Mémoire de Maîtrise en médecine N°3465

Percutaneous treatment of acquired pseudoaneurysms after ascending aortic surgery; a case serie

Etudiant
Piccon Sandrine

Tuteur
Eeckhout Eric
Dpt of Cardiologie, CHUV

Expert
Dine Qanadli Salah
Dpt de Radiodiagnostic et Radiologie interventionnelle, CHUV

Lausanne, 26.04.2017

« Percutaneous treatment of acquired pseudoaneurysms after ascending aortic surgery; a case serie »

Sandrine Piccon, Eric Eeckhout, Salah Dine Qanadli

Context

Pseudoaneurysms of the ascending aorta (PSAA) is a high-risk complication following cardiac surgery. Surgical repair is the conventional treatment but carries high morbidity and mortality rate.
If left untreated PSA can reach to aortic dissection, thrombosis, distal embolization and fistula formation. Since 2005, further report show an increasing use of percutaneous technique as an alternative for PSAA closure in patient ineligible for surgery repair. This method seems to give promising results.

Objectives

Our aim was to investigate the efficiency and the feasibility of percutaneous treatment to close ascending aorta pseudonaeurysms and report the existing data concerning this technique to evaluate the potential generalization for high-risk patient.

Methods

In this work, we examined the literature of percutaneous approach to treat PSAA and sought to report all cases which have been treat by this technique. We selected patients who underwent catheter-based intervention with Amplatzer septal occluder technology (ASO) sometimes combined with coils embolization to close ascending aorta pseudoaneurysm. For each patient, we reviewed the medical history, the characteristics of the PSAA, the direct result of the intervention and the follow-up period.
We also present a serie of four patients involving the use of Amplatzer septal occluder device in addition, for three cases, with coils embolization, as an alternative strategy in the management of ascending aorta pseudoaneurysms. All cases were treated in our institution and we used the Interventional Cardiology Database to retrospectively collect the informations.

Results

Including our cases, percutaneous method shows and efficacity of 84.78% (39/46) with good midterm follow up outcomes. Coils and Amplatzer occluder device combined technique demonstrates a similar success rate of 81.81% (9/11). However, rare complications as structure damage (2.1%(1/46) due to catheter or device embolization (4.5%(2/44)) can appear during procedure and may have unfortunate outcomes.

Conclusion

This work demonstrates that the percutaneous method is a feasible and effective alternative to treat patient no eligible for surgery repair. It's a relatively easy to use technique with shorter time of hospitalization and better recovery after intervention for the patient. This technical intervention should be considered for selected patients with high risk for redo sternotomy.

Introduction

Pseudoaneursyms of the ascending aorta (PSAA) are rare but serious complication after cardiac or ascending aorta surgery. The vast majority of pseudoaneurysms typically arise from suture line or cannulation site after cardiac and ascending aorta surgery including aortic valve replacement, coronary artery bypass grafting or ascending aorta replacement [1,2]. Endocarditis and trauma are other common aetiologies [1]. False aneurysms can develop early or many years after surgery, the incidence at 15 years post intervention is 23% [3]. Clinically, patients present symptoms related to structures compression as chest pain, angina, dysphagia or stridor but can also remain totally asymptomatic [4]. Consequently, it's essential to make a regular follow-up of patients having undergone cardiac and ascending aorta operations [10,11]. Computer tomodensitometry (CT) scanner and transoesophageal echocardiography (TOE) are medical imagery that allow detection of these complications and provide precious information on the location, the aneurysm bag size, the neck size and the surrounding structure of the pseudoaneurysm.

Surgical management of PSAA is the conventional treatment but limited by poor outcomes with high morbidity and mortality rates. The main elements increasing risk for surgical repair include the following; cardiac insufficiency (New York Heart Association III or IV), PSAA's dimension (>55 mm in diameter), the age of patient (>65 years), active endocarditis, urgent procedure and long cardiopulmonary bypass time during the intervention [7]. Furthermore, it was found that severe systolic dysfunction (left ventricular ejection fraction <35%) and obesity (BMI >30kg/m^2) are both mortality predictors related to PSAA surgery [7 & 33].
Instead, if left untreated PSAA can reach to aortic dissection, thrombosis, distal embolization and fistula formation. Mortality rate for patient not eligible for surgery is more than 61% [3]. In this context, new percutaneous approach has been developed to manage this complication and appears to be less invasive with good final results.

Endovascular Techniques

In literature, several endovascular techniques to close pseudoaneurysms have been described such as coils embolization, stent grafting, occluder devices implementation (Amplatzer Septal Occluder) or thrombin injection.
Stent grafts technique may not be indicated for PSAA because of proximity with the coronary ostium and aortic branches leading to an important risk of occlusion [7,8]. Moreover, for good placement and efficacity, stent graft has to be place in a « landing zone » of healthy aorta tissue measuring at least two centimetres. This technique is mainly used for distal arch, descending or abdominal aorta repair [7].
Possibility of thrombin injection was tested in a study [8] and was complicated by transient ischemic attack resolved with abciximad adjunction. Proximity of aorta branches may be a limitation. There are no clear recommendations in Literature for this technique application so far.
Coils embolization is an effective method for small to middle-sized pseudoaneurysms with narrow neck [10] or for saccular pseudoaneurysm with a bag larger than the neck to decrease risk of coils embolization in blood flow. Except for a few cases [11,12], coils are commonly used as adjunctive therapy along with occluder devices or stent grafts [6]. Advantages of this technique is the possibility of coils retraction and redeployment if position is not satisfactory. Treatment by coils embolization has been reported to be a good therapy for the treatment of anastomotic pseudoaneurysms in complex locations [11,12].
Off-label use of occluder devices started in 2005 with the first case of successful pseudoaneurysm exclusion reported by Bashir et al. [20]. Since then, experiences with occluder devices kept increasing and are now the most reported percutaneous technique to close PSAA in the Literature. Those devices are all made of nitinol and are available in different type and size.

Amplatzer septal occluder (ASO) type is arranged with a single nitinol disk together with an internal mesh, it's one of the most commonly used device for PSAA closure [10,13–22]. Amplatzer muscular ventricular septal defect (mVSD) type with two symmetrical disks is known to reduce wall rupture risk and to provide better anchoring because of wider connecting portion[17]. Amplatzer vascular plug types numbered I through IV are made with two conical disks, the most experience is with type II. Amplatzer cribriform occlude (ACO) and Amplatzer patent foramen ovale occluder (PFO) are two other type but these are not used in this review.
As with coils technology, occluders can easily be adjusted and redeployed if needed by retrograde approach. All devices are effective for moderate to large size PSAA with narrow neck[9].

Methods

In this literature review we have sought articles published between 2005 and 2016 using various databases as PubMed, Google Scholar and WebofScience. Keywords used for the literature research included the followings «percutaneous treatment», « pseudoaneurysm » or « false aneurysm » and « ascending aorta ». Among 120 articles, 22 were Case Report relating to percutaneous closure of PSAA with Amplatzer Septal Device occluder (ASO), coils embolization or both at the same time.
We identified all the cases of PSAA since the first one in 2005 focusing on ASD implementation added or not to coils embolization.

Furthermore, we present four cases of ascending aorta pseudoaneurysm which developed following aortic or cardiac surgery and treated by the use of ASD technology combined or not with coils embolization. For each patient, clinical information's have been retrospectively collected though the Interventional Cardiology Database from the CHUV in Lausanne. We analysed and reported medical history, co-morbidities, percutaneous treatment, post-intervention issue and follow-up time.

