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Mustard baffle obstruction and leak – How successful are percutaneous interventions in adults?

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Abstract

Atrial switch operations for D-Transposition of the great arteries (D-TGA) were performed until the late 20th century. These patients have substantial rates of re-operation, particularly for baffle related complications. This study sought to analyze the efficacy of percutaneous transcatheter intervention (PTI) for baffle leak and/or stenosis in adult atrial switch patients. Adult patients with a prior atrial switch operation who underwent heart catheterization (2002–2014) at a tertiary adult congenital heart disease referral center were retrospectively analyzed. In 58 adults (30 ± 8 years, 75% men, 14% New York Heart Association (NYHA) functional class 2) who underwent 79 catheterizations, PTI was attempted in 50 (baffle leak ($n = 10$, 20%), stenosis ($n = 27$, 54%), or both ($n = 13$, 26%)). PTI was successful in 45 and 5 were referred for surgery due to complex anatomy. A total of 40 bare metal stents, 18 covered stents, 16 occlusion devices, 2 angioplasties, and 1 endovascular graft were deployed. In isolated stenosis, there was improvement in NYHA functional class after PTI (8 vs. 0 patients were NYHA FC > 2, $p = 0.004$), which was matched by improvement in maximal oxygen consumption on exercise testing (VO_2) (25.1 ± 5.4 mL/kg/min vs. 27.9 ± 9 mL/kg/min, $p = 0.03$). There were no procedure-related deaths or emergent surgeries in this cohort.

This single-center cohort is the largest reported series of adult atrial switch operation patients who have undergone PTI for baffle stenosis and/or leak. We demonstrate that PTI with an expert multi-

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Financial/Other Disclosures/Conflict of Interest

Elisa Bradley, MD – none.

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Joanne Chisolm, MSN, RN – none. Tracey Sisk, RN – none.

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disciplinary team is a safe and effective alternative to surgery in adult patients with an atrial switch operation.

Keywords

D-transposition of the great arteries; Mustard repair; Percutaneous intervention; Baffle leak; Baffle stenosis

1. Introduction

Cyanotic congenital heart patients have benefitted from cardiothoracic surgical innovation that occurred in the mid to late 20th century, without which, these conditions would not be survivable. Among this group, patients with dextro-transposition of the great arteries (D-TGA) are unique. Atrial switch operations, such as the Mustard [1] or Senning [2] procedures, became available in 1963 and 1957 respectively, and have subsequently been supplanted by the arterial switch (Jatene) operation [3]. Late re-operation is often required after Mustard/Senning repairs, and most frequently this is for baffle-related complications such as stenosis and/or leak. In an effort to avoid the morbidity and mortality associated with re-operation, percutaneous transcatheter interventions (PTI) aimed at treating baffle stenosis and leaks are often sought. To date, there is limited data describing the efficacy and outcomes with currently available percutaneous treatment options. We sought to analyze the efficacy of PTI in adult atrial switch patients undergoing PTI for baffle leak and/or stenosis at a large U.S. tertiary referral adult congenital heart disease center with expertise in both routine and high risk percutaneous interventions.

2. Methods

Adult patients with a prior atrial switch operation who underwent heart catheterization (2002–2014) at our center were retrospectively analyzed. We collected basic demographics, exercise test results, echo-cardiograms and advanced cardiac imaging (computed tomography or magnetic resonance imaging) when available, as well as the results of cardiac catheterization/PTI. More specifically, when collecting invasive hemodynamic results, we included baseline and post-PTI oxygen saturation, baffle diameter, and baffle gradient measurements. Information specific to the intervention performed, devices used, presence of post-angiographic leak, and major adverse events (death, need for emergent operation, bleeding requiring transfusion, need for urgent/emergent repeat percutaneous intervention) were also collected. In patients who received an electrophysiology study (EPS) or device (pacemaker or defibrillator), data specific to this procedure was reviewed: inducible arrhythmia, ablation, device placed, and lead extraction if required.

