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Platypnea Orthodeoxia Syndrome and Patent Foramen Ovale closure: single-center experience

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''If I have seen further, it was by standing upon the shoulders of giants.''
Isaac Newton

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Resumo

Introdução: A síndrome de platipneia-ortodeoxia (SPO) é incomum e caracteriza-se por dispneia e dessaturação arterial induzida pela posição ortostática e aliviada em supinação. Embora a SPO tenha várias etiologias, esta é principalmente devido a um fluxo espontâneo intracardíaco direito-esquerdo (D-E), maioritariamente através de um foramen oval patente (FOP). A posição ortostática altera a anatomia cardíaca com aumento do grau de fluxo D-E ao alongar o septo interauricular e abrindo a válvula do FOP. O fluxo D-E ocorre com elevação transitória da pressão nas cavidades cardíacas direitas, com reversão espontânea do gradiente de pressão interauricular. Menos comumente, alterações anatómicas também provocam fluxo espontâneo D-E através de um FOP, redirecionando o fluxo sanguíneo da veia cava inferior para a aurícula esquerda, mesmo na presença de pressões direitas normais. O encerramento percutâneo do FOP é o tratamento de eleição para correção da SPO. O objetivo deste estudo foi avaliar as características clínicas e gasométricas e descrever os resultados a longo prazo do encerramento percutâneo do FOP num grupo de pacientes com SPO.

Métodos: Nesta série unicêntrica, entre janeiro de 2010 e janeiro de 2020, 14 pacientes foram estudados no Centro Hospitalar Universitário do Porto com SPO e foram submetidos a encerramento percutâneo de FOP. O resultado de eficácia primário foi a razão PaO2/FiO2 antes e 24 horas após o procedimento. Um sucesso clínico total foi considerado quando ocorreu melhoria da SpO2 para >94% na posição ortostática e sentada sem oxigênio suplementar, enquanto um sucesso parcial foi considerado se a SpO2 melhorou desde o valor basal, mas ainda a requerer oxigênio para atingir SpO2 > 94%. O resultado secundário foi a melhoria absoluta da SpO2 e da sensação de dispneia sem fluxo interauricular residual significativo no ecocardiograma transtorácico (ETT) de seguimento.

Resultados: Dos 168 pacientes submetidos a encerramento de FOP ou defeitos do septo auricular, 14 tinham SPO (8,3%) e foram eleitos para o encerramento do FOP. O encerramento percutâneo foi realizado com sucesso em todos os pacientes com um único dispositivo. 12 dos 14 pacientes tiveram sucesso clínico total (86%) e um paciente teve sucesso parcial. A razão PaO2 / FiO2 aumentou de 155,9 ± 50,6 para 318,3 ± 73,4 após o encerramento do FOP, (p = 0,002). Todos os pacientes com sucesso clínico total atingiram o resultado secundário com melhoria absoluta da SpO2, resolução completa da dispneia e sem fluxo residual significativo por ETT entre 12 e 24 meses de seguimento.

Conclusão: O encerramento percutâneo do FOP é um método eficaz e seguro para pacientes com SPO, permitindo uma grande melhoria dos parâmetros gasométricos e da qualidade de vida.

Abstract

Introduction: Platypnea orthodeoxia syndrome (POS) is an uncommon condition characterized by dyspnea and arterial desaturation induced by an upright position and relieved in the supine position. Although POS has several etiologies, it is mostly due to an intracardiac right-to-left shunt (RLS), usually through a patent foramen ovale (PFO). The upright position alters the cardiac anatomy and increases the degree of shunting by stretching the interatrial septum and opening the PFO flap valve. RLS occurs with transient elevation in the right cardiac chambers pressure causing a spontaneous reversal of interatrial pressure gradient. Less commonly, anatomic conditions may also cause a significant RLS via a PFO by redirecting preferential blood flow streaming from the inferior vena cava to the left atrium, even in the presence of normal mean right atrial pressure. Percutaneous closure of PFO is the treatment of choice to improve POS. The aim of this study was to evaluate the clinical and gasometrical characteristics and to describe long-term outcomes of percutaneous PFO closure in a group of patients with POS.

Methods: In this single-center series, between January 2010 and January 2020, 14 patients were referred to Centro Hospitalar Universitário do Porto with platypnea orthodeoxia and were treated with percutaneous closure of a PFO. The primary efficacy outcome was the PaO2/FiO2 ratio before and after the procedure evaluated 24h post-procedure. A total clinical success was considered if SpO2 improved to >94% in the supine and sitting position without supplemental oxygen while a partial success was considered if SpO2 improved from baseline but still requiring oxygen to achieve SpO2 >94%. Secondary outcomes were the absolute improvement of SpO2 and sense of dyspnea without significant residual shunt by transthoracic echocardiography (TTE) at follow-up.

Results: Of 168 patients undergoing PFO or atrial septal defect closure, 14 had platypnea orthodeoxia (8.3%) and were elected to PFO closure. Percutaneous PFO closure was successfully performed in all patients with a single device. 12 out of 14 patients had a total clinical success (86%) and one patient had a partial success. PaO2/FiO2 ratio increased from 155.9 ± 50.6 to 318.3 ± 73.4 after PFO closure, ($p = 0.002$). All patients with total clinical success had a successful secondary efficacy outcome with an absolute improvement of SpO2, complete resolution of dyspnea and did not have a significant residual shunt by TTE between 12 and 24 months of follow-up.

Conclusion: PFO percutaneous closure is an efficient and safe method for patients presenting with platypnea orthodeoxia allowing a major improvement in both gasometrical parameters and quality of life.

Keywords (MeSH from Index Medicus): Patent Foramen Ovale, Platypnea-orthodeoxia syndrome, Hypoxemia, Right-to-left shunting

Abbreviations and acronyms

AF – Atrial Fibrillation
Ao – Aorta
ASA – Atrial Septal Aneurysm
ASD – Atrial Septal Defect
ASO – Amplatzer Septal Occluder
CHF – Chronic Heart Failure
EAPCI – European Association of Percutaneous Cardiovascular Interventions
FiO2 – Inspiratory Oxygen Fraction
Hb – Haemoglobin
IAS – Interatrial Septum
IQR – Interquartile Range
IVC – Inferior Vena Cava
LA – Left Atrium
NYHA – New York Heart Association
OAC – Oral Anticoagulation
OSA – Obstructive Sleep Apnea
PaO2 – Arterial Oxygen Pressure
PFO – Patent Foramen Ovale
POS – Platypnea-Orthodeoxia Syndrome
RA – Right Atrium
RLS – Right-to-left Shunt
SD – Standard Deviation
SpO2 – Arterial Oxygen Saturation measured by pulse oximetry
SVC – Superior Vena Cava
TEE – Transoesophageal Echocardiography
TTE – Transthoracic Echocardiography

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1. Introduction

Platypnea-orthodeoxia syndrome (POS) is a rare clinical condition characterized by dyspnea and hypoxemia in the upright position that resolves in the supine position, named platypnea and orthodeoxia respectively. The first case of POS was described in 1949 by *Burchell et al* in a patient with post traumatic intrathoracic arteriovenous shunt.[1] The terms 'platypnea' and 'orthodeoxia' where only coined in 1969 by *Altman et al* and in 1976 by *Robin et al*, as a result of hepatic and pulmonary diseases respectively.[2,3] In 1984, POS was first described in patients with intracardiac right-to-left shunt (RLS), without hepatic or pulmonary dysfunction nor elevated right heart pressures.[4]

Hypoxia is caused by the mixture of deoxygenated venous blood with oxygenated arterial blood through a shunt.[5] The mechanisms underlying orthodeoxia and platypnea can be classified as intracardiac or extracardiac shunts.