Procedural Technique

Interventions were performed in a catheter room under local or general anaesthesia. In all cases, initial access was made by femoral artery with a 6Fr or 7Fr introducer. Then a 6Fr pig catheter was advanced up to the ascending aorta and contrast agent was injected allowing to visualize the location of the neck and the aneurysm bag. After aortography, we selected the conform size of Amplatzer occluder to match the size of the PSAA neck and prepared the corresponding delivery sheath system. Then, the aneurysm sac was engaged either with a 6Fr coronary catheter (Multipurpose Cordis) or a Judkins Right 4 catheter (Medtronic) over a 0.035" x 260 Amplatzer super stiff guidewire (Boston scientific). Occluder delivery system are often not long enough for ascending aorta, this is why we used multipurpose catheter. Finally, selected Amplatzer Septal Occluder (ASO, mVSD or AVP IV) was inserted thought over the delivery sheath and deployed. Correct position was verified with aortography.
Coils embolization was performed using catheter and guide previously passed in the ascending aorta. After occluder deployment, catheter was left in position and pseudoaneurysm cavity was filled with coils. Presence of the device reduce risk of coils displacement in aortic blood flow. Then, last aortogram was made indicating position and if any residual leak were persistent. For one of our case, only occluder deployment was performed.

Ethical considerations

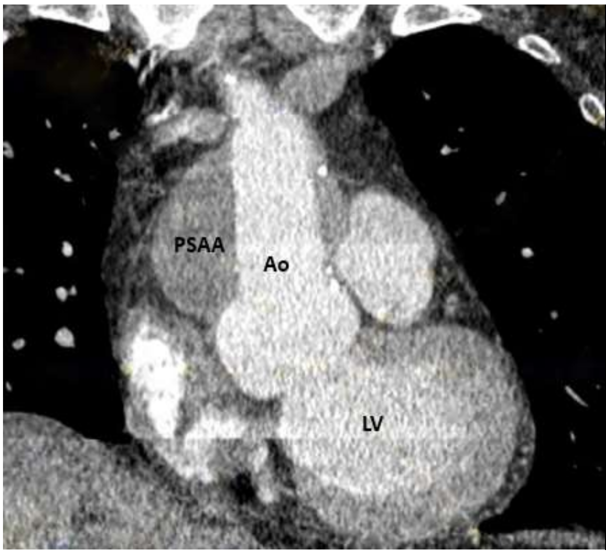
Review of patient's data for this case report was approved by the Institutional Ethics Committee and complied with the Declaration of Helsinki regarding investigations in humans.

Case Report

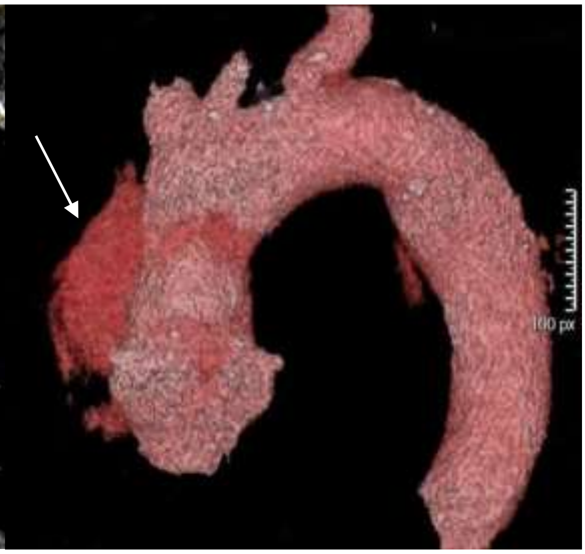
<u>Case 1</u>

A 60-year-old man with history of ascending aorta replacement with Gelveave graft comes for computer tomography (CT) scan follow-up exam five years post-surgery. His medical history was significant for severe hypertension, Type II diabetes, obesity (33kg/m2) and smoking.

CT of the chest showed the presence of a leak at the distal anastomotic site between the prosthesis and the native aorta. The leak filled a pseudo aneurysmal bag measuring 57x63mm. The patient had no complaint and remained asymptomatic from the PSAA.

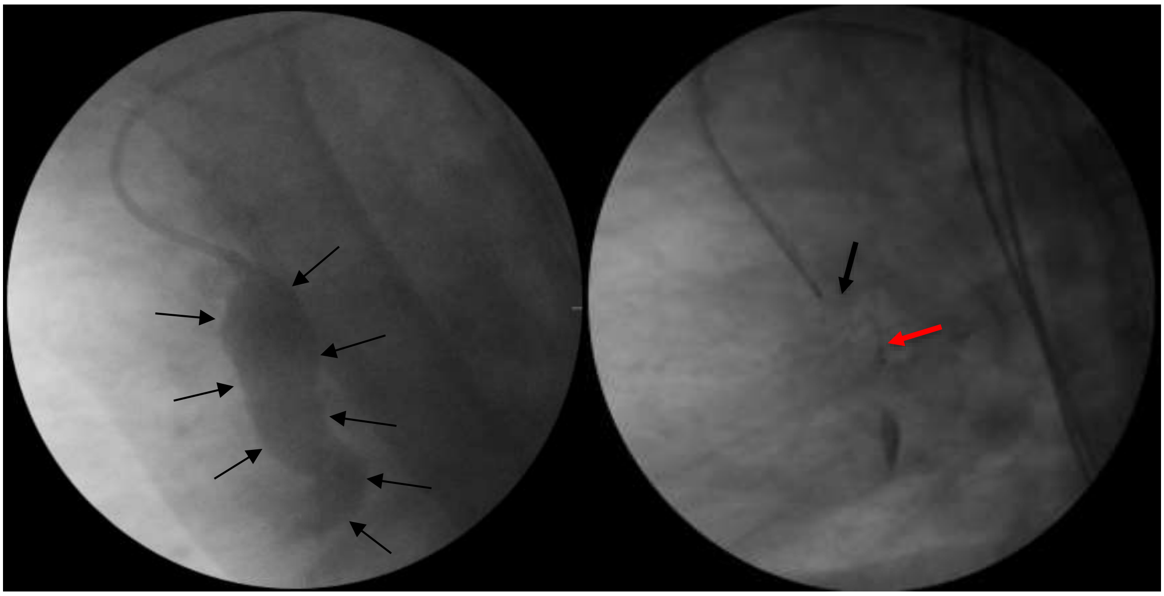


***<u>Figure 1.</u>* Contrast enhancer coronal CT scan demonstrated ascending aorta pseudoaneurysm (PSAA). Ao (Aorta) LV (left ventricle)**