Given the retrospective nature of this study comprised of data from the previous 12 years, consent waiver was obtained, and the local institutional review board approved this study. Descriptive data analyzing baseline characteristics of the total population, those with isolated baffle stenosis, isolated baffle leak, and combination leak/stenosis was generated. Descriptive characteristics of devices placed, with respect to the underlying baffle abnormality (leak or stenosis), were also generated. When evaluating for differences

between pre-PTI and post-PTI parameters, dependent T-tests were used to compare continuous variables and Fisher's exact tests were used to analyze categorical and ordinal variables. All significance tests were evaluated with type I error rate of 5% ($\alpha = 0.05$). All data are presented as means with standard deviation. The data were analyzed using SPSS (IBM Corp. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY).

3. Results

There were 58 adults (30 ± 8 years, 75% men) who underwent 79 catheterizations at our institution over 12 years. In those who underwent catheterization, PTI was attempted in 50 cases, 45 of which received successful PTI. Of these, there were 2 cases where combination PTI/surgery was done. Ultimately there were 5 cases where PTI was not performed, and the patient was referred for surgery due to complex anatomy. (Fig. 1) At baseline, a minority of patients had advanced New York Heart Association (NYHA) functional class defined as NYHAFC 2 ($n = 11$) or significant systemic (right) ventricular dysfunction ($n = 23$). In patients with an isolated baffle leak, the nadir oxygen saturation on VO_2 testing was low ($87 \pm 6\%$). The remainder of baseline patient characteristics is outlined in Table 1.

Patients undergoing PTI had baffle leak ($n = 10$, 20%), stenosis ($n = 27$, 54%), or both ($n = 13$, 26%). A total of 40 bare metal stents, 18 covered stents, 16 occlusion devices, 2 angioplasties, and 1 endovascular graft were deployed. Covered stents were placed in 11 patients, and of those 8 patients received the device under compassionate use criteria and 3 under emergency use criteria. Stenoses were found in the superior limb of the systemic venous baffle (SVC) ($n = 39$), the inferior limb (IVC) ($n = 13$), and in the pulmonary venous baffle ($n = 1$). In this cohort average fluoroscopy time was 53 ± 33 min and average procedure length was 178 ± 84 min.

3.1. Isolated baffle stenosis

In patients with isolated baffle stenosis ($n = 27$), there was significant improvement in NYHA functional class after PTI, which was matched by improvement in VO_2 . In this group, the average pre-PTI mean gradient was 5 ± 11 mmHg and post-PTI was 0.6 ± 1.6 mmHg. Stenosis diameter went from 6 ± 5 mm to 18 ± 7 mm post-PTI (Fig. 2A). Of the 11 patients with a pre-existing device (pacemaker or implantable cardiac defibrillator – ICD), a total of 4 patients with isolated stenosis required lead extraction and re-implantation at the time of PTI. Three additional patients received a device at the time of PTI. Individual characteristics of each intervention are outlined in Table 2. Representative angiography from an example case which required lead extraction and intervention to the SVC and IVC limbs of the systemic venous baffle is demonstrated in Fig. 3.

3.2. Isolated baffle leak

In the 10 patients with isolated baffle leak, the resting O_2 was $93 \pm 4\%$ and post-PTI was $96 \pm 2\%$. Leaks were documented in the SVC ($n = 16$), IVC ($n = 11$), and pulmonary venous baffle ($n = 2$). A combination of covered stents, septal and patent foramen ovale (PFO) occluders, and endovascular stents were used to treat isolated leaks. Although the nadir O_2 level on VO_2 improved post-PTI, it was not significantly different than pre-PTI levels (Fig.

2B). In this group, 2 patients had a prior pacemaker or ICD, one of which required lead extraction and re-implantation at the time of PTI. Of the remainder, 2 patients had a new device placed at the time of catheterization. (Table 3).

3.3. Combined baffle leak and stenosis

Several patients had both baffle leak and stenosis ($n = 13$) and were treated with a combination of bare metal stents, covered stents, and septal/PFO occluders. There was no significant difference in pre and post-PTI oxygen saturation ($94 \pm 5\%$ vs. $97 \pm 2\%$, $p = 0.07$) and post-PTI gradients and diameters were similar to the isolated stenosis group. In these patients, 7 had a pre-existing pacemaker or ICD, 2 of which required lead extraction and replacement at the time of PTI. In addition, 2 new devices were placed at the time of PTI. Individual characteristics and results of PTI are reviewed in Table 4. Angiography from a case requiring covered stenting to treat both baffle leak and stenosis along with pacemaker removal and reimplantation by a combined EP-interventional catheterization team is illustrated in Fig. 4.