Intracardiac communications are the most common causes of POS and usually occurs in the setting of a RLS between the atriums. Blood shunting occurs through a *patent foramen ovale* (PFO) in the majority of patients, from an atrial septal defect (ASD) or a fenestrated ASD. The *foramen ovale* is an interatrial communication essential for fetal circulation. In utero, the oxygenated blood flows directly from the right atrium (RA) to the left atrium (LA) bypassing the non-functional fetal lungs through it and entering the fetal systemic circulation. At birth, once the pulmonary circulation is established, the pulmonary vascular resistance decreases. As LA pressure exceeds RA pressure due to venous return, LA pressure forces the flap-valve (*septum primum*) to close against the *septum secundum,* resulting in a functional closure of the *foramen ovale.*[6] The complete fusion generally is completed by 2 years old in 75% of the population. The remaining 25% will have a PFO.[7] PFO is usually an incidental finding without any clinical repercussions but it has also been associated with cryptogenic stroke, decompression illness, migraine and POS.[8,9]

PFO is the most common anatomic defect associated with POS.[7] Two mechanism are linked to the RLS dynamics. First, a transient elevation in the right cardiac chambers pressure causes a spontaneous reversal of interatrial gradient leading to RLS. This occurs by an increase in venous return during physiologic manoeuvres such as inspiration, coughing, sneezing and the Valsalva manoeuvre.[10] Such clinical scenario also occurs in decreased right-sided compliance (right ventricular ischemia), or with high right-sided filling pressures such as pulmonary hypertension, pericardial effusion or mechanical ventilation.[11] Second, any anatomical feature that distort the interatrial septum (IAS) redirecting flow from the inferior vena cava (IVC) toward a PFO in the upright position, even in the presence of normal right atrial pressure, may increase the degree of shunting. The upright position alters the cardiac anatomy and increases the degree of shunting by stretching the IAS and

opening the PFO flap valve leading to the development of a RLS. The presence of a persistent prominent Eustachian valve or a Chiari network may lead to a diversion of blood flow directly from the IVC to the LA towards a PFO.[12] A dilated aortic root, an ascending aorta elongation or an aortic aneurysm can exacerbate the IAS distortion.[13-17] Changes in posture due to kyphosis[18], unilateral paralysis of the diaphragm[19] or mediastinal shift after pneumectomy[20,21] may all contribute to rotation of the heart such that the PFO is more directly in line with the blood flow from the IVC.

The treatment of POS due to an intracardiac shunt is the correction of the primary anatomic defect. Currently, percutaneous closure of these defects has largely surpassed surgical treatment since it has lower rate of morbidity and mortality and lower cost, with very good outcomes.[22,23]

The aim of this study was to evaluate the clinical and gasometrical characteristics and long-term outcomes of percutaneous PFO closure in a group of patients with POS.

2. Materials and Methods

2.1. Study population and Definitions

The local ethics review board approved the study 261-2020 (205-DEFI/206-CE), informed consent was waived due to the retrospective nature of the analysis.

POS was characterized by dyspnea and hypoxemia in the upright position that resolves in the supine position. Desaturation is defined as a drop in arterial oxygen pressure (PaO2) greater than 4 mmHg or arterial oxygen saturation measured by pulse oximetry (SpO2) greater than 5% when standing that improves back to normal in the recumbent position. The primary efficacy outcome was the evaluation of the PaO2/FiO2 ratio post-procedure as compared to baseline. A total clinical success was considered if SpO2 improved to >94% in the supine and sitting position without supplemental oxygen, a partial success was considered if SpO2 improved from baseline but still requiring oxygen to achieve SpO2 >94%. Secondary outcomes were the absolute improvement of SpO2 and sense of dyspnea without significant residual shunt by transthoracic echocardiography (TTE) at follow-up (passage of more than 10 microbubbles within the first three cardiac cycles with or without Valsalva manoeuvre).

All patients underwent an initial evaluation with standard TTE as per current guidelines. PFO was documented by the demonstration of RLS after injection of saline contrast by the forearm. The appearance of microbubbles in the LA within the first 3 cardiac beats after opacification of the RA was considered positive for the presence of an intracardiac shunt such as a PFO. Provocative manoeuvres such as the Valsalva manoeuvre were performed to transiently increase the RA pressure over the LA pressure. A moderate to large shunt was considered if more than 10 bubbles appeared in left atrium by visual inspection. Shunt was classified as passive if RLS was present without any provocation. Patients positive for a moderate to large RLS underwent transoesophageal echocardiography (TEE) to confirm and to better ascertain anatomical features before consideration to percutaneous closure.

An atrial septal aneurysm (ASA) was considered when an excursion of the septal tissue - typically the fossa ovalis - of greater than 10mm from the plane of the atrial septum into the RA or LA or a combined total excursion right and left of 15mm was documented by TTE and then confirmed by TEE.

Aortic root enlargement was diagnosed when aortic root was greater than 39 mm.

2.2. Procedure

After informed consent was obtained, all patients underwent percutaneous closure of PFO under general anaesthesia and TEE guidance with 3D reconstruction (Philips ie33, Eindhoven, Netherlands). Right heart catheterization with evaluation of pulmonary artery pressure was performed to exclude pulmonary hypertension if appropriate. A left oblique projection was used in all procedures. All but one PFO were closed without balloon calibration. The size of the device was estimated by TEE and by fluoroscopy. Device deployment was echo-guided on bi-caval view as visualized by TEE.

Different devices were used: Amplatzer PFO (Abbott Medical, 5050 Nathan Lane North Plymouth, Minnesota, USA) – four of 25mm, one of 30mm and two of 35mm; Amplatzer Multifenestrated Septal Occluder – "Cribriform" – three of 30mm and three of 25mm; and one Amplatzer Septal Occluder (ASO) of 18mm. A TTE was done the next day to all patients in order to exclude residual shunt or any other post-procedural complication (namely pericardial effusion). Gasometrical parameters were evaluated before discharge.

Patients were instructed to take aspirin plus clopidogrel for 3 months and aspirin lifelong, unless oral anticoagulation (OAC) was mandatory. When OAC was required, patients were instructed to take clopidogrel plus OAC within the first three months, remaining with OAC alone for life.

2.3. Immediate outcomes and mid-term follow-up

The primary outcome was evaluated 24h post-procedure. Follow-up was evaluated by review of electronic medical records. A TTE with bubble test was undertaken between 12 and 24 months to determinate residual shunting, along with clinical evaluation for the reassessment of dyspnea with pulse oximetry and blood gas analysis if appropriate.

2.4. Statistical analysis

Continuous distributed data are expressed by means ± standard deviation (SD) and by medians and interquartile range (IQR). Shapiro-Wilk test was performed to examine if a continuous variable is normally distributed in the population. Paired samples t-Test was performed to compare paired means for continuous outcome that are normally distributed. Nonparametric Wilcoxon signed-ranks test was performed to compare paired means for

continuous data that are not normally distributed. Categorical variables are presented descriptively as numbers and percentages.

All tests were 2-sided, and a p-level ≤ 0.05 was considered significant. Analysis was performed using the per protocol principle and all data were analysed using IBM SPSS Statistics version 26.0 (SPSS, Chicago, Illinois).