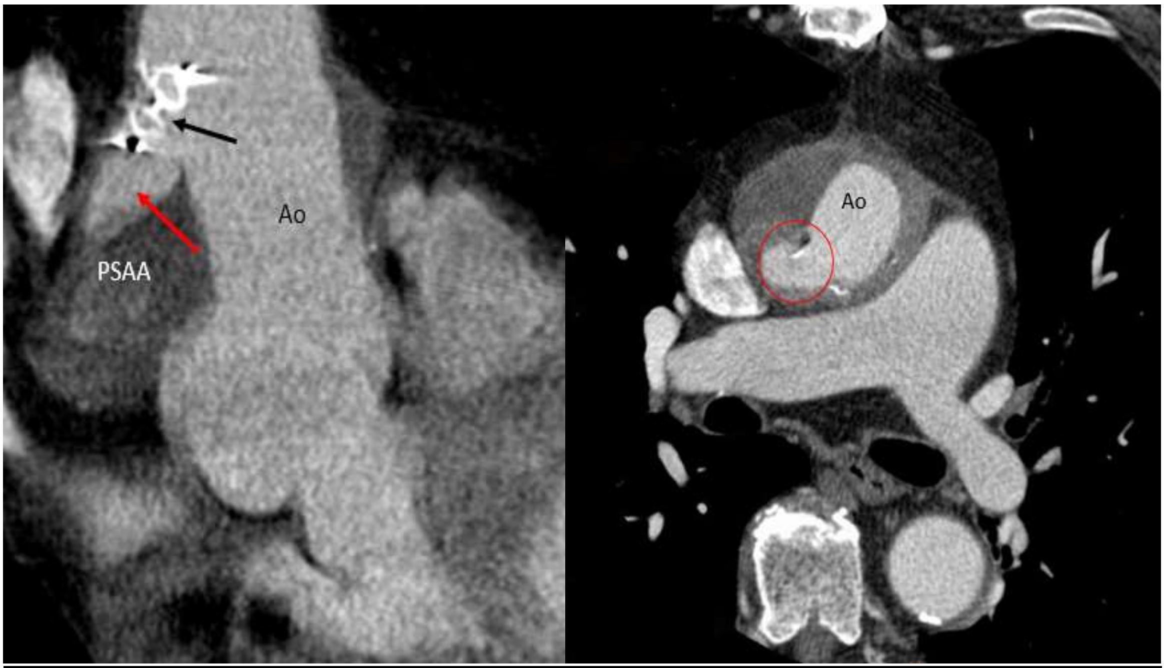
***<u>Figure 2.</u>* Three-dimensional CT reconstruction view of the ascending aorta pseudoaneurysm (white arrow).**

After evaluation by the catheterism team, the choice of an percutaneous approach was decided. The intervention consisted of Amplatzer Vascular Plug IV (AVP IV) type implantation into the leak at the junction of the aortic prosthesis and the native aorta on the right side of the ascending aorta. Procedure was performed under local anaesthesia via femoral approach and with fluoroscopic guidance angiography.



<u>Figure 3</u>. Left: Aortography with contrast opacification showing PSAA (black arrows). Right: Post-deployment aortogram of Amplatzer Vascular Plug IV (AVP IV) device. The distal disk (red arrow) of the AVP IV device was opening inside the PSAA cavity and the proximal disk (black arrow) inside the ascending aorta.

One year later, control CT scan demonstrates the persistence of a residual leak in the aneurysmal bag with a measuring neck of 17 mm in the plan of the aorta and 11 mm in the antero-posterior side. Aneurysmal bag was slightly increased by size spending 63 to 65 mm of maximal transverse axis.



<u>Figure 4.</u> Left: Sagittal CT-scan showing good placement of the Amplatzer device AVP IV (black arrow). Red arrow indicates persistence of a residual leak still feeding the partially thrombosed PSAA bag. Right: Enhancer transverse CT view showing the residual leak (red circle).

A novel intervention was necessary to completely close the pseudoaneurysm by means of a second occlusion device (AVP IV) combined with coils embolization technique. Under local anaesthesia, we proceeded to the setting-up of several coils into the PSAA and closed the access with the Vascular Plug implanted parallel to the first. Post-operative CT scan showed successful closure of PSAA with an insignificant leak and a decrease of the collet's size, the aneurysm bag was mainly thrombosed.
At four years follow-up the leak as well as the thrombosed PSAA were all stable.

<u>Figure 5</u>. Left: Transverse CT scan demonstrates both parrallel AVP IV devices (black arrows) Right: Coils into the aneurysm bag (wide black arrow).

Case 2

The patient was a 45-year-old male with a long complex medical history of aortic insufficiency, who underwent aortic valve replacement for valve prolapse and bicuspidie. Three years after the patient developed a dehiscence of the aortic mechanic valve because of presumed endocarditis, which required an emergency surgery and new mechanical valve implementation (St Jude medical valve). In 2005, following endocarditis complications, a second change of valve is made for a biological one.

Six years after the last surgery the patient presented with NYHA grade III (New York Heart Association) dyspnoea and constants oppressive chest pain. CT scan was made revealing a voluminous false aneurysm of the posterior aorta with a size of 80x40mm. By using transoesophageal echocardiogram (TEE), the pseudoaneurysm was found to be fed by two communications; one sub-valvular hole arising from the left ventricle (18x14mm) and one sus-valvular hole (4x5mm) arising from the ascending aorta. Elsewhere, with coronography exam we noticed that the left main coronary artery (LMCA) was compressed by the PSAA during the diastole.

Figure 6. ***Three-dimensional CT reconstruction of the ascending aorta demonstrated the PSAA with a size of 80mm x 40mm.***

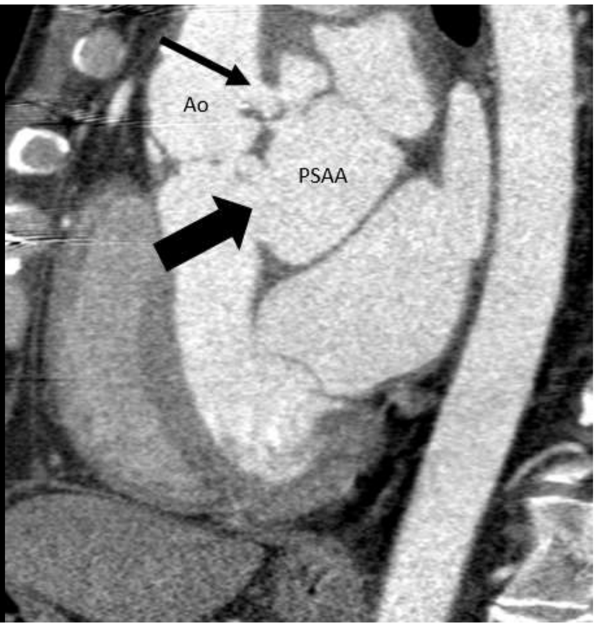


Figure 7. ***Sagittal CT scan showing PSAA with two communications holes (both black arrows). Large arrow reveals wider sub-valvular neck (18mm x 14mm).***

