REVIEW

Interventional treatment of pulmonary hypertension: an update

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Abstract: Pulmonary hypertension (PH) is a progressive disease with apparently implacable evolution. Among the therapeutic methods in the advanced forms more and more various possibilities of interventional procedures are discussed. All of these usually are palliative methods, reserved either for refractory PH or as a bridge to lung transplantation. The older and the newer directions are discussed in turn, presenting the advantages, difficulties, complications and results obtained starting with the old one described and applied, balloon atrial septostomy, then the transcatheter Potts shunt creation and balloon pulmonary angioplasty in chronic thromboembolic pulmonary hypertension.
Keywords: pulmonary hypertension, balloon atrial septostomy, transcatheter Potts shunt creation, balloon pulmonary angioplasty, interventional treatment

Rezumat: Hipertensiunea pulmonară este o boală progresivă cu o evoluție aparent implacabilă. Între metodele terapeutice din formele avansate sunt luate în discuție din ce în ce mai mult diverse modalități de abordare intervențională. Toate aceste metode sunt paliative, rezervate fie formelor refractare de hipertensiune pulmonară, fie ca o punte către transplantul pulmonar. Sunt discutate pe rând modalitățile mai vechi și cele mai noi dintre acestea prezentând avantajele, dificultățile, complicațiile și rezultatele obținute pornind de la cele mai vechi septostomia interatrială cu balon, apoi crearea transcateter a shuntului Potts și angioplastia pulmonară cu balon din boala cronică trombembolică pulmonară.
Cuvinte cheie: hipertensiune pulmonară, septostomie interatrială cu balon, crearea transcateter a shuntului Potts, angioplastie pulmonară, tratament intervențional

INTRODUCTION

Pulmonary hypertension (PH) is a complex physiopathological state, more frequently, a complication of different other disease, and rarely a primary disease. The diagnosis and classification of PH can be accurately established by right cardiac catheterization. PH means a value of the mean pulmonary arterial pressure (PAPm) which is higher or equal to 25 mmHg at rest. A simple classification of the PH consists in precapillary and postcapillary PH, depending on the measured value of the pulmonary artery wedge pressure (PAWP ≤15 mmHg for precapillary PH associated with pulmonary vascular resistance index PVRi >3iWU)[1,2]. The precapillary may be encountered as pulmonary arterial hypertension (PAH) of idiopathic or heritable type, or induced by drugs or toxins, or associated to congenital heart disease (CHD), connective tissue disease, human immunodeficiency virus infection, portal hypertension or schistosomiasis. Other precapillary causes are related to lung diseases, chronic thromboembolic pulmonary hypertension (CTEPH) or other rare diseases. The postcapillary PH is mainly due to left heart disease (pulmonary veins stenosis, valvulopathies, left ventricle LV dysfunction – systolic or diastolic, cardiomyopathies)[1]. Sometimes, especially in chronic evolution of the heart disease, both types (pre- and postcapillary) of PH may be encountered in which case right and left cardiac catheterization is recommended[3].

The treatment of PH may vary depending on the severity and especially on the etiology. In PAH associated to CHD, which is found in 30% of the cases, the interventional treatment may be the treatment of choice for correctable systemic-to-pulmonary shunts (atrial septal defect-ASD, ventricular septal defect-VSD, patent ductus arteriosus-PDA). In such situations, the cardiac defect is moderate to large, shunting left-to-right, with anatomical characteristics that makes it suitable for interventional closure and the PVR is mildly to moderately increased[4].

CHD associated with severe PAH is a complex situation sometimes due to late presentation of the CHD. In such cases, some authors choose to close directly the defect. Such experience is showed by Sadiq on 45

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patients with large PDA and severe PAH (mPAP 67 mmHg), of late presentation of a CHD (10 years of age). Depending on the oxygen saturation in room air (>97%) and the response to the pulmonary vasoreactivity test some of the defects were closed, safe and effective, with a success rate close to 90%[5]. But in 4 of 46 patients in the Sadiq study, although the PVR was reduced, the patients remained with severe PAH after the closure of the PDA. For such patients maybe, a better approach would be to fenestrate the device intended to close the defect with a short stent (4.5X20 mm), with the intension to reduce the flow but not to close it, like in the case published by Singh[6]. Also, there are custom-made fenestrated device reported for similar cases[7]. Implantation for ASD of an atrial flow regulator is another option[8].