In the entire group (stenosis, leak, combination stenosis/leak), there were no major adverse events: death, need for emergent surgery/intervention, or blood loss requiring transfusion. On average, patients were observed overnight, and discharged from the hospital within 24 h after PTI.

4. Discussion

Patients with D-TGA had little hope for long-term survival prior to the Mustard/Senning procedures. For those that underwent an atrial switch operation, long-term survival is good, ranging from 71% to 94% at 10–20 years follow up [4–9] and 68–80% at >20 years follow up [10–12]. The study reporting the longest follow up was at 39 years where 68% survival was documented. [10] However, event-free survival and need for re-operation is substantial, [9,13–16] with many of these patients requiring re-operation to treat baffle stenosis, leak, or a combination of both. [4,17–20] Repeat surgeries in this group are common, occurring in 15–20%, and when required, over half are due to baffle-related complications (stenosis and/or leak). [10,21].

4.1. The history of PTI in baffle leak/stenosis

In the last 20 years, several cases of percutaneous baffle stenting and baffle leak closure have been reported. [22–36] Two case series have more recently demonstrated good short and medium-term outcomes with these procedures. [37,38] The first case series came out of Germany, where 12 of 13 patients with a median age of 20.8 years underwent 14 successful procedures including baffle stent and septal occluder placement without complication, baffle rupture, or hemorrhage. In this group, at 21 months of follow-up there was no recurrent stenosis or leak. [37] The second case series in 2012 included data from three U.S. institutions where 29 percutaneous interventions were completed in 22 patients at an average age of 32 ± 8 years. In this cohort, ventricular arrhythmia led to one death 2 days after angioplasty to the pulmonary venous baffle, and one patient had inferior systemic venous baffle obstruction that was treated with a stent. At 33 months of follow-up, there was no

evidence of symptom recurrence related to baffle stenosis or leak. The authors concluded that stent placement for baffle obstruction is effective and likely safer than surgical intervention, and baffle leak occlusion is safely treated from a percutaneous approach, albeit the presence of residual leak in the short-term. [38].

4.2. Multi-disciplinary team approach

We report the largest overall, and single-center, description of PTI offered to adult patients with a prior atrial switch procedure and late baffle leak and/or stenosis. Our results demonstrate that PTI is a safe and effective alternative to surgery for the treatment of late baffle related stenosis and/or leak. In late D-TGA survivors with a prior atrial switch operation, we found that isolated baffle stenosis was more common than baffle leak or combination stenosis/leak. When isolated stenosis was present, patients were more likely to report symptoms, evidenced by higher NYHA functional class, and had objective evidence of improved exercise capacity after PTI (VO_2). From a functional standpoint, this group benefitted the most from PTI, with bare metal stents comprising the majority of interventions performed.

Previous authors have published institutional criteria defining stenosis or leak in atrial switch patients. [39–41] However, it is our opinion that significant baffle stenosis cannot be solely defined by a specific gradient, because some patients will develop large decompressing veins that lower the mean gradient. In addition, some patients will have baffle narrowing that might be considered mild by gradient (mean gradient <3 mmHg) yet the neck of the stenotic area is significantly smaller than the maximal diameter. One must also consider that many of these patients will eventually require transvenous pacemaker lead placement, in particular whereby treating the SVC baffle narrowing, will allow device wires to be placed through a patent baffle and decrease the need for combined future interventional/electrophysiology procedures. Higher than usual fluoroscopy and procedure times were seen in this cohort, however, considering that all treatment was performed in a single procedure rather than up to 3 separate procedures, we believe slightly higher times are justified.