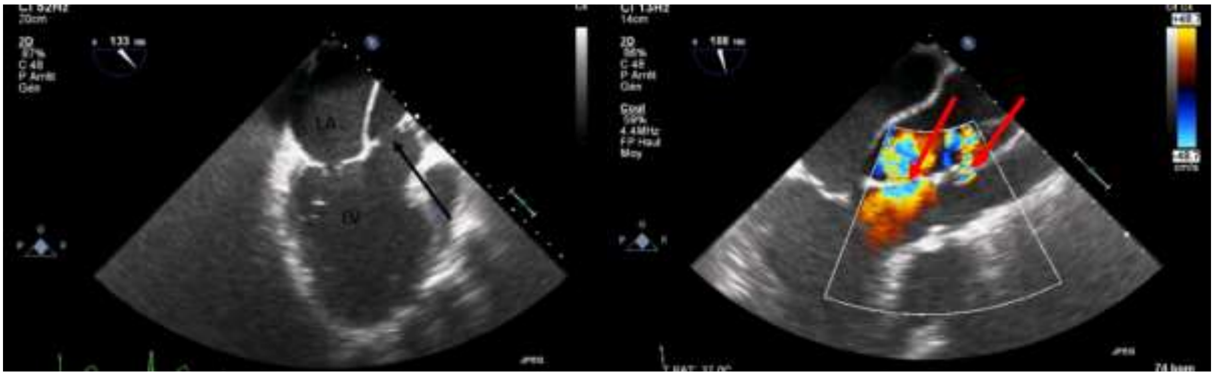
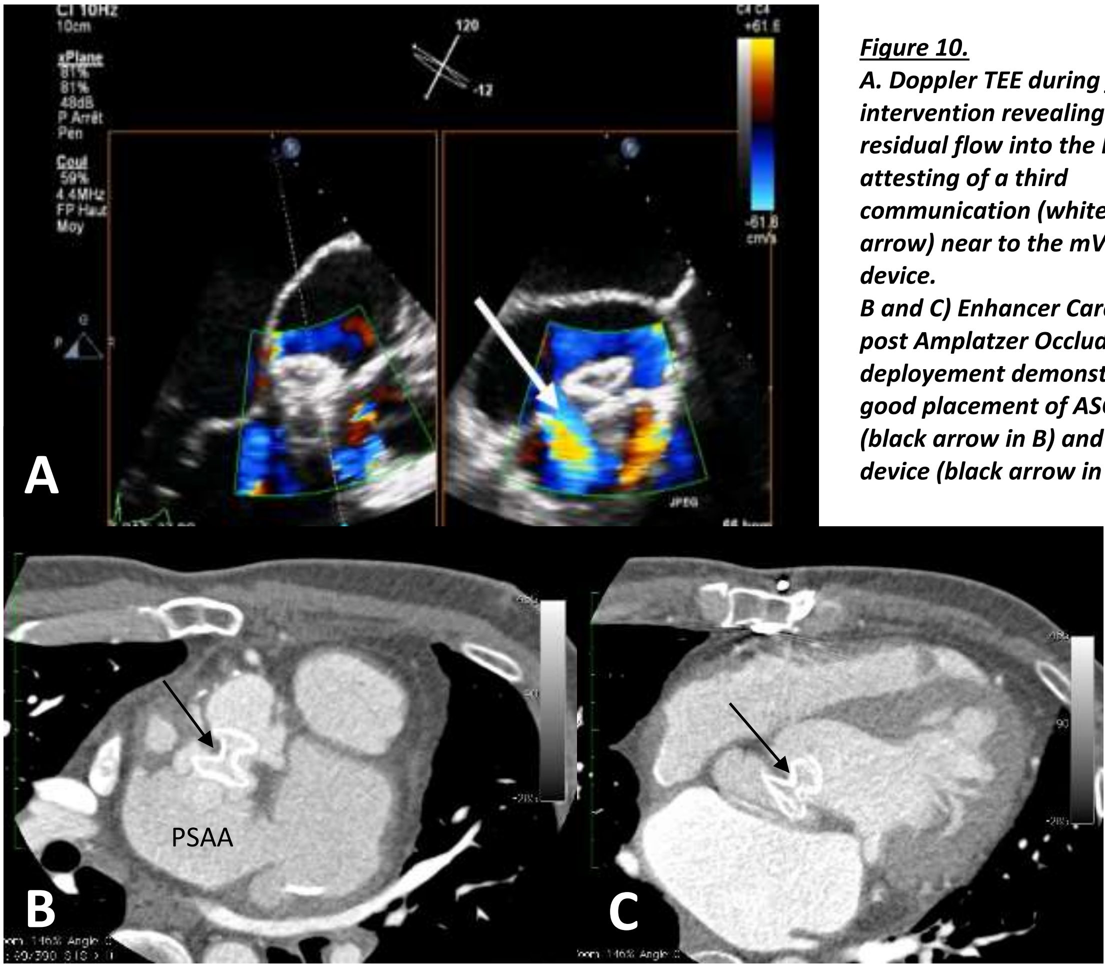


Figure 8. ***Left: TEE showing a large sub-valvular communication (black arrow) between the left ventricle outflow tract and the PSAA. Right: Doppler TEE in long-axis view revealing both PSAA communications (both red arrows).***

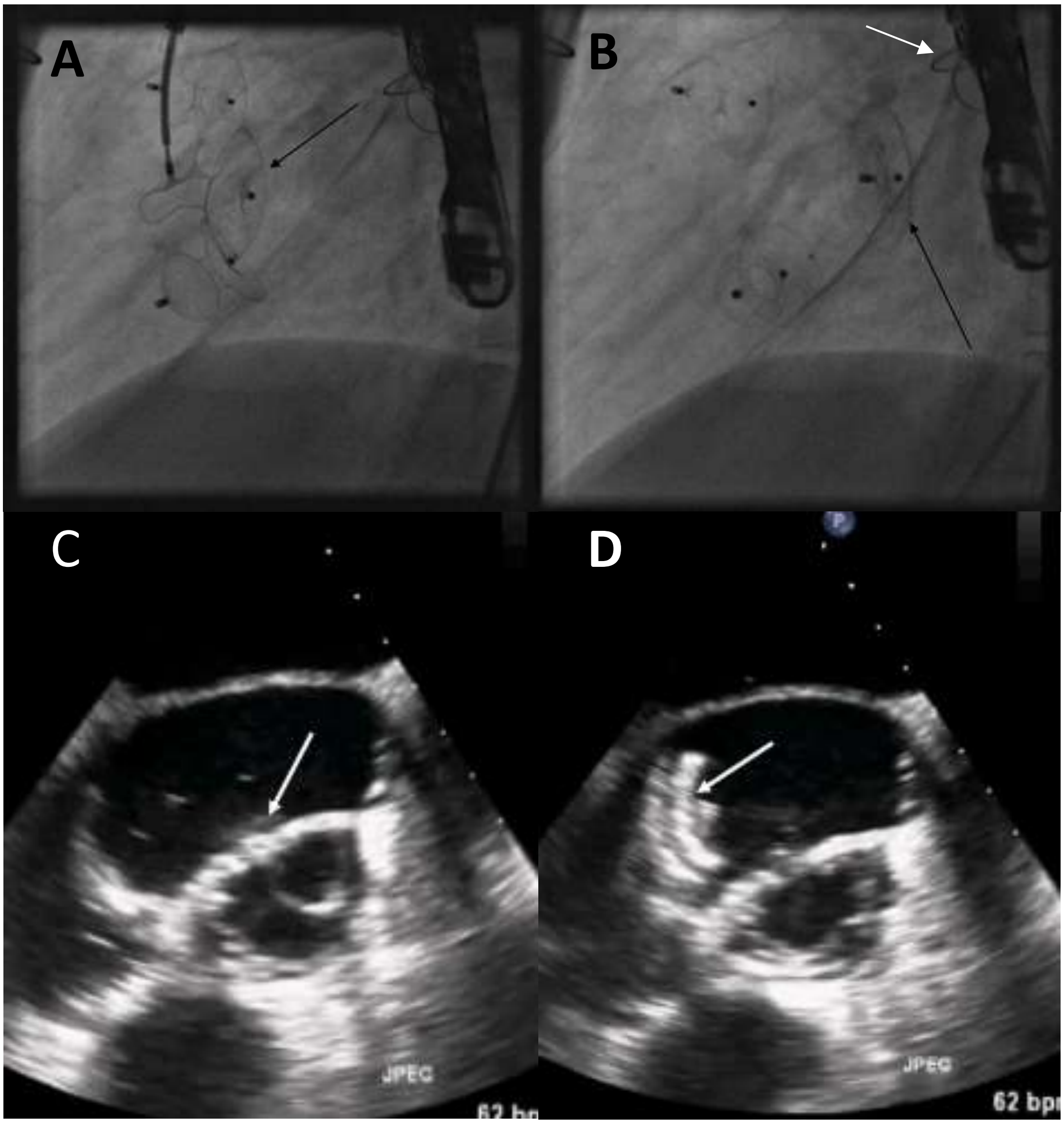
Given the patient comorbidities (NYHA III, obesity) and the size of the PSAA (> 55mm in diameter) he was considered to be high-risk candidate for repeat surgery so he was referred for percutaneous management consideration. Strategy was to do a retrograde closure of the two communications using Amplatzer Septal Occluder (ASO) technology. During the intervention, a 18mm mVSD (muscular Ventricular Septal Defect) occluder was introduced into the sub-valvular communication and a 10mm ASO was used to close the communication between the PSAA and the ascending aorta, both devices were successfully placed.