3. Results

Between January 2010 and January 2020, 168 patients were considered for a PFO or ASD closure at our center. 14 (8.3%) were found to have a PFO related to POS. Table I summarises patients' demographics and comorbidities.

Nine patients were female, the mean age at the time of referral was 76.2 ± 7.4 years and body mass index was 27.1 ± 5.8 kg/m2. Lung disease was present in 4 patients: two had obstructive sleep apnea (OSA) syndrome, one had asthma and one had interstitial pulmonary disease. Nevertheless, after a thorough investigation, the attending pneumologist or internist considered that the POS was deemed to be the plausible explanation for the chronic hypoxemia in spite of the lung disease. Six patients had a previous history of ischemic strokes, two patients had chronic atrial fibrillation (AF) and four had chronic heart failure (CHF). Two patients had chronic renal failure. Six out of fourteen patients (43%) were on chronic continuous oxygen supplementation (range 2.5 L/min to 6L/min).

Six out of fourteen patients were diagnosed with POS during the workup study of chronic type I respiratory failure. Four patients were diagnosed following a respiratory tract infection. One had blunt chest trauma and lung contusion needing prolonged orotracheal intubation. POS was considered after difficulty on weaning from mechanical ventilator. Three patients presented with hypoxemia and POS after syncopal events. The median time from POS diagnosis and PFO closure was 7.4 (IQR 40.7) weeks. Pre-procedural echocardiographic (TTE) images were available for review in all 14 patients. All patients had a positive bubble test, 13 had a passive RLS on bubble test whereas one patient required a Valsalva manoeuvre to demonstrate RLS. No signs of pulmonary hypertension were appreciated on standard echocardiographic evaluation. The major anatomical condition associated with PFO and POS was an aortic root enlargement in 7 patients (mean aortic root was 37.1 ± 5.8 mm, ranging from 30 mm to 45 mm). An ascending aortic aneurysm was observed in 1 patient and measured 49 mm. An ASA was observed in 10 patients (71%). None had a prominent Eustachian valve or Chiari network. Aside from one patient with a small *ostium secundum* atrial septal defect alongside a PFO, no other patient had a spontaneous concomitant left-to-right shunt.

Transcatheter closure was successfully performed in all patients with a single device. In-procedural TEE showed complete shunt closure without a residual shunt. Aside from one groin hematoma treated conservatively, no other major complications occurred. Periprocedural AF occurred in one patient who spontaneously reverted to sinus rhythm.

Primary efficacy outcome:

PaO2/FiO2 ratio increased from 155.9 ± 50.6 to 318.3 ± 73.4, (p = 0.002) (Graphic 1). Oxygen saturation increased immediately after PFO occlusion in the majority of patients, from 91.5 ± 3.8 to 95.1 ± 2.2 (p = 0.021) (Graphic 2). A total clinical success was observed in 12 patients (86%). One patient had a partial clinical success using oxygen supplementation overnight (1L/min) after the diagnosis of OSA; one remained with dyspnea and hypoxemia as before.

Before PFO closure, six patients were on long-term oxygen supplementation. Afterwards, five patients no longer required oxygen supplementation. The above-mentioned patient who did not improve still requires continuous oxygen supplementation (3.5L/min at rest and 5L/min on exertion).

There was no significant variation between haemoglobin and haematocrit before and after the procedure. The average decrease of haemoglobin was 0.4 ± 1.8 mg/dL and the average decrease of haematocrit was 1.8% ± 5.6 (p= 0.416 and p= 0.271 respectively).

Follow up:

All patients were discharged after PFO closure. The mean follow-up time was 37 ± 20 months, ranging from 11 months to 6 years. No patient was lost to follow-up. Since all patients' observations are entered in a national electronic database, we were able to inspect their clinical status irrespective of where they are actually being followed.

Secondary efficacy outcome:

Twelve out of fourteen patients (86%) had a successful secondary efficacy outcome with an absolute improvement of SpO2, a complete resolution of sense of dyspnea and did not have a significant residual shunt by TTE between 12 and 24 months of follow-up.

4. Discussion

In our study, PFO closure lead to complete resolution of platypnea and orthodeoxia in 86% of our patients instantly after the procedure. Systemic saturation immediately increased in the majority of our patients. Patients where on different oxygen supply before the procedure, therefore the PaO2/FiO2 ratio is a more accurate measure of hypoxemia severity than SpO2. According to the Berlin Definition of Acute Respiratory Distress Syndrome established in 2012, the average oxygen impairment increased from moderate degree of hypoxemia (155.9 ± 50.6) to normal (318.3 ± 73.4) after PFO closure, p=0.002.[24] One patient had a partial clinical success still requiring oxygen to achieve a SpO2 > 94% despite dyspnea resolution. After workup study, this patient was diagnosed with OSA and started oxygen supplementation with 1L/min at night.

OSA is a prevalent disease in the general population, with increasing prevalence caused by the rising rates of obesity and some studies have shown a higher prevalence of PFO in subjects with OSA.[25] *Mojadidi et al* observed that RLS, most commonly due to a PFO, is much more frequently in OSA patients compared to a control population without diagnosed sleep apnea (42% vs 19%, p<0.0001). Moreover, they observed that patients with OSA and a PFO are more likely to become symptomatic at a younger age and have higher arterial desaturation proportionally to the frequency of respiratory disturbances.[26]

Symptomatic improvement was seen in most of our patients (93%). Of the 14 patients, only one patient had no change in symptoms after PFO closure, remaining with dyspnea and hypoxemia as before, needing oxygen supplementation. We don´t have a simple explanation for this. Further investigation was inconclusive, but an interstitial lung disease has been suggested in recent lung CT scan.

Out of the 6 patients who were on long term oxygen supplementation, five no longer required oxygen supplementation after the procedure.

Comparing our therapeutic success with past studies, we observed that our success rate is higher than that of *Mojadidi et al* (64.8%) but lower than of *Shah et al* in which all patients demonstrated acute improvements in oxygen saturation (100%).[27,28] Unlike other multiple case series that reported a need for repeat intervention due to residual shunt or device related complications, all our patients were successfully treated with a single device and none required repeated interventions.[29-31] As observed by *Godart et al* and *Shah et al*, one of our patients required an ASO device for closure of the PFO.[28,32] Interestingly, *Shah et al* described septal characteristics that may be correlated with device selection for complete occlusion of the PFO. They stated that an aneurysmal septum, angulated and a shorter overlap with the *septum secundum* required a non-PFO device to achieve optimal defect closure.[28]

Periprocedural AF occurred in one of our patients, as reported in previous series.[28,29] The patient spontaneously reverted to sinus rhythm, not requiring anti-arrhythmic treatment nor cardioversion and AF did not reoccur. Aside from one groin hematoma treated conservatively, no other major adverse event occurred.

At long term follow-up (mean 3 years), all patients in whom a favourable immediate outcome had been achieved, an absolute improvement of SpO2 was maintained, a complete resolution of sense of dyspnea was reported and no significant residual shunt in TTE was found. Only one patient who was diagnosed with OSA two years after the procedure started using nocturnal oxygen supplementation. No late complications were observed, and no late deaths occurred by the time this study was completed.

Although PFO is present since birth in 20 to 30% of the population, platypnea and orthodeoxia usually occurs later in life. The average age of our patients was 76 years old. The late onset of symptoms may be explained by age-related anatomic distortion of the heart leading to an altered axis of the atrial septum and re-direction of blood flow preferentially to the LA via PFO.[17] Another feature related to desaturation in POS is an aortic root enlargement[33,34] or aneurysm[14,15] which was present in 50% of our population (examples in Figure 1).