There were no adverse events including death, emergent surgery, or blood loss requiring transfusion, in this cohort. However, in order to offer safe and effective PTI in these complex patients a team approach is required, as is used at our institution. This team consists of adult congenital heart disease (ACHD) experts, a dedicated interventional cardiology and surgical service experienced in complex congenital heart disease, and a specialized adult/pediatric electrophysiology team. This team has to work together to perform combined interventions in the same patient, such as device lead extraction and baffle stenting, during the same procedure. In addition to the specific skills required by the interventional cardiology team, a wide variety of inventory, including but not limited to bare metal stents (BMS), covered stents (both balloon and self-expandable, and intracardiac closure devices) should be available. In patients where a covered stent was required, the majority was under compassionate use by U.S. Food and Drug Administration (FDA) as requested by the sponsor/manufacturer. This typically requires documentation including: physician request outlining the clinical indication for the device, a letter from a physician remote to the case (in our institution this was typically a cardiothoracic surgeon who was not involved with the

case), patient consent with post-device deployment follow-up outlined, and IRB along with institutional approval for the procedure. The remainder were placed under emergency use, which required participation in a clinical trial or a pending compassionate use application. We underscore the importance of pre-procedural planning, as often the need for lead extraction, device placement, special equipment, and advanced imaging can be identified prior to the procedure. Meticulous planning ensures that necessary personnel and equipment are available in these complex cases.

4.3. Limitations

Referral and temporal bias are limitations of this study. The clinical review of this data identified adult patients in a cohort that were able to successfully undergo PTI for late baffle-related complications after atrial switch operations. However, inherent to the retrospective nature of this study, there is limited ability to prospectively predict outcomes at other institutions where local practice and expertise differ from the treatment team that performed complex interventions in this group.

5. Conclusions

This single-center cohort is the largest reported series of adult atrial switch operation patients who have undergone PTI for treatment of baffle stenosis and/or leak. We demonstrate that several percutaneous options are available to successfully treat late stenosis and leak in this group and emphasize the need for a skilled multi-disciplinary team approach to achieve optimal patient outcomes. Patients with isolated baffle stenosis had the most improvement in functional capacity after intervention, although subjectively nearly all patients noted some improvement in symptoms. We conclude that percutaneous transcatheter intervention with an expert multi-disciplinary team is a safe and effective alternative to surgery in adult patients with an atrial switch operation.

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Database query patients with prior atrial switch operation
and cardiac catheterization (n=79 , in 58 patients)

Fig. 1.
Search methods.

Fig. 2.

Characteristics pre/post percutaneous intervention A. Isolated baffle stenosis cases: Mean pre and post-PTI gradient, diameters. Mean VO2 test results and NYHA functional class pre and post-PTI B. Isolated baffle leak cases: Pre and post-PTI baseline oxygen saturation, VO2, and nadir oxygen saturation on VO2 testing. * $p < 0.0001$. † $p < 0.05$. PTI: Percutaneous transcatheter intervention.

Fig. 3.
Multiple baffle stenoses Significant superior and inferior baffle stenoses that have been treated with bare metal stents. Lead extraction and re-implantation was required in this case.

Fig. 4.

Combined baffle stenosis/leak Baffle stenosis and leak treated during a single procedure using a combined EP-interventional catheterization team. Superior baffle stenosis along with a large right to left shunt at the old right atrial appendage (arrow) with contrast seen entering the pulmonary venous atrium (double arrows) (A), intracardiac pacing leads removed and subsequent placement of a covered stent was implanted to treat both the superior baffle stenosis and leak (B). Small baffle leak (arrow) in the inferior baffle (C), interval placement of an Amplatzer PFO Occluder to close the inferior baffle leak and replacement of permanent pacing leads (D). EP: Electrophysiology PFO: Patent foramen ovale.

Table 1

Patient Characteristics.