<u>Figure 9.</u>
Transesophageal echocardiography following PSAA closure with occluder device. White arrows indicate good placement of the mVSD device (left white arrow) and ASO device (right white arrow).

Per-operative TEE monitoring highlighted a third connection arising from the left ventricle. Attempts to close this communication with ASO device was unsuccessful, the patient remained stable but procedure was interrupted. The next day, patient came home without complications.



<u>Figure 10.</u>
A. Doppler TEE during first intervention revealing a residual flow into the PSAA attesting of a third communication (white arrow) near to the mVSD device.
B and C) Enhancer Cardiac CT post Amplatzer Occluder deployement demonstrates good placement of ASO (black arrow in B) and mVSD device (black arrow in C).



<u>Figure 11.</u> Embolization of the ASD occluder. Angiography view (A&B) and TEE view (C&D)
A) Angiography during second intervention showing attemp to close the third communication with an ASD device (black arrow). B) Failure of device stabilisation leading to ASD embolization into the PSAA (black arrow) White arrow indicates the coils. C) Peroperative TEE in short view. White arrow indicates the ASO device stable at first. D) Embolization of the ASO at the bottom of the aneurysm bag.

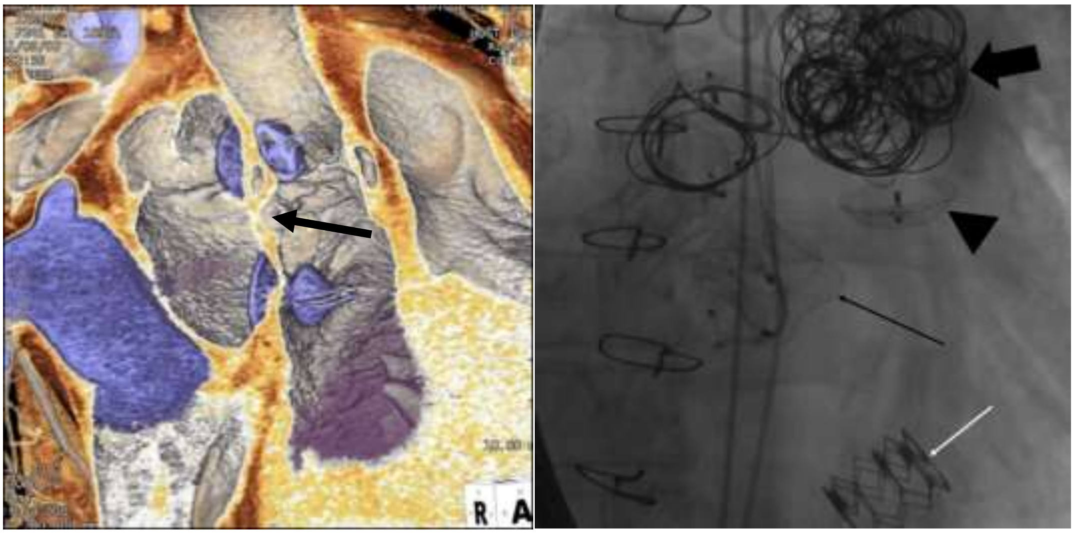
After the first intervention, the patient felt really better, his general condition was improved with a decrease of thoracic pains and dyspnoea. However, two months later symptoms re-emerged and second intervention was required. It was decided to exclude the pseudoaneurysm with simultaneous Amplatzer occluder device and coils method. The second intervention took place three months later. We proceeded of Coils embolization (310 cm in total) with some technical difficulties due to coils migration in the rear part of the aneurysm. Because of that, purpose of neck thrombosing was unsuccessful. We tried again to close the second sub-valvular communication and after two attempts the last ASO device was finally placed in a good position (Figure 11A & 11C). Nevertheless, the occluder couldn't be stabilize and embolized at the bottom of the aneurysm bag (Figure 11B & 11D).

<u>Figure 12.</u> Thorax Radiography after second intervention. Coils are seen into the PSAA (black arrow).

Patient get worst with NYHA IV cardiac insufficiency and resting angina. Options of further management were discussed with him, in particular the possibility of transplantation, which he refused. He was still not eligible for surgery given the high risk of mortality and morbidity. Because of the technical difficulty with standardised occluder size, which wasn't specific for the complex neck shape of this PSAA, we requested the Occlutech company to produce a custom-made implant (Figure 13) with measurements obtained by specific four dimensional cardiac CT scan (Figure 14 on the left).

Final intervention occurred five months later, the customized device was successfully implanted within the last communication hole and was stable. Unfortunately, the delivery sheath of the custom-made implant led into the heart damaged an aortic valvular leaflet generating severe aortic insufficiency. The patient was considerate unsuitable for surgery so decision to replace the valve via trans catheter method was take. At first, the new aortic valve was deployed in a good position, but fifteen minutes later, position was unstable and the valve embolized leading to the death of the patient in catheters room.

<u>Figure 13.</u>
Custom-fit implant created by the Occlutech compagny.



<u>Figure 14.</u>
Left : Four dimensional reconstruction of the PSAA which allowed establishment of specific measure for customized device creation.
Right : Peroperative Angiography showing the coils (black wide arrow) into the aneurysm bag with the embolized ASO (black arrowhead). Thin black arrow indicates the custom-made device in good position and stable. White arrow indicates new mechanical valve implantation before embolization.