Comparing our patients with those from other case series describing POS, we found that the most commonly identified precipitating or associated conditions were an hypermobile ASA (10/14), similar to the report of *Delgado et al*[30], and an aortic root enlargement (7/14). In other studies, lung disease or post-pneumonectomy were the most frequent characteristics deemed to be related to POS.[27-29,31,32]

The association between ASA and peripheral arterial embolism was first identified by *Gallet et al* in 1985.[35] The presence of a PFO with ASA portends a higher risk factor for a "cryptogenic stroke".[36] Five out of our 6 patients with previous strokes also had an ASA associated with PFO. However, we cannot extrapolate these neurological events to the PFO due to the age and risk factors of our cohort.

Invasive mechanical ventilation causing positive airway pressure results in high right-sided filling pressures. This reverses the pressure gradient across the intracardiac defect leading to RLS and was the suspected underlying mechanism of RLS in a patient with difficulty on weaning from mechanical ventilation.

Given that POS results from RLS through PFO with transient inversion of the interatrial pressure gradient and episodic arterial oxygen desaturation in orthostatism, it is understandable that there is no compensatory erythrocytosis with an increased haematocrit.[37] The majority of patients did not have high haemoglobin (Hb) values (>15 g/dL) before the procedure. The average Hb levels for all patients was 13.9 g/dL of which 3 patients had a Hb > 15 g/dL (range 15.2 to 16.9 g/dL). Interestingly, the patient with a

Hb=16.9 g/dL was the same who took longer time between POS diagnosis and PFO closure – 2 years and 3 months. The decrease of haemoglobin and haematocrit values after the procedure was not significant (p= 0.416 and p= 0.271 respectively).

Since there are low certainty existing evidence about PFO related clinical scenarios, the European Association of Percutaneous Cardiovascular Interventions (EAPCI) brought together eight European scientific societies to develop interdisciplinary position statements on the management of PFO, based on systematic assessments of the literature.[38] The key for the diagnosis resides in a meticulous clinical history and a careful physical exam since dyspnea and hypoxemia are two of the most frequent signs and symptoms evaluated daily in clinical practice.[10,39] Patients' presentation can range from chronic hypoxemia requiring long term oxygen supplementation to acute symptoms with rapidly progression.[38]

Prior to considering a PFO closure, severe pulmonary hypertension should be ruled out, since this condition, in principle, excludes patients from PFO closure.

Percutaneous closure of a PFO related to a POS is a relatively simple procedure. Because nearly 25% of the population has a PFO, and in order to avoid a futile procedure, a diagnostic workup must be thoroughly undertaken to disclose all different potential causes of hypoxemia.

5. Case Report

A 78-year-old woman was admitted to our hospital after reporting recurrent episodes of dizziness, asthenia and feeling of weakness in the lower limbs in orthostatism. She reports feeling tired immediately after standing up.

She had oxygen desaturation and dyspnea (NYHA III). Her SpO2 on FiO2=0.4 supplementary oxygen was 75.9% in the upright position, 92% while sitting and 98% in supine. TEE revealed RLS through PFO (Figure 2) and an aortic dilatation of 44 mm with an ascending aortic aneurysm with 49 mm, with no signs of pulmonary hypertension (Figure 3 and 4).

Percutaneous transcatheter PFO closure was performed using an Amplatzer Multifenestrated Septal Occluder of 25 mm (Figure 5, 6 and 7). The device was successfully placed (Figure 8). After the procedure, no residual shunt was appreciated on colour Doppler (Figure 9) and the patient had immediately resolution of oxygen desaturation. Before discharge, she denied any sense of dyspnea and her SpO2 improved to 95% while sitting on room air (Table II).

At 12 months follow up, contrast TTE with agitated saline showed no residual shunt (Figure 10). The patient remained asymptomatic without hypoxemia.

6. Limitations of study

The current study had some limitations that should be taken in account. This is a rare condition and alike published reports our sample is small. Further multicenter studies would be of best interest to establish a standardized approach to PFO closure regarding improvement of POS.

7. Conclusion

As far as we are aware, this was the first Portuguese study concerning the role of PFO closure in resolution of platypnea orthodeoxia. In our retrospective single-center study, percutaneous closure of a PFO as treatment of POS was efficient and safe with remarkably successful resolution of symptomatic postural dyspnea and hypoxemia. Platypnea-orthodeoxia syndrome is an uncommon diagnosed condition, mostly with an interatrial RLS through a PFO as the underlying aetiology. Taking into account the prevalence of PFO in adult population is approximately 25% and age-related modification of the orientation of the IAS, it is likely that POS is underdiagnosed and greater awareness about this syndrome should be implemented among physicians.

It is recommended a shared decision to determine the role of a PFO in POS and to rule out the presence of severe pulmonary hypertension. In this setting, percutaneous PFO closure is safe and has the potential to cure arterial desaturation.

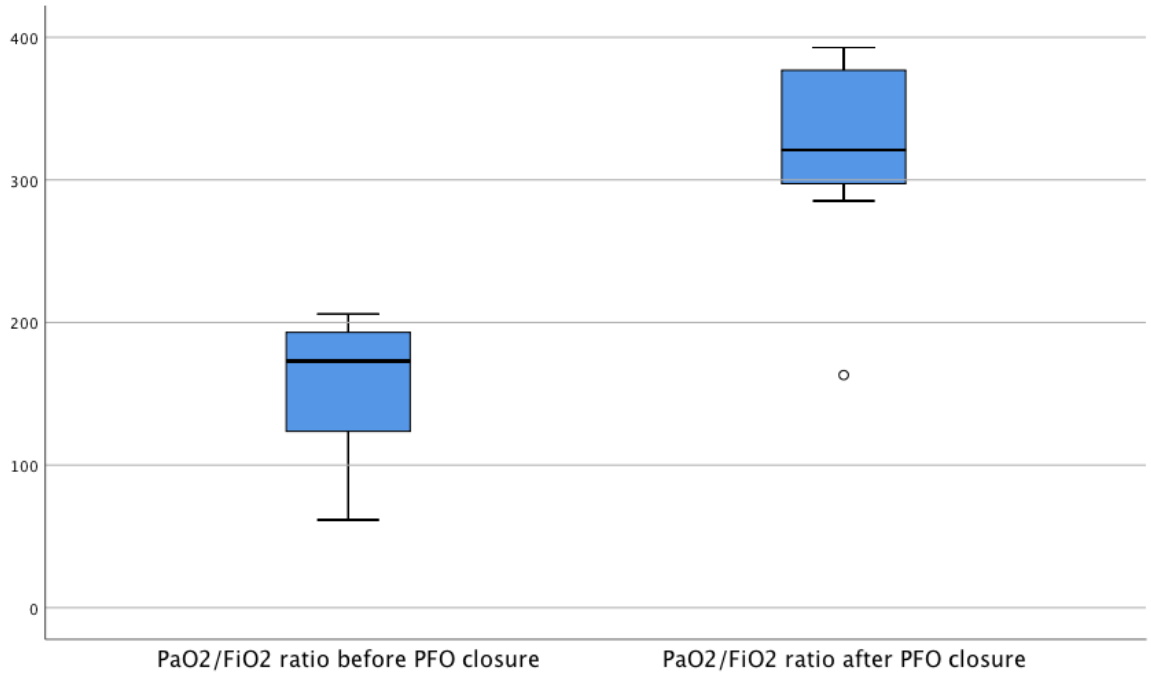
Table I - Patients demographics and comorbidities

