Severe hypoxemia and stroke caused by a patent foramen ovale with right-to-left interatrial shunt despite normal right atrial pressures

1. Introduction

We describe a new mechanism for reopening a patent foramen ovale (PFO) after pulmonary embolism despite normal atrial filling pressures.

2. Case

A 69 years old female patient was admitted to our intensive care unit after a failed suicide attempt, which she performed because of progressive symptoms of respiratory distress in the months before. Even after stabilizing the patient the peripheral O2-saturation was only 90% despite high flow oxygen therapy with an oxygen admixture of 80–100%. Echocardiography demonstrated normal-sized heart chambers with normal function of both ventricles and without valvular heart disease. N-terminal pro b-type natriuretic was 80 ng/ml. Computer tomography scan of the thorax and pulmonary function test were normal according to age. Only perfusion-ventilation scintigraphy revealed a marked perfusion deficit of the right lung caused most likely by longer existing pulmonary embolism (Fig. 1). However, these findings could not adequately explain the patient's clinical picture. The situation worsened after the patient was temporarily paralyzed in the right arm, which appeared to be a thromboembolic stroke by CT morphology. Thrombectomy was successfully performed. Transesophageal echocardiography revealed a PFO with severe right-to-left shunting confirmed by color Doppler ultrasound and contrast echocardiography (Fig. 2 and video 1). The interatrial septum fluttered back and forth between both atria indicating low and changing pressure differences in these chambers. This finding was confirmed by invasive pressure measurements demonstrating normal pulmonary as well as right and left atrial pressures. Left atrial pressures were especially low in atrial diastole being even negative during inspiration. An oximetry run detected a relevant right-to-left shunt (Qp/Qs 0.68). After PFO-closure with a 12 mm Amplatzer™ septal occluder device the patient's symptoms markedly improved immediately. The oxygenation index increased markedly from 95 before implantation to 348 immediately after the procedure, so she could be discharged 4 days later.

3. Discussion

PFO occurs in up to 30% of the general population [1] and several case studies were reported about PFO with relevant right to left shunts despite normal pulmonary and right sided cardiac pressures [2,3].

Pathophysiologically, the main reasons for these shunts are either hemodynamic situations with a low interatrial pressure gradient or flow phenomena based on a preferential flow of blood directed towards the foramen ovale in the left atrium [2,3]. Normally, left atrial pressures are higher than right atrial pressures. Increased right atrial pressures may be induced by atrial myxomas, atrial thrombi, limited right atrial or right ventricular compliance thereby inducing right to left atrial blood flow [4–6]. A targeted blood flow that is directed to the foramen ovale even without an interatrial pressure gradient can result from a distinctive Eustachian valve or due to morphological and axial changes of the heart with age or as a consequence of an aortic aneurysm [7,8]. In such cases additional injection of the contrast medium via the lower limbs should be considered.

In our case a targeted blood flow towards the fossa can be excluded since the predescribed morphological changes were absent in our case and the shunt was detected after injection of contrast medium via the upper vena cava. This excludes an abnormal blood flow from the inferior vena cava maldirected by an Eustachian valve. In contrast, underfilling of the left atrium (“left atrial hypovolemia”) as a result of pulmonary embolism with reduced flow via the pulmonary vasculature caused by increased pulmonary vascular resistance (pulmonary vessel resistance 204
dynes × sec cm⁻²) appeared most likely responsible for the right-to-left shunt in our case (about 1.4 l/min). Consequently, the reduced return of blood volume into the left atrium during diastole (about 3.3 l/min) may create a suction effect on the septum membrane resulting in reopening of the foramen ovale. During inspiration this effect is even aggravated since additional blood is pooled in the pulmonary vascular bed, while venous return into right atrium is increased. Accordingly, the shunt also prevents the pressure in the pulmonary artery from increasing after a pulmonary thromboembolism, and may promote crossed embolisation as well. Pulmonary pressures increased after closure of the PFO with a device system (systolic pressure of the pulmonary artery enhanced up to 30 mm Hg estimated by postinterventional echocardiography).

Considering the high incidence of both venous thromboembolism - third most frequent cardiovascular disease [9] - as well as PFO in the general population (up to 30%) [1] it is appropriate to speculate that pulmonary embolism could more often be associated with atrial right-to-left shunts than expected and may therefore be considered in the daily echocardiographic routine.

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**Fig. 1.** A) Inhalation lung SPECT/CT after inhalation of 345 MBq ⁹⁹ᵐTc-pertechnegas (ca. 30 MBq deposit into the lung). Transaxial slice. Complete tracer accumulation in both lungs. B) Perfusion lung SPECT/CT after intravenous application of 123 MBq ⁹⁹ᵐTc-MAA. Transaxial slice. Incomplete tracer accumulation in the right lung with pathologically reduced tracer accumulation in the ventral areas of the right lung, segment IV and V (mismatch compared to the ventilation scintigraphy), indicating lung embolus in this area. Physiological tracer accumulation in the left lung. C) SPECT of A) D) SPECT of B).
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5. Disclosures

The authors report no relationships that could be construed as a conflict of interest.

Informed consent was obtained from the patient.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijcha.2021.100759.

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