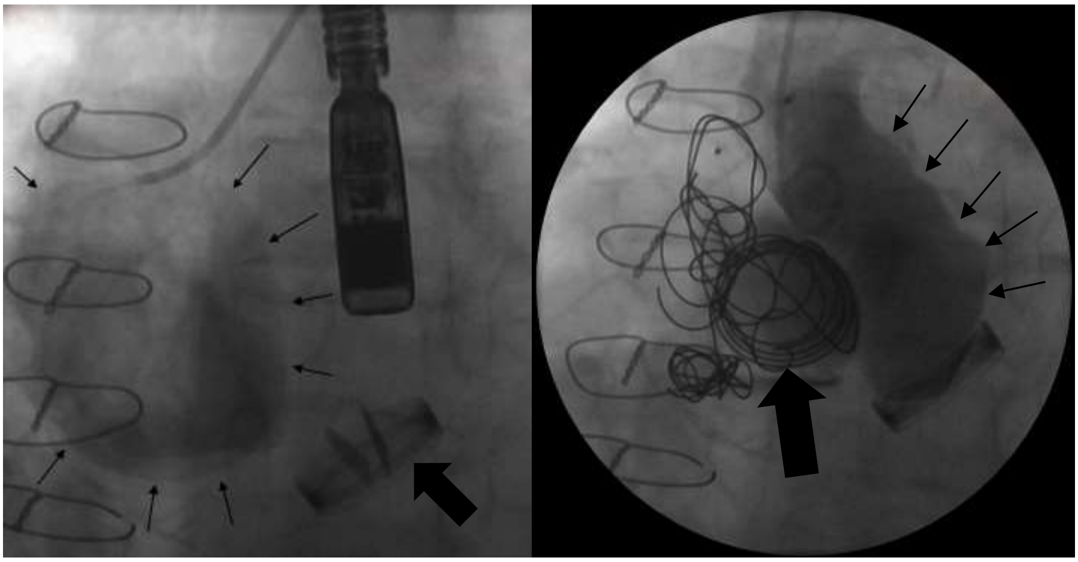
Case 3

The patient was a 67-years-old man with previous aortic valve reconstruction and ascending aorta repair (Gelweave Vaskutek tube) for aortic Type A dissection in 1995.
His medical history was significant for atrial fibrillation, hypertension, hypercholesterolemia and Type II Diabetes.
Ten years after prior surgery he underwent a replacement of the ascending aorta by Bentall technique because of severe aortic insufficiency due to ascending aortic root aneurysm.
Six years post-procedure, a chest X-ray revealed residual dissection and marked widening of the mediastinal silhouette (Figure 15). CT-scan was made and confirmed a large pseudoaneurysm measuring 78x74mm with a narrow neck (3x4mm) located at the right anterior wall of the ascending aorta.

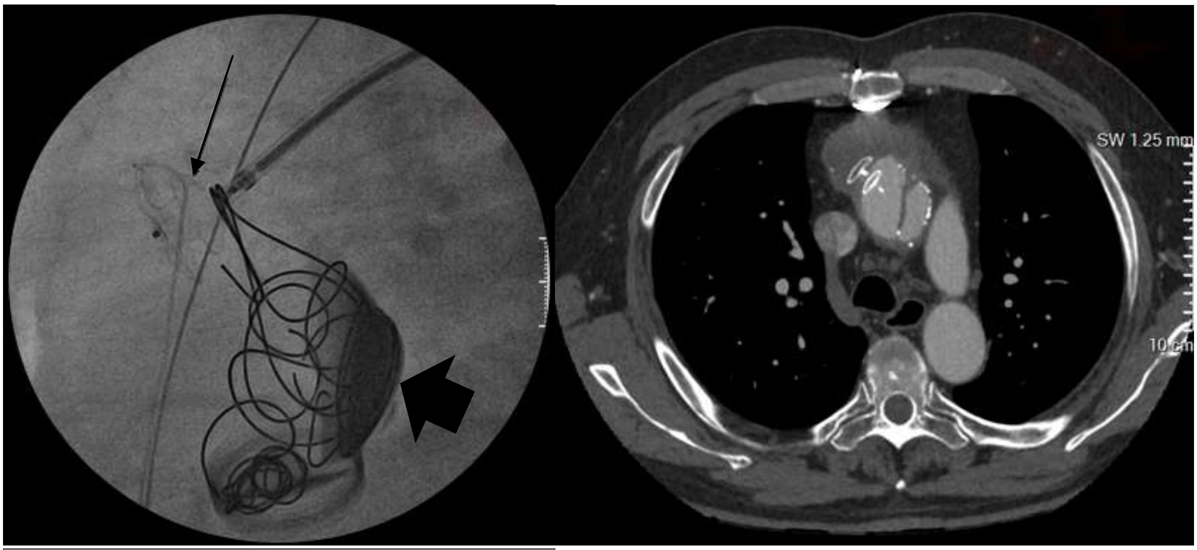
Figure 15. ***Chest Radiography shows widening of mediastinal silhouette which makes suspect dissection or aneurism.***

Figure 16. ***Left : Transversal enhancer CT scan view confirmed the PSAA directly posterior to the sternum. Right : Oblique CT-scan view. The neck of the PSAA is indicated by the black arrow. (Ao) Aorta, (PSAA) Pseudoaneurysm of Ascending Aorta***

Because of the PSAA location, we proposed an percutaneous approach. Under general anaesthesia and using femoral artery, we confirmed position of the pseudoaneurysm by Angiography. Then we embolized several coils (2x(20mmx30cm)) and 4x(15mmx14cm)) and occluded the aneurysm neck using an 10-mm Amplatzer Septal Occluder device (ASO). At the end of the intervention, aortogram showed a minor leak along the closure system but the aneurysm bag was globally no longer fed. Procedure was well tolerated by the patient who went home the next day with no following complications.
At 6 month's follow-up, CT scan demonstrated a decrease of pseudoaneurysm's size and partially thrombosed bag. After three years, Angio-CT chest showed a reduction of the endoleak size. The patient has no complain and remains without any events.



<u>Figure 17</u>. Left : Per-operative angiography with selective opacification of the PSA (black thin arrows). Wide black arrow indicates the mecanical aortic valve.
Right : Angiography during coils embolization. Several coils were embolized into the aneurysm bag (wide black arrow).
Thin arrows show the ascending aorta with contrast agent.



<u>Figure 18</u>. Left: Angiography showing ASD deployement, left atrial disc implanted in pseudoaneurysm cavity and right disc implanted in the ascending aorta (black arrow). Wide arrow show the coils.
Right: Three years follow-up CT-Scan demonstrates totally thrombosed aneurysm and right position of the ASD.

Case 4

A 71-years-old man with systemic hypertension and hyperlipidaemia recently underwent a three vessels coronary artery bypass grafting and pericard patch implementation for a giant left Valsalva sinus aneurysm. One month later, follow-up TEE revealed a tear of the patch device.
CT scan was made and demonstrated persistence of pseudoaneurismal formation at the expense of the left cusp with a partially thrombosed aneurysm cavity measuring 60x45x41 mm.

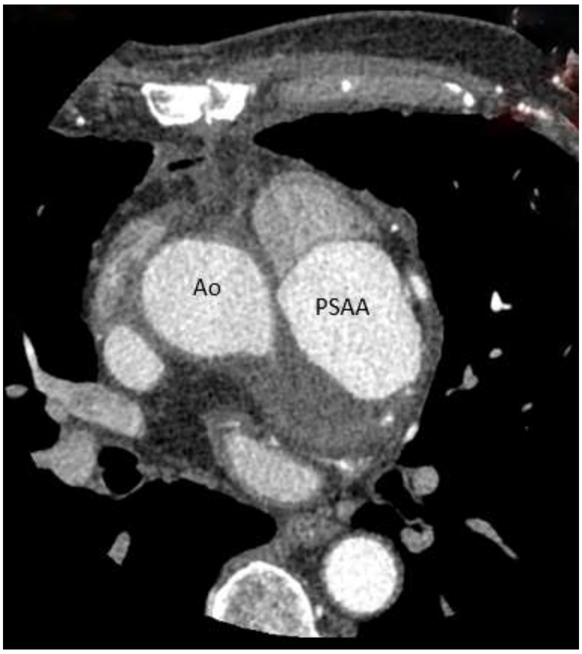


Figure 19. ***Contrast-enhanced cardiac CT scan in transverse view demonstrates a large PSAA (60x45x41mm).***

Because of latest surgery, comorbidities, age of the patient and the actual failed of pericard patch implementation, percutaneous approach was recommended.
Preoperative coronarography confirm the communication between the aorta and left Vasalva sinus aneurysm and showed a significant compression (50-70%) of the left main coronary artery (LMCA) by this saccular PSAA, extended of circumflex artery (CX) and anterior interventricular artery (IVA) proximal segments (Figure 21). At this very moment, the patient was asymptomatic with no sign of angor.