(values are expressed in means ± SD or n (%))

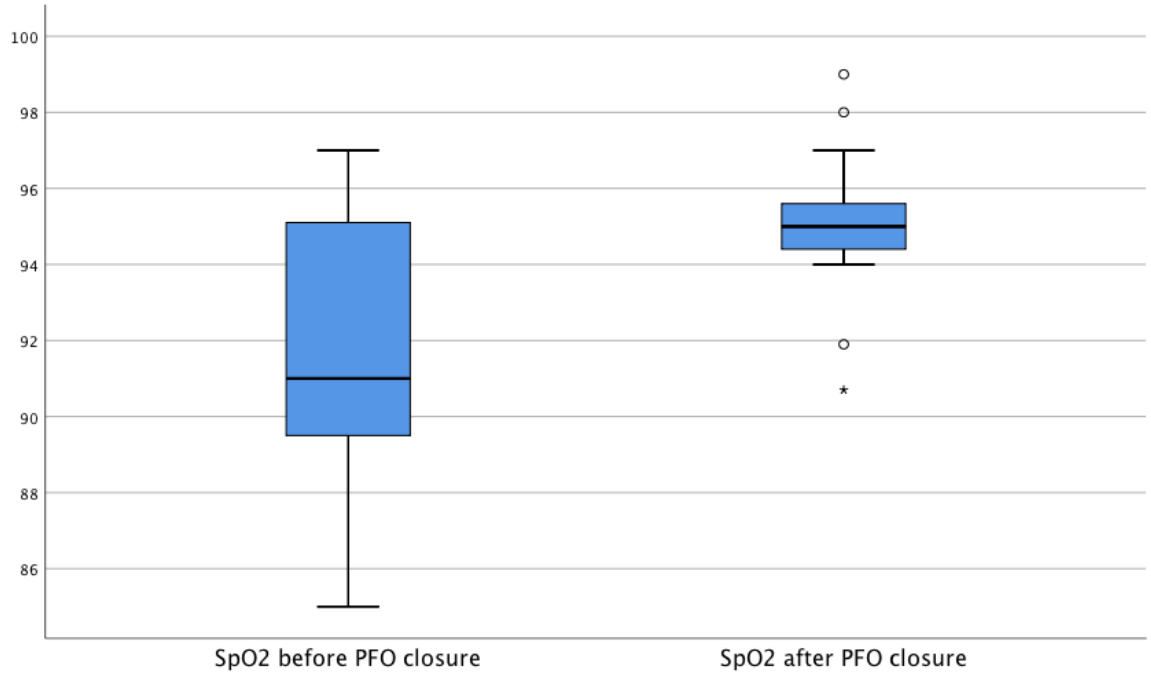
Age, years	76.2 ± 7.4
Female	9 (64.3)
BMI, kg/m2	27.1 ± 5.8
Comorbidities	
Hypertension	14 (100)
Dyslipidemia	11 (79)
Diabetes Mellitus	6 (43)
Previous myocardial infarction	1 (7)
Chronic atrial fibrillation	2 (14)
Chronic heart failure (≥ NYHA Class II)	4 (29)
Stroke	6 (43)
Obstructive sleep apnea	2 (14)
Asthma	1 (7)
Pulmonary interstitial disease	1 (7)
Chronic renal failure (Creatinine clearance < 40ml/min)	2 (14)
Anatomical findings	
Aortic root enlargement	7
Ascending aortic aneurysm	1
Atrial septal aneurysm	10
Atrial septal defect – ostium secundum	1
Eustachian valve or Chiari network	0
Positive bubble test	14
Passive	13
After Valsalva maneuver	1

Table II - Case Report

	Before PFO closure	After PFO closure
Haemoglobin (g/dL)	15.2	14.1
Haematocrit (%)	46.5	42.3
Long term oxygen	No	No
FiO2	0.4	0.21
SpO2 orthostatism (%)	75.9	-
SpO2 sitting (%)	92	95
SpO2 supine (%)	98	97
Dyspnea - NYHA class	Yes III	No
Aortic root (mm) Ascending aortic aneurism (mm)	44 49	



Graphic 1 - PaO2/FiO2 ratio before and after the procedure



Graphic 2 - Oxygen saturation before and after the procedure

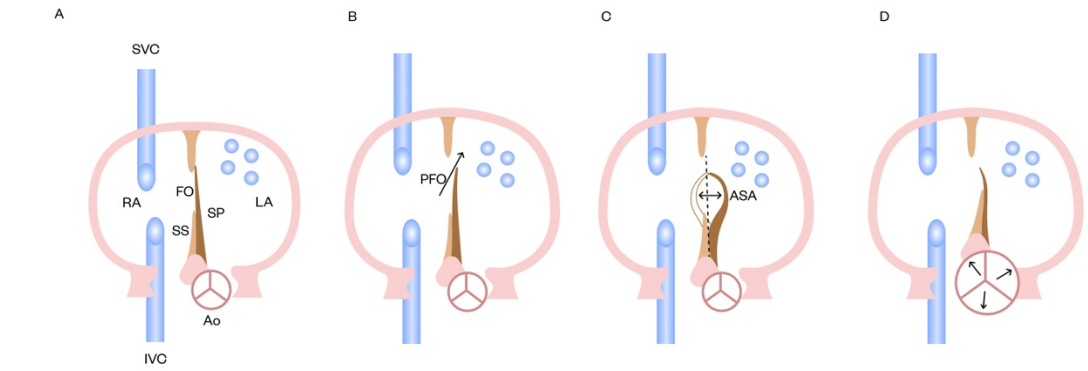


Figure 1 - Schematic description of RLS through PFO

(A) Normal configuration of the interatrial septum in supine position; (B) The septum primum and septum secundum unfused leading to a PFO with RLS, in the upright position (arrow); (C) Hypermobile interatrial septum due to an atrial septal aneurysm, in the upright position; (D) Aortic root enlargement compressing and increasing mobility of the interatrial septum, in the upright position

Ao, aorta; ASA, atrial septal aneurysm; FO, fossa ovalis; IVC, inferior vena cava; LA, left atrium; PFO, patent foramen ovale; RA, right atrium; SP, septum primum; SS, septum secundum; SVC, superior vena cava