Recently, the interventional treatment in PH may be applied also in other cases then in those mentioned before, in which this may be a part of the paliative treatment or a bridge to transplantation. Creating a stable interatrial communication (with implantation of an atrial flow regulator) or by transcatheter creation of a pulmonary – aortic shunt (Potts shunt) both for decompressing the right heart and increasing the systemic cardiac index[1]. Practically, this interventions consist in transforming the a case of pulmonary arterial hypertension in a case with Eisenmenger physiology[3] which was demonstrated to have a better RV performance and a more hypertrophied RV free wall, correlated with a better survival[9]. This methods developed in connection with the observations that the patients with patent foramen ovale and Eisenmenger syndrome live longer than those with similar mPAP, but without a comunication. Also, the cardiac index and the right ventricle (RV) performance are better in Eisenmenger syndrom[10].

In CTEPH pulmonary artery angioplasty may be recommended in special cases in which the patients are either considered technically non-operable or the risk:benefit ratio for pulmonary endarterectomy is too high[1].

Balloon atrial septostomy and other possibilities

This is a method applied to decompress the right heart chambers by trans-atrial puncture and progressive balloon dilatation septostomy into the interatrial septum. This has as objective both decompression of the right heart chambers and increment of the left ventricle stroke volume (by increasing the preload) and cardiac index1 with the adverse effect of systemic desaturation. Several methods were applied: blade technic, graded balloon dilatation, stenting or, more recently, implantation of a fenestrated ASD device with the reason to secure the opening after initial transeptal puncture and atrial septostomy. The interatrial septum is perforated with a Brockenbrough needle, then the hole is progressively dilated with a Mullins's dilator, under transesophageal or intracardiac echocardiographic guidance[11]. Then non-compliant peripheral balloons of different sizes are used to complete the shunt dimension[12]. For perforation of the interatrial septum some authors recommend the radiofrequency use[11]. Sometimes, especially in the first mentioned techniques, the created hole is predisposed to spontaneous closure[1,13,14] and this applies also for artisanal manufactured fenestrated devices[10]. For this reason, recent studies were published to emphasize the importance to secure the standard hole with a fenestrated type device called atrial flow regulator (AFR) (from Occlutech), which would be implanted after the dilatation of the septum[8]. In the report of Rajeshkumar, at a follow-up media of 189 days, all 12 patients had a patent AFR[8].

Indications for balloon atrial septostomy (BAS) are the patients usually on maximal medical therapy waiting for lung transplantation with limited response to the medical therapy, recurrent syncope, refractory right heart failure (WHO class III or IV). Mean right atrial pressure >20 mmHg, oxygen saturation on room air <85%, severe right-heart failure manifested by low cardiac output and a LVEDP >18 mmHg are contraindications for the methods, the risks/benefit ratio and the procedural mortality in this situation being too high[1,15]. An increase of the LV volume, which is already elevated may lead to pulmonary oedema and respiratory failure[11].

Experiments on interatrial shunting in PH are more than 50 years old[10]. Initially, there were surgical interventions. Although the first description of the balloon atrial septostomy was done by Raskind in 1966, only in 1983 this method was applied in PH patients. The first patient to whom the BAS was applied died in the first 24 hour. The stipulated cause may be a shunt of 9 mm that created pulmonary congestion or because of severe decrease in systemic oxygen saturation to 57% afterwards. In 1991, small series of patients were reported with progressive reduction in mortality rate[10]. Now, after each dilatation, evaluation of both systemic saturation and left ventricle end diastolic pressure (LVEDP) are done. The dilatation proces is stopped

after obtaining a decrease of 10% in saturation comparing with the initial saturation and for less than 18 mmHg LVEDP[10] or if any complication appears (risk for pericardial tamponade is 1.2%)[11]. From all interventional methods for PH, only BAS was approved in the palliative treatment of PH[13]. There are 372 procedures reported on 324 patients in literature. The mortality rate is 14% (at 30 days). The rest of 86% of the patients had a 90% improvement in the functional capacity[10]. The mortality rate may vary according to the experience of the centres, between 5-50%[15] and it is insisted that this intervention should be performed only in centres with a good experience in PH management and has BAS experience[1,15].

Transcatheter Potts anastomosis creation

Transcatheter Potts shunt (TPS) creation is more an experimental method for decompression of the pulmonary artery, which consists in creation of a direct communication between the left pulmonary artery and the descending aorta[13,16]. From physi-pathological point of view, this method is a better solution than the BAS, because the mixing of the blood (right-to-left shunt) is at the great vessels level, after the take-off of the coronary and carotid arteries, which means that the saturation in these territories is not decreased[13].