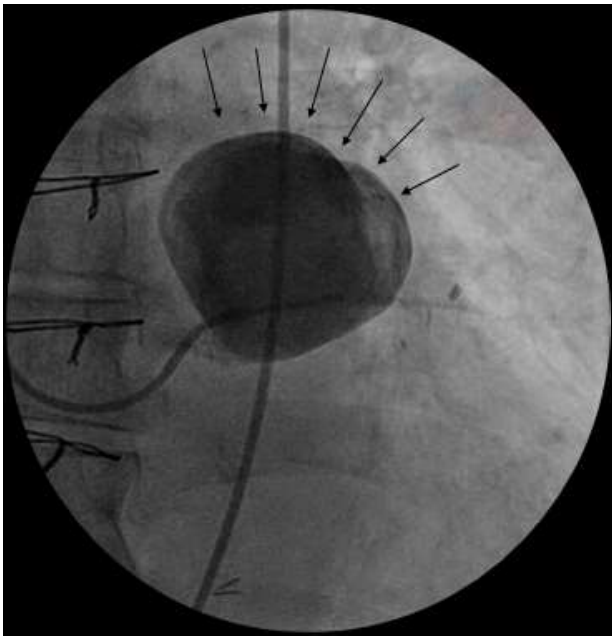


Figure 20. ***Pre-operative coronarography. Contraste opacification define the saccular pseudoaneurysm (black arrows).***

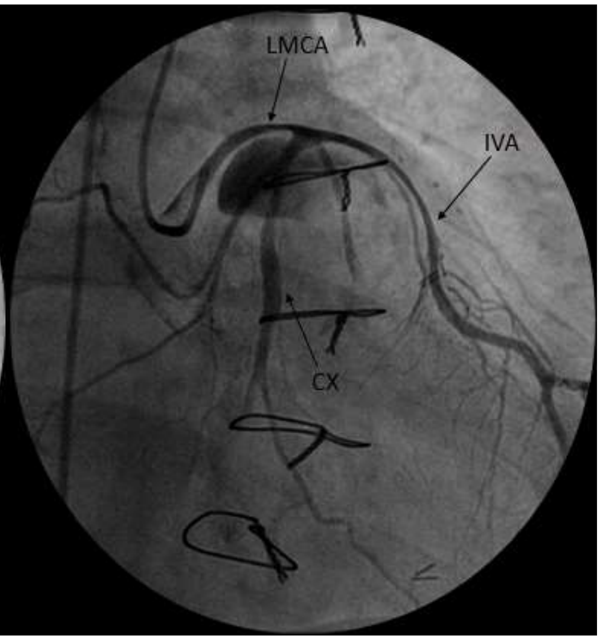
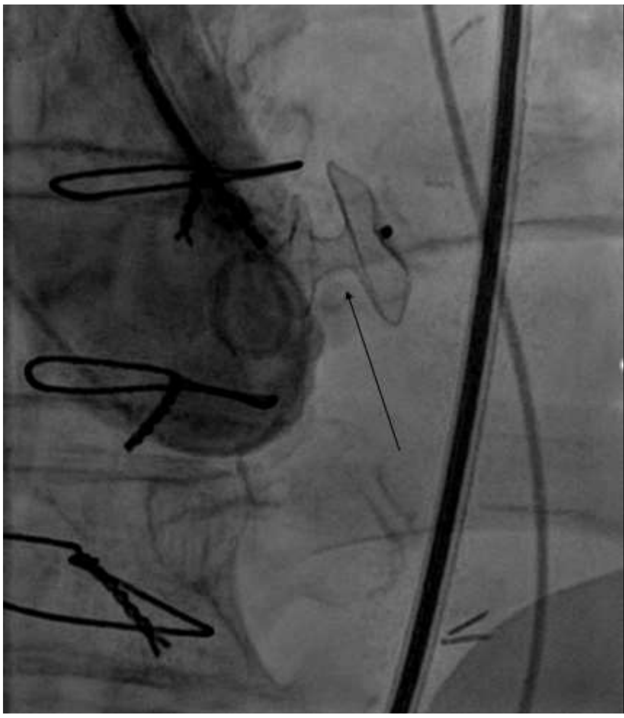


Figure 21. ***Pre-operative coronarography demonstrates compression of the left main coronary artery (LMCA) by the PSAA.***

After discussion with the patient, we decided to treat this PSAA by trans catheter approach under local anaesthesia. The intervention was successfully realized by implementation of a 8mm Amplatzer ASO device. Ascending aortogram showed a right device position and procedure occurred without complications. The patient was able to go home the day after. Two months CT follow up showed a well-positioned plug and a totally thrombosed PSAA cavity.



<u>Figure 22.</u> Per-operative angiography showing Amplatzer deployement (black arrow) with no opacification of the PSAA which indicates good tightness and well positioned device.

<u>Figure 23.</u> Transverse contrast-enhanced CT scan of the thorax 2months post-procedure demonstrated exclusion of PSAA with Amplatzer Septal Occluder device (black arrow).

Discussion

In this case report, three patients underwent occlusion device combined with coils embolization procedure whereas one patient benefits of occluder device therapy only. Regular follow up for patients with medical history of ascending aorta or cardiac surgery is really important because most of the aneurysms were detected by surveillance program[2] and 75% (3/4) of our patient were asymptomatic.
Interventional procedure was conducted in two steps for 50% of our patients. At first with an Amplatzer occluder implementation and in a second time using coils embolization with additional occluder technology if residual leaks persist. All patients were treated though the use of different Amplatzer Occluder device as mVSD, ASO, AVP IV and even a custom-made device created by the Occlutech company. Choice of the device was based on the size of the pseudoaneurysm neck in diameter.

Among our four cases, three were successfully treated. The second case was a very sensitive situation with serious patient's medical history and complex anatomy of the PSAA with three communication holes. Technically, the deployment of both initial occluders (mVSD and ASO) were successful but the difficulty was to find a device that match exactly the shape of the last communication. Otherwise, the leak was very close to the mVSD not given much available place and we needed sufficient rim of tissue wall to allow good anchoring of the device[13]. Instability of the first ASO placement leading to embolization and damage caused by the guide to the aortic valve are two serious complication of endovascular treatment. Challenging situation such as this case shows interest of having adapted devices like custom-made occluder and essential need of sensitive imaging techniques to help the physicians being as specific as possible. Transesophageal echocardiography and CT scan allow the preceding, by assessing the location, the size and the surrounding structure of the pseudoaneurysm, these are the most used imaging technology[4,5,7,9,13–19,23,27].

Overall, including the patients we report on, percutaneous method for PSAA management has a success rate of 84.78% (39/46) any method included. More specifically, occluder devices used alone have a similar rate of 84.84% (28/33) of success.
A recent large study of 12 cases [14] shows good results for Amplatzer occluder method combined with coils implementation. As we also report in this review, using occluder with coils turns to be an efficient technique with a success rate of 81.81% (9/11).
One case of occlude embolization has been reported by Noble et al.[3] and together with our case shows an embolization rate of 4.5% (2/44) for percutaneous treatment.
For seven cases (15.90%) of all patients in Literature including our, complications have been reported; 4.54% had surgery reopen because of percutaneous technique failure (2/44), 4.54% had embolization device (2/44) and 6.81% had unknow complications (3/44).
Follow-up period was really different amongst all the cases, we found that the average period without any significant events is 13 months (13.89 months). Because of the low frequency of PSAA, we need larger clinical study with longer time follow-up.