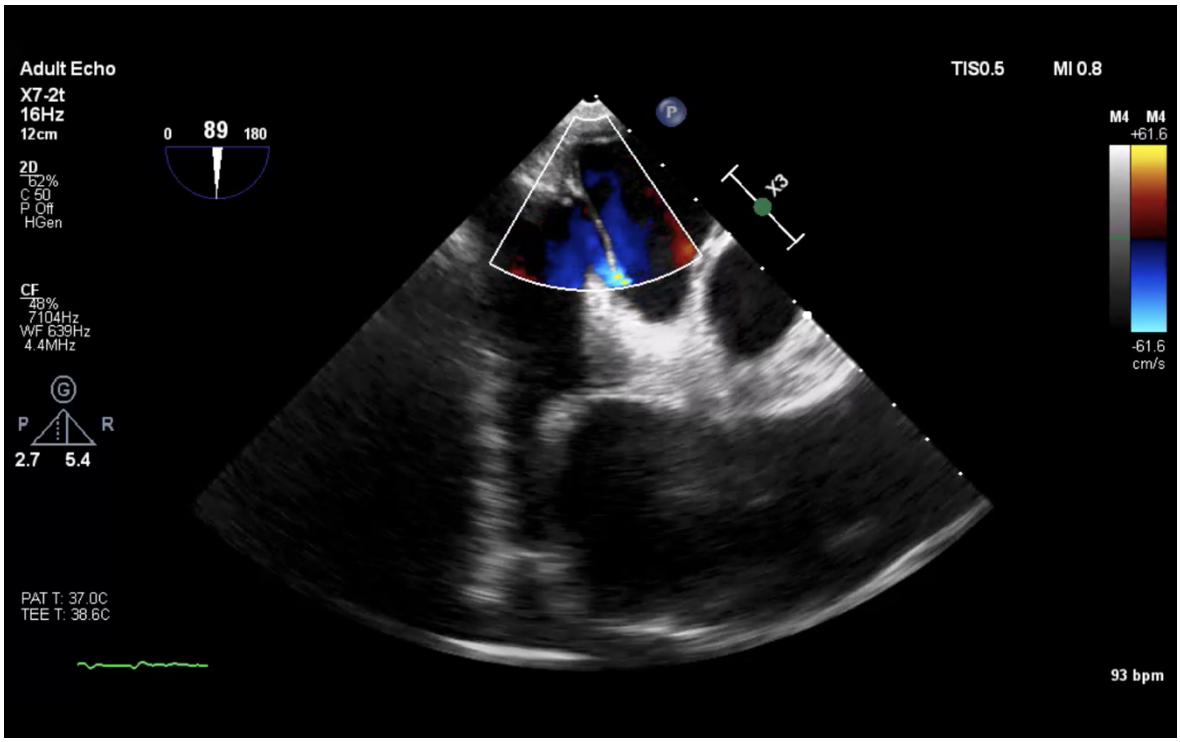


Figure 2 - TEE diagnosis of PFO and spontaneous shunt

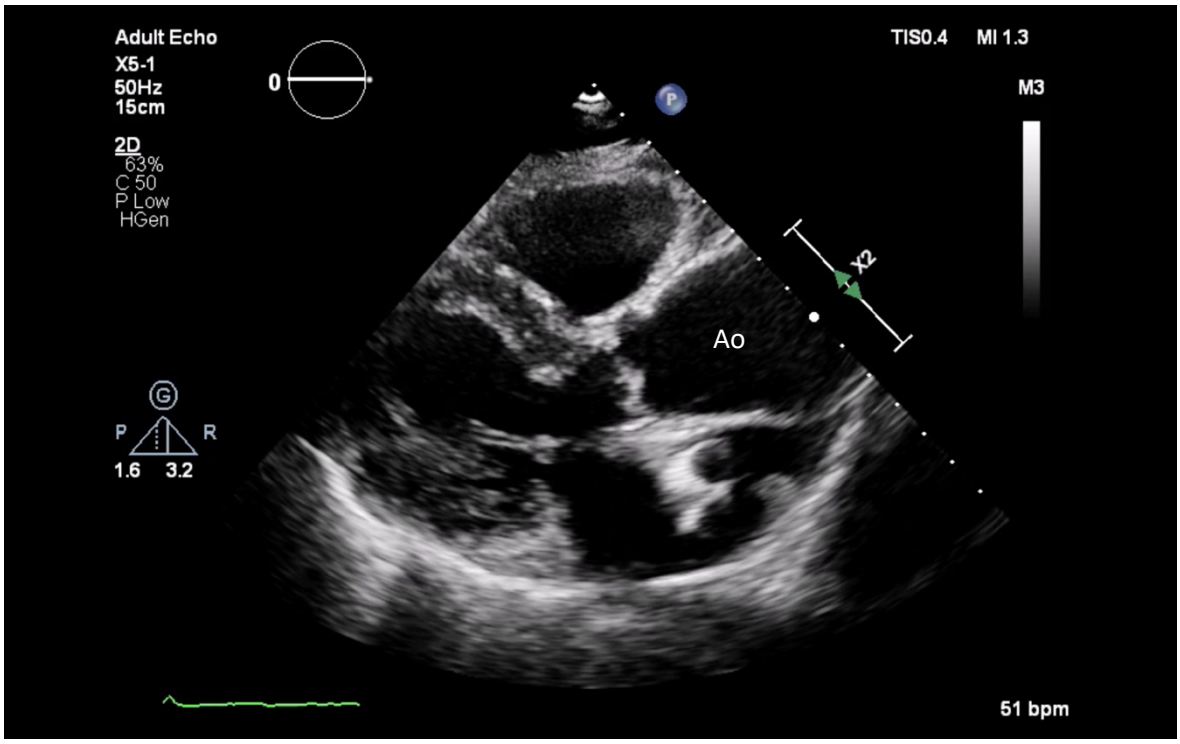


Figure 3 - Ascending Aorta Aneurysm

Ao, aorta

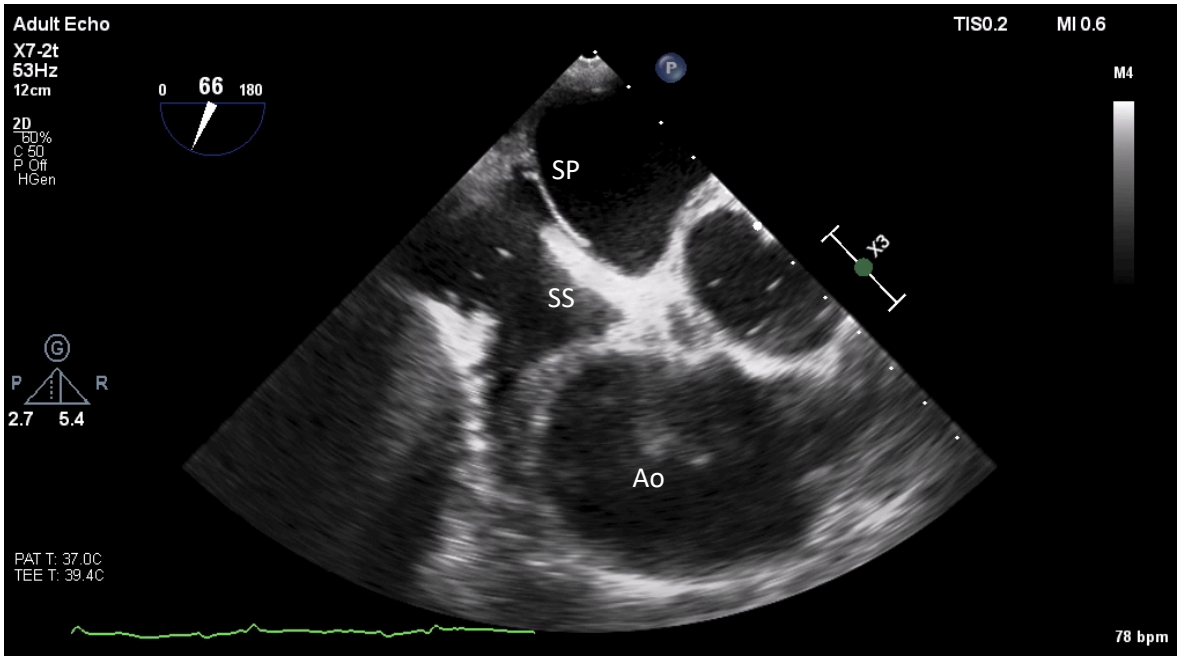


Figure 4 - Ascending Aorta Aneurysm