	Overall Mean $\pm$ SD or Frequency (%) (n = 50)	Isolated Leak Mean $\pm$ SD or Frequency (%) (n = 10)	Isolated Stenosis Mean $\pm$ SD or Frequency (%) (n = 27)	Stenosis and Leak Mean $\pm$ SD or Frequency (%) (n = 13)
Age	30 $\pm$ 8	31 $\pm$ 6	31 $\pm$ 9	29 $\pm$ 7
Age original surgery	2 $\pm$ 3.3	3.3 $\pm$ 5.4	1.2 $\pm$ 2.7	1.4 $\pm$ 1.6
Male	37 (75)	7 (70)	19 (70)	11 (84)
NYHA FC 2	11 (22)	1 (10)	8 (30)	2 (15)
Moderate RV dysfunction	23(46)	4 (40)	13(48)	6(46)
Ejection fraction by CT or MR	39 $\pm$ 14	39 $\pm$ 11	37 $\pm$ 15	45 $\pm$ 12
Moderate tricuspid (SAVV) regurgitation	2 (4)	0	2 (7)	0
Baseline oxygen sat	98 $\pm$ 2	97 $\pm$ 2	98 $\pm$ 2	100 $\pm$ 0
Nadir oxygen sat (on VO ₂)	93 $\pm$ 7	87 $\pm$ 6	97 $\pm$ 2	98 $\pm$ 0
Average VO ₂	26 $\pm$ 5	24 $\pm$ 2	25 $\pm$ 5	29 $\pm$ 5
Indication for catheterization				
DOE	12 (24)	1 (10)	8 (30)	3 (23)
Desaturation	3 (6)	2 (20)	0	1 (8)
Symptoms of heart failure	3 (6)	0	3 (11)	0
Asymptomatic	6 (12)	0	4 (15)	2 (15)
Fatigue	6 (12)	2 (20)	4 (15)	0
Other	20 (40)	5(50)	8 (30)	7(54)

CT = computed tomography scan, DOE = dyspnea on exertion, MR = magnetic resonance imaging, NYHA FC = New York Heart Association functional class, RV = right ventricle, SAVV = systemic atrioventricular valve, SD = standard deviation, VO₂ = maximum oxygen consumption on exercise test.

Table 2

Characteristics of patients with isolated baffle stenosis.*

ID	Age	Indication	Site	Intervention	Pre/post gradient	Pre/post diameter	EP Study
2.1	48	Other	SVC	Max LD stent 26 mm	2/0	12/20	NAFAT
3.1	38	Fatigue	IVC	Max LD stent 16 mm	5/0	5/15	No
6.1	18	Other	Both	No intervention; stenosis felt to be secondary to pulmonary venous atrial contraction	2	5	Prior CHB and pacemaker, AVNRT induced, no ablation
9.1	24	Asymptomatic	SVC	Max LD stent 18 mm	8/0	0/18	IART clinically – DCCV, No EP study
15.1	30	Desaturation	Both	SVC: Max LD stent 26 mm IVC: Max LD stent 26 mm	0/0	SVC: 11/22 IVC: 11/22	No
17.1	22	Asymptomatic	SVC	Max LD stent 36 mm	0/0	9/18	Prior ICD
19.1	34	DOE	Both	SVC: Balloon angioplasty IVC: Max LD stent 26 mm	3/0	SVC 8/11 IVC 10/24	No
22.1	40	Heart failure	SVC	Max LD stent 26 mm	0/0	2/20	Prior ICD
23.1	25	Syncope	SVC	Max LD stent 36 mm	5/0	0/20	Prior ICD for CHB
25.1	30	Heart failure	Both	Max LD stent 26 mm × 2	SVC: 2/0 IVC: 3/0	SVC: 14/26 IVC: 15/26	No
26.1	44	Fatigue	Both	Palmaz XL 20 mm × 2	SVC: 4/0 IVC: 5/0	SVC: 9/20 IVC: 7/20	Prior ICD, VF, lead extraction/re-implanted
28.2	18	Arrhythmia	SVC	NuMed CP covered stent 50 mm	13/0	0/8	Lead extraction/re-implanted
30.1	17	Arrhythmia	SVC	Balloon angioplasty	0/0		IART, ablation done
32.1	24	Asymptomatic	SVC	Palmaz XL 18mm	9/0	0/18	Lead extraction/re-implantation
34.1	37	Fatigue	SVC	NuMed covered CP stent × 2, 45 mm, 39 mm		13/18	Pacemaker upgraded to ICD
35.1	29	DOE	SVC	Max LD stent 26 mm	0/2	8/25	No
37.2	43	Fatigue	Both	SVC: Palmaz XL 20 mm IVC: Palmaz XL 24 mm	SVC: 8/0 IVC: 3/0	SVC: 8/20 IVC: 15/24	Lead extraction/re-implantation
38.1	20	Fatigue	SVC	Max LD stent 26 mm	3/1	12/20	NAFAT, NSVT with ICD placed
39.1	32	DOE	SVC	Max LD stent 36 mm × 2 Max LD stent 26 mm	8/1	2/14	Upgrade ppm to ICD
40.1	39	DOE	SVC	Max LD stent 36 mm	2/0	8/25	No
40.2	42	DOE	SVC	Balloon expansion of stent to 20 mm	0/0	16/20	ICD placed
42.1	30	Fatigue	SVC & PVB	SVC: Genesis XD 39 mm SVC	6/4	0/18	AVNRT