Percutaneous treatment has obvious applications for patients with high-risk surgical. This technique has some benefits as general anaesthesia and surgical morbidity avoidance. Patients are also able to come back home more quickly. Nevertheless, it's always necessary to keep in mind that this alternative method has inherent complication as material embolization and possibility of structure damage in rare case.

Conclusion

Our results confirm that percutaneous approach is a feasible method, easy to use and efficient for patient who had undergone previous surgery and are high risk for open repair. Procedure avoid general anaesthesia, provides shorter time of hospitalization and carries less complications than surgical management. It should be considered in patients for whom redo sternotomy carries significant risk.

Acknowledgements

I would like to especially thank my tutor Prof. Eric Eeckhout for his considerable patience and his encouragement. I'm grateful for having had the opportunity to work on that interesting subject.

I'll already express my gratitude to my expert, Prof. Salah Dine Qanadli for his precious future advices and expertise.

I thank Nathalie Lauriers for her big help with administrative requests and her ability to solve problem.

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Annexes. Table 1.
Cases of ascending aortic pseudoaneurysms closed by percutaneous method in Literature since 2005.

Author	Year	Age Gender	Prior surgery	PSA Size (mm)	PSA Neck (mm)	Devices	Device Sized (mm)	Time Follow-up	Purpose
Bashir & al	2005	63 M	CABG (twice) and MVR	/	26	ASO	28	6 weeks	Complete closure of the PSA
Komanapalli & al.	2005	79 F	AVR, AA replacement	38x65	/	ASO	5	6 months	Good device placement, exclusion of PSA
Kanani & al.	2007	78 F	Sternectomy for breast cancer, Sternal reconstruction	20x41	14	ASO	18	1 months	Exclusion&decrease in size of the PSA
		68 F	CABG	71x54x54	47	ASO	6	2 days	Successful closure with PSA thrombosis
		51 M	CABG	70	/	ASO	19	/	PSA exclude
Kpodonu & al.	2008	51 M	AVR (twice) and endocarditis	76x80	8	ASO	/	18 months	PSA bag decrease
Kannan & al.	2008	60 M	AA dissection repair	55	9	mVSD	10	6 months	Asymptomatic
		63 F	Potts Shunt, Blalock-Taussig shunt, Aortic surgery	45	14	mVSD	18	3 months	Asymptomatic
Stasek & al.	2008	51 M	Endocarditis, AVR, CABG	150	12x14	ASO	15	2 years	Thrombosed PSA, spherical scar

/= unknow ; CABG=Coronary artery bypass grafting ; AA= Ascending Aorta ; MVR= mitral valve replacement ; AVR= Aortic Valve replacement ; PSA= Pseudoaneurysm
ASO = Amplatzer Septal Occluder ; mVSD= muscular Ventricular Septal Defect ; AVP II= Amplatzer Vascular Plug II ; ACO= Amplatzer cribiform occluder

Norgaard & al.	2008	74 F	AVR, AA replacement	/	25	Coils	/	2 weeks	Total neck occlusion, decrease PSA size
Hussain & al.	2009	58 M	AA aneurysm repair	/	/	ACO	18	/	Occluded PSA
		75 M	Endocardite, MVR	76x80	6-7	ASO	18	/	Minor leak
		81 M	/	/	16	ASO	18/22/2	/	Converted to open
Scholtz & al.	2010	74 M	CABG, AVR	78x47	/	AVP II	8	3 months	Complete occlusion
Kumar & al.	2010	59 M	Bentall, CABG, PSA repair	/	/	ASO	10	/	Asymptomatic
		59 M	Bentall, CABG, aneurysm repair	/	/	ASO	10	/	Mild residual Flow
		71 M	AA dissection repair	/	/	AVP II	14	2 months	Asymptomatic
Fine & al.	2011	59 M	Bentall, CABG	/	/	ASO	10	/	Successful device's placement
Noble & al.	2011	62 F	CABG	28x22.5	9.45	mVSD	10	27 days	Embolisation of the mVSD in aorta
Agarwal & al.	2011	57 M	CABG	40x44	9	ASO	12	6 months	No residual leak
		35 M	AVR, MVR	45x50	7	ASO	10	2 months	No residual leak
Scantlebury & al.	2012	46 F	Sternal surgery	/	5	AVP II	/	/	No complication

Shreenivas & al.	2013	80 F	CABG	6x12	4	AVP II	8	/	No flow into cavity
Patel & al.	2014	59 M	AA dissection repair, CABG, HIV	70	14	ASO	24	6 weeks	Mild leak
		56 M	AA dissection repair, CABG	/	/	AVP IV	6	1 week	Mild leak around the plug
Zhang & al.	2014	45 M	AVR	80x65	6	mVSD	/	3 days	No residual flow across PSA
De Boo & al.	2014	71 M	Aortic root repair, AVR	/	/	AVP II/Coils	/	1 month	No complications
Jain & al.	2014	77 M	AA dissection repair	16x17	/	Coils	4x60(2x) BSI	3months	Complete exclusion of PSAA
Garcia & al.	2015	81 F	AVR	40x27	/	AVP II	8	/	Complete occlusion of the PSA
Nogueira & al.	2016	81 M	AA repair	98x48	/	ASO	20	14 months	Complete closure of the PSA, thrombosis of the cavity

Table 1. Suite

Author	Year	Age Gender	Prior surgery	PSA Size (mm)	PSA Neck (mm)	Devices	Devices size (mm)	Time Follow-up	Purpose
Lyen & al.	2016	69 /	AVR	75x60	5.4	ASO Coils	4 and 5 14x100 IC 7x70(4x) HFC 6x60(3x) HFPC	38months	Stable PSAA (patient died of unrelated cause)
		26 /	Composite valve graft of AR, Distal arch replacement	35	12	ASO Coils	13 14x20 IDC (3x)	4months	Development of a 2nd PSAA, closed with ASD but patient died of haemorrhage
		47 /	Dacron jump graft	90x43x43	6x3	ASO Coils	10 20x20 (8x)	60months	Asymptomatic Increase of the thombus inside PAA
		76 /	CABG	90x56x67	6	ASO Coils	9 18(6x) / 20(9x) NEC	53months	No leak
		65 M	Aortic dissection repair	38x25x30	8x5	AVP IV Coils	8 20x140(x9) 18x140(x5) NEC	44months	No leak
		78 /	AVR	44x30x40	9	ASO Coils	15 20x200 / 18x200 18x140 NEC	32months	No leak

71 /	AVR, AA replacement, CABG	75x64x32	5	ASO Coils	7 20x200 NEC	2months	No leak
66 F	AVR	123x74x78	14x10	ASO	17	4days	Persistant leak, surgery
51 F	AVR	32x46x49	9 and 4	AVP II	20	44days	Leak, patient died before surgery
63 M	AVR	27x17x15	4	ASO	15	4months	Patient died from post-operative complications
84 /	AVR, AA replacement, CABG	54x45x43	4x4	ASO	9	2months	Persistant leak, patient stable
66 M	None		9x8	ASO	9	7months	No leak

IC= Interlocking Coil/ HFC= helical fibered Coil/ HFPC= helical fibered platinum coils/ IDC= Interlockind detachable coils/ NEC= nestor embolization coils