This method was described by Potts, in 1946, as part of the surgical treatment in different congenital heart disease[17]. Recently, it was applied for the management of PAH, surgically (in 2004)[18] and interventionally (in 2013, by Esch from Boston Children Hospital)[19]. Esch described a technique for transcatheter creation of a Potts shunt, using two femoral access (arterial and venous), a long sheath positioned into the descending aorta, through which a Brockenbrough needle was advanced. With the help of a guiding positioned snare wire into the left pulmonary artery, the needle is advanced to perforate the aorta and the pulmonary artery, then the perforation is secured by balloons, used to progressively dilate the communication, then a covered stent, called iCAST 7- × 22-mm, is placed between left pulmonary artery and descending aorta and anchored to the vessel walls[19]. In this initial experience the success rate was 50% (from 4 patients attempted, one died during the procedure with uncontrolled haemothorax and another one died later on because of critical state and comorbidities). After this initial experience other centres performed it as well[20-23]. In 2015, five TPS cases were described by Baruteau, from the group of 24 interventional and surgical Potts shunt creation. The early postoperative complication rate was 25% and the early mortality rate 12.5% through low cardiac output for the hole group (both surgical and interventional cases). After a median of 2.1 years follow-up, all the rest of the patients were improved, clinically and functionally (20). Continuing the experience described by Baruteau, from the same centre, Boudjemline reported 6 cases of transcatheter Potts shunt creation[21]. Boudjemline reported 2 deaths, both in patients with severe preexisting biventricular dysfunction in which the decrease of the LV preload, by shunt creation, contributed to low-output state followed by cardiac arrest. Also, he described a stent dislodgement and embolization, which was followed by implantation of the stent into the iliac artery and a second stent deployed successfully[21]. Schranz described a Potts shunt creation in a patient suffering from Moya Moya syndrome associated with PAH. The shunt creation was uneventful and the author used radiofrequency (RF) for perforating the aortic and pulmonary wall, which seems to be better in terms of controlled extravasation of blood (due to the fact that RF has the potential to coagulate the tissue and prevent extravasation). Also, the author emphasize the importance of magnetic resonance imaging (MRI) preoperatively, because it allows the measuring of the distance and evaluating the anatomy at the puncture places in the descending aorta and the left pulmonary artery, which should be preferably less than 4 mm (type I)[22].

Also, a special form of Potts physiology was described by Latus. Latus created a "functional" Potts shunt, which was performed by inserting stents into the PDA of new-borns or small infants with supra-systemic pulmonary pressure[24].

Balloon pulmonary angioplasty in chronic thromboembolic pulmonary hypertension

Chronic thromboembolic pulmonary hypertension is a rare form of precapillary PH, with a prevalence and incidence of 3.2 cases per million and 0.9 cases per million per year 1, appeared as a complication in 0.5 to 2% of the acute pulmonary embolism many times associated with predisposing factors like thrombophilic disorders or splenectomy[1].

Similar to the BAS as a palliative method, the balloon dilatation of the pulmonary arteries (BPA) in CTEPH is usually indicated in non-operable severe forms of CTEPH. The first description of this method was in 2001, by Feinstein on 18 patients and despite decrease of the PAPm, more than 50% developed reperfusion pulmonary oedema.

The purpose of the procedure is to ensure the patency of the obstructed or stenotic vessel and consists of passage of a guidewire through a lesion then dilating the lesion by undersized balloon[25]. First, repeated angiographies are performed in different projections, using digital-substraction technique. Selective angiographies are performed to better delineate the anatomy: location and type[26]. They may appear as obstructions, narrowing, punching defects or webs[25,26]. Sometimes other imaging techniques may be necessary, optimal coherence tomography being more and more used, more than intravascular ultrasound, for its provided information. Afterwards, a guiding catheter, 6-to-8 Fr, is fixed into the pulmonary branch, corresponding to the worst perfusion area on scintigraphy, usually the right lower lobe. Then the lesion is approached following the principle of stenosis dilatation, or vessel occlusion as for a chronic total occlusion type lesions[25]. Since 2001, the technique has been changed to the use of smaller balloons in several sessions (usually 4-5, up to 10), at more than one-week interval, with no more than 1-2 segmental inflations, sometimes assisted by intravascular imaging. Applying this technique, the risk for reperfusion pulmonary oedema decreased to 2% in individual centres[1].

Complications of this procedure may appear. The most severe complications are reperfusion pulmonary oedema, haemoptysis, and death. Initially death was reported in 5.6% of the cases, but now decreased to 0.34%. Other more frequent complications are dissection and rupture of the vessels, guidewire perforation and parenchymal or pleural bleeding. Indicators for success treatment are the duration of symptom onset, baseline diastolic PAP and diastolic pressure gradient[25].

Hybrid therapy (surgical, interventional and medical treatment - riociguat) may be a good choice in the complex cases[25,26].

CONCLUSION

All these methods may be applied to severe, refractory cases or as a bridge to lung transplantation. BAS is the older method to decompress the right heart, but the mortality rate is still high. TPS creation is looked as an experimental method, only few cases being reported. The mortality rate is still very high, between 33-50%. Opposite to BAS, the BPA is more and more used, the main indication being represented by the non-operable CTEPH patients.

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