ID	Age	Indication	Site	Intervention	Pre/post gradient	Pre/post diameter	EP Study
43.1	34	Asymptomatic	SVC	PVB: Recommended surgery Max LD stent 36 mm Max LD stent 26 mm	3/0	10/18	No
45.1	24	Arrhythmia	SVC	Max LD stent 36 mm	2/0	13/18	ICD placed
47.1	33	DOE	SVC	Max LD stent 36 mm	1/0	9/22	No
49.1	23	DOE	Both	SVC: Max LD stent 26 mm × 2 IVC: Max LD stent 26 mm	SVC: 2/0 IVC: 3/0	SVC: 10/18 IVC: 11/20	No
51.1	33	DOE	SVC	Max LD stent 26 mm	1/0	8/20	Prior ICD

*“Both” refers to involvement of the SVC and IVC. CHB = complete heart block, DCCV = direct current cardioversion, DOE = dyspnea on exertion, EP = electrophysiology, IART = intra-atrial reentrant tachycardia, ICD = implantable cardiac defibrillator, IVC = inferior vena cava limb of systemic venous baffle, NAFAT = Non-automatic focal atrial tachycardia, PVB = pulmonary venous baffle, SVC = superior vena cava limb of systemic venous baffle, VT = ventricular tachycardia.

Table 3

Characteristics of patients with isolated baffle leak.*

ID	Age	Indication	Leak site	Intervention	Baseline oxygen saturation (%)	Post-procedure oxygen saturation (%)	Post PTI Angio Leak	EP Study/Device
3.2	38	Fatigue	IVC	Palmaz XL stent + Zenith TX2 endovascular graft × 2	89	96	Yes	No
7.1	27	DOE	SVC	NuMed CP covered stent *2	95	99	No	VF on EPS, ICD placed
13.2	30	Other	IVC	Amplatzer septal occluder × 2 (4 mm, 6 mm)	95	95	No	IART on EPS, Prior ICD
14.2	21	Other	IVC	Max LD stent	99	99		ICD placed for NSVT
21.1	25	Desaturation	SVC	NuMED CP covered stent			No	No
21.2	33	Fatigue	IVC	Amplatzer septal occluder 32 mm placed – almost completely obstructed pulmonary venous chamber, removed, referred for surgical repair	89	89	Yes	No
21.3	34	Desaturation	IVC	Found CS draining into IVC which prevented safe placement of endovascular graft – referred for surgical repair	96	96	Yes	No
24.1	40	Fatigue	SVC	Amplatzer septal occluder 24 mm sizing balloon occluded the SVC with azygous decompression, referred for surgical repair	91	92	Yes	No
50.1	23	Chest pain	IVC SVC	IVC: Amplatzer septal occluder 34 mm SVC; Amplatzer septal occluder 4 mm × 2	97	97	No	No
55.2	37	Arrhythmias	IVC PVB	IVC: Amplatzer septal occluder 4 mm PVB; Amplatzer septal occluder 5 mm	93	NA	No	Prior ICD, leads extracted/re-implanted at cath

CHB = complete heart block, DCCV = direct current cardioversion, DOE = dyspnea on exertion, EP = electrophysiology, IART = intra-atrial recanalization, ICD = implantable cardiac defibrillator, IVC = inferior vena cava limb of systemic venous baffle, NA = not available, NAFAT = Non-automatic focal atrial tachycardia, NSVT = non-sustained ventricular tachycardia, PVB = pulmonary venous baffle, SVC = superior vena cava limb of systemic venous baffle, VF = ventricular fibrillation, VT = ventricular tachycardia.