Ao, aorta; SP, septum premium; SS, septum secundum

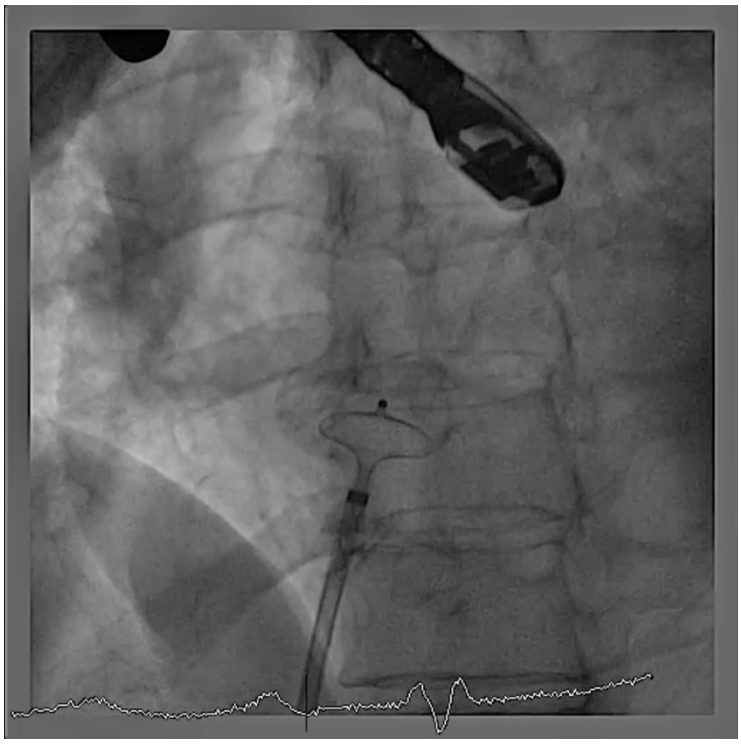


Figure 5 - Left-side implantation of Amplatzer Multifenestrated Septal Occluder

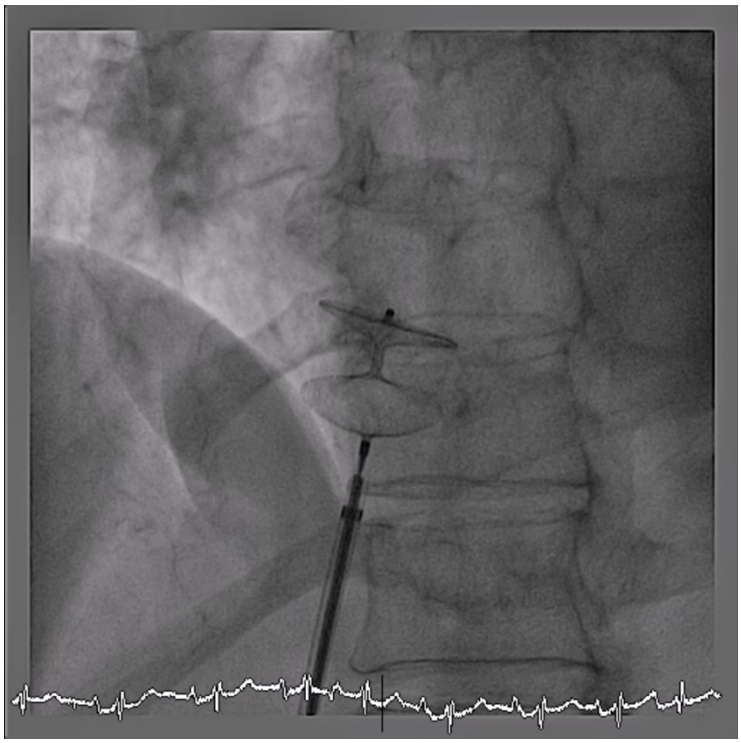


Figure 6 - Verification of the correct device implantation by stretching the guidewire

