study demonstrates that the stents are generally well seen on routine PA and lateral chest radiographs. Radiography was also useful in identifying the two procedural complications that were encountered. With increased use of these devices, knowledge of their radiographic appearances will be essential.

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