*“Both” refers to involvement of the SVC and IVC.

Table 4

Characteristics of Patients with Both Baffle Stenosis and Leak.*

ID	Age	Indication	Site	Intervention	Baseline O ₂ sat (%)	Post- procedure O ₂ sat (%)	Pre/post gradient (mmHg)	Pre/post diameter (mm)	Post PTI Angio Leak	EP Study/Device
4.1	26	Palpitations	SVC	Amplatzer septal occluder 4 mm	98	98	3/0	7/35	No	Prior ICD
12.1	32	DOE	Both	Amplatzer PFO occluder 25 mm, NuMed CP covered stent 55 mm	88	98	6/1	5/18	Yes	Prior pacemaker
16.1	25	Asymptomatic	SVC	Max LD stent 36 mm × 2 Max LD stent 26 mm	93	96	10/1	2/20	No	No
20.1	37	Desaturation	Both	SVC: Max LD stent 26 mm SVC: Amplatzer septal occluder 8 mm IVC: 2 small leaks, no treatment	87	96	2/0	5/20	Yes	No
29.2	23	ICD generator change	SVC	NuMed CP covered stent 45 mm	88	100	2/0	10/22	No	VF induced, ICD replaced
31.3	37	Desaturation	SVC	NuMed CP covered stent 45 mm	93	97	SVC: 2/0	SVC: 11/18	No	AVNRT induced, Prior ICD
33.2	26	DOE	SVC	NuMed CP covered stent × 4; 45 mm × 3, 39 mm × 1	97	98	2/0	0/22	No	ICD placed for heart failure
48.1	38	DOE	SVC	Max LD 36 mm, Amplatzer septal occluder	95	99	2/0	8/20	No	No
53.1	24	Asymptomatic	Both	SVC: Max LD stent 26 mm IVC: Max LD stent 16 mm, Amplatzer septal occluder 5 mm	95	97	SVC: 4/1 IVC: 3/1	SVC: 4/20 IVC: 12/22	No	ICD placed for known VT
56.2	18	Palpitations	IVC	Amplatzer septal occluder × 2, 8 mm & 5 mm. No treatment for stenosis.	100	100	NA	NA	No	No
56.3	25	Asymptomatic	SVC	SVC: NuMed CP covered stent 34 mm	100	100	5/0	0/18	No	Pacemaker leads extracted, replaced
57.1	37	TIA	Both	SVC: NuMed CP covered stent 45 mm	96	97	5/0	5/16	No	Pacemaker leads extracted, replaced

ID	Age	Indication	Site	Intervention	Baseline O ₂ sat (%)	Post- procedure O ₂ sat (%)	Pre/post gradient (mmHg)	Pre/post diameter (mm)	Post PTI Angio Leak	EP Study/Device
58.1	28	TIA	SVC	IVC: Amplatzer septal occluder 12 mm NuMed CP covered stent × 39 mm, 45 mm, 50 mm	NA	95	2/0	10/20	No	Prior ICD in place

CHB = complete heart block, DCCV = direct current cardioversion, DOE = dyspnea on exertion, EP = electrophysiology, IART = intra-atrial reentrant tachycardia, ICD = implantable cardiac defibrillator, IVC = inferior vena cava limb of systemic venous baffle, NA = not applicable, NAFAT = Non-automatic focal atrial tachycardia, NSVT = non-sustained ventricular tachycardia, PVB = pulmonary venous baffle, O₂ sat = oxygen saturation, SVC = superior vena cava limb of systemic venous baffle, TIA = transient ischemic attack, VF = ventricular fibrillation, VT = ventricular tachycardia.

*“Both” refers to involvement of the SVC and IVC.