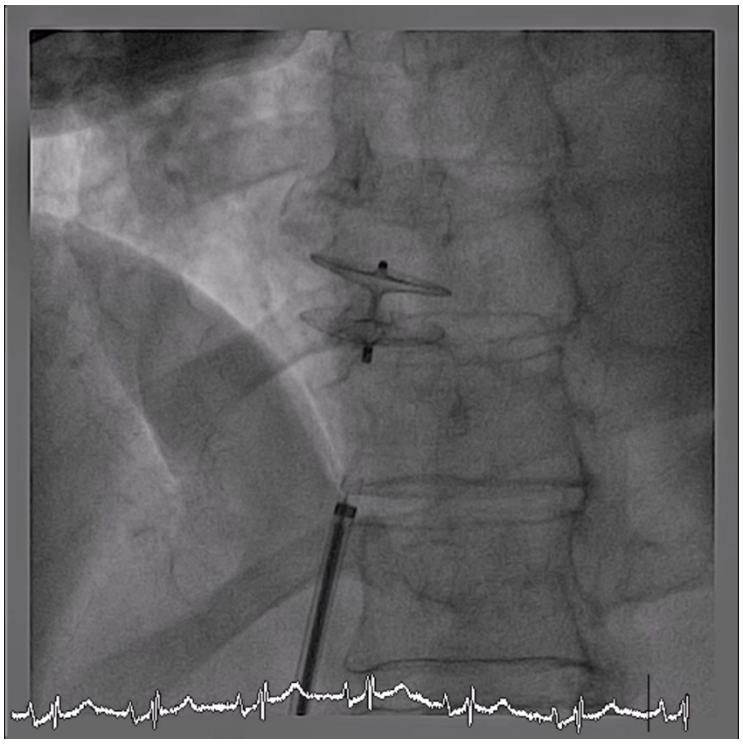


Figure 7 - Release of the Amplatzer Multifenestrated Septal Occluder

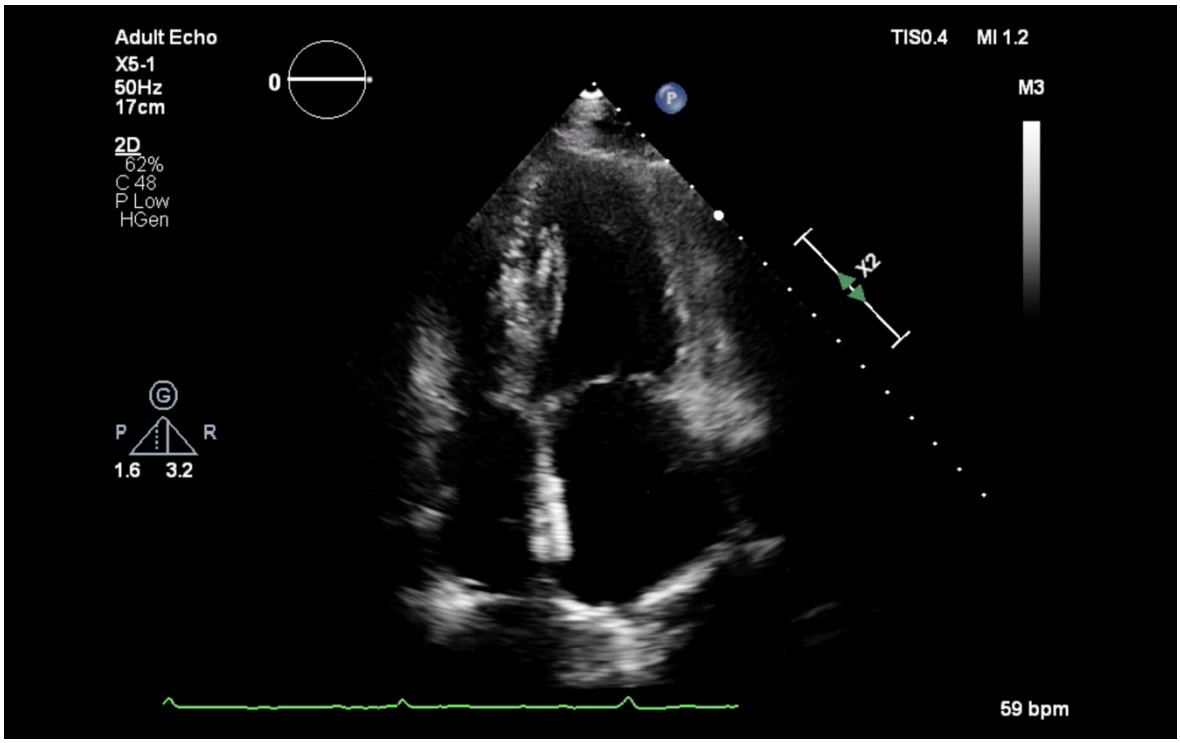


Figure 8 - TTE post-procedure showing a correct device implantation

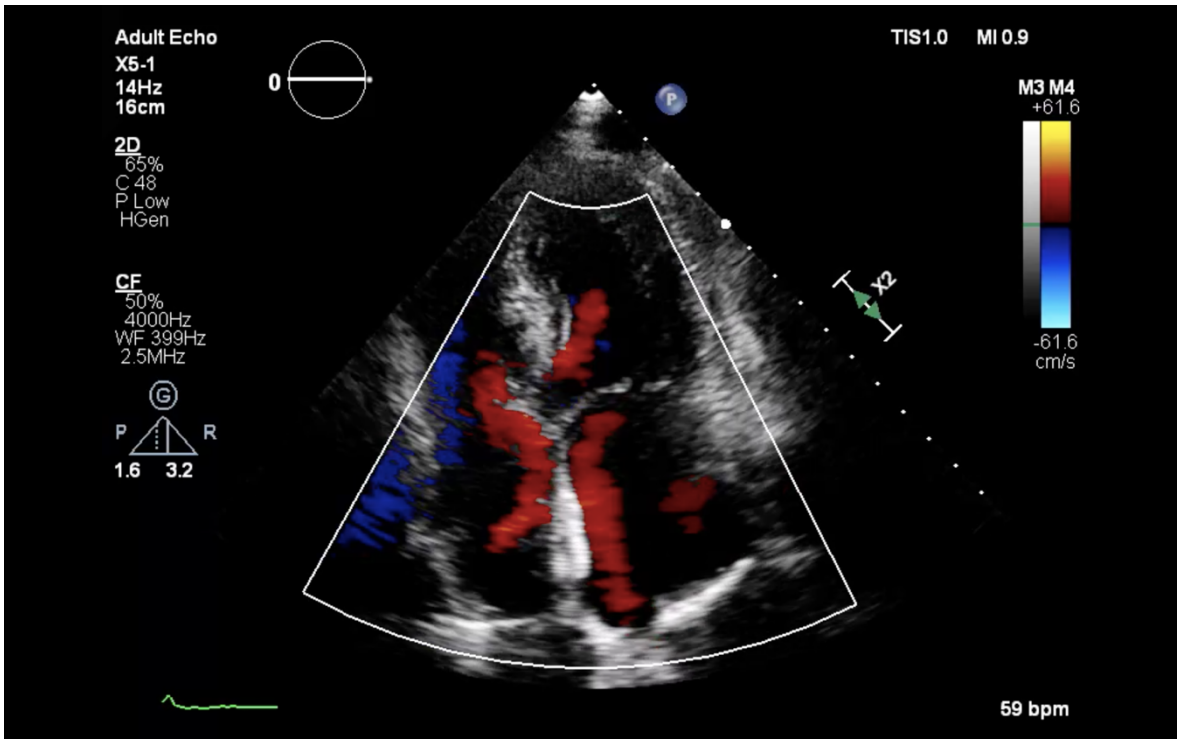


Figure 9 - TTE post-procedure with colour Doppler showing no residual shunt

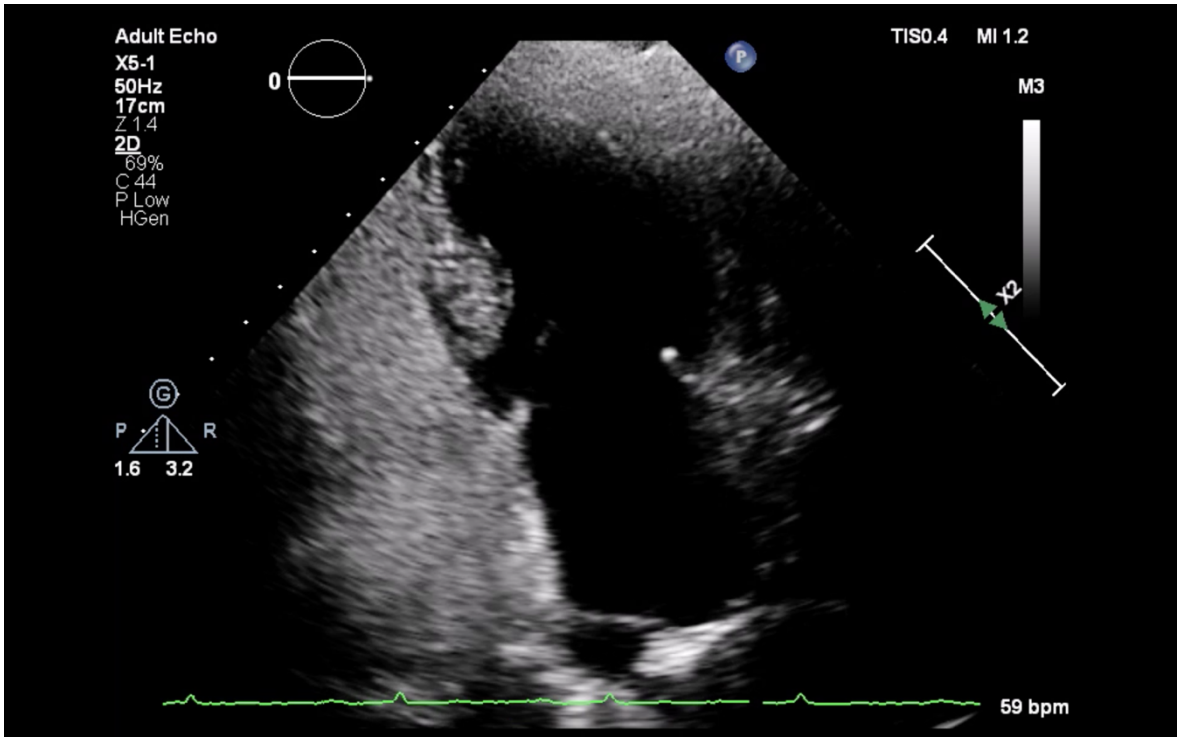


Figure 10 - TTE with saline contrast injection 12 months after the procedure without contrast shunt between the two atriums

8. References

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