5 Discussion

In 35%-40% of patients with an ischemic stroke, the cause remains cryptogenic (75). If transesophageal echocardiography in these patients shows a PFO and other sources for a right-to-left shunt are excluded, a paradoxical embolism through a PFO is suspected to be the main source of embolism (10, 75, 76, 77).

Over the last 25 years, several transcatheter closure techniques have been developed for the occlusion of interatrial communications (78). Transcatheter PFO closure in patients with a paradoxical embolism has emerged as an alternative to lifelong anticoagulation, antiplatelet agents, or surgical closure (79-83).

Although high occlusion rates and low complication rates of PFO have been reported for a percutaneous occluding device (44), there were still some adverse events such as embolisation of thrombus formed on the device, disturbed atrioventricular valve function, perforation of the atrial wall and malpositioning or embolisation of the device.

Little information about atrial performance following ASD closure is available. Tissue Doppler can be used to assess global and regional systolic and diastolic cardiac function and to identify abnormal heart relaxation and contraction in a variety of conditions. It displays the velocity of a selected myocardial region against time, with high temporal resolution. In this study, tissue velocity imaging and strain rate were used to analyze the effect of percutaneous PFO closure by three kinds of devices on longitudinal mitral annular motion, tricuspid annular motion and atrial septal motion.

5.1. Effect of interventional PFO closure on the left ventricular regional and global function.

The motion of the mitral annulus at the LV free wall can be assessed with TDI for determination of global LV function (73, 84). Mitral annular Sm and Em velocities are well established indexes of longitudinal LV systolic (57,2,86) and diastolic function (67, 87, 88), whereas Am (late diastolic velocity) is probably more related to left atrial function. In some studies, it has been confirmed that Em is related to both LV relaxation and elastic recoil (87, 89), and other studies have suggested that Em at the cardiac base in the apical views is less preload-dependent than early transmitral inflow velocity (68, 90). Yalcin et al. reported that E wave by TDI during early LV diastole might be regarded as a more useful index of diastolic function as it provides an after-load independent assessment of left ventricular filling (91). Sm had a good correlation with LV ejection fraction. Many studies (92, 93, 94) have demonstrated that the decreased Sm may be an expression of regionally reduced systolic function.

In this study, the pulsed Doppler derived transmitral E wave, A wave and E/A ratio were nearly normal before device closure and showed no significant changes after intervention treatment (Table 1). In addition, the tissue Doppler derived early diastolic peak and late diastolic peak velocities (both are markers of the regional longitudinal diastolic function) derived from the lateral mitral annulus showed no changes after device closure (Tables 2, 3). This may reflect that the left ventricle global and regional diastolic function was not significantly altered by interventional device closure.

Tissue Doppler derived systolic peak velocity (a marker of the regional systolic function) showed also no significant change before and after interventional PFO closure (Tables 2, 3). This may indicate that device closure has no significant effect on the regional LV longitudinal function. Accordingly, in agreement with other studies, we demonstrate that left ventricle global and regional functions are not affected by transcatheter closure of PFO (37, 88, 94, 95).

5.2. Effect of interventional PFO closure on the right ventricular regional and global function

Right ventricular function can be assessed using TDI analysis of tricuspid annular motion (96). Some studies have shown that systolic and diastolic velocities of TDI correlated well with RV function in patients with myocardial infarction, heart failure and chronic pulmonary hypertension (97-99).

Lange et al.(100) found that in patients with transcatheter ASD closure procedure, the E-wave of tissue Doppler derived tricuspid annulus decreased after device closure due to a consequence of a reduction in right ventricular volume overload , but was not affected by the Amplatzer device. Hanseus et al. (37) used TDI and M-mode echocardiography to analyse atrioventricular plane movements in patients with ASD. They found that systolic and diastolic amplitudes and velocities of the tricuspid annulus were reduced but not significantly between measurements before and after interventional ASD closure. Dhillon et al.(95) used M-mode echocardiography to measure ventricular long axis function. They found right ventricular function was not affected by ASD closure.

In our study, the tissue Doppler derived early diastolic (E peak) and late diastolic (A peak) velocities obtained from the lateral tricuspid annulus did not significantly change after device closure when compared to pre-closure conditions (Table 2, 3). Global diastolic RV function assessed by transtricuspid pulsed Doppler echocardiography did not show significant change before and after device closure. This may indicate that the regional and global diastolic function of RV was not altered after interventional PFO closure.

Assessment of the global RV systolic function was not possible in this study since it requires magnetic resonance tomography, a procedure which is not indicated in our patients. Regional systolic RV function assessed by tissue Doppler derived systolic peak obtained from the lateral tricuspid annulus did not significantly change after

device closure (Tables 2, 3). This may indicate that transcatheter PFO closure does not affect the regional systolic RV function.

5.3. Effect of interventional PFO closure on atrial septal motion

Strain rate imaging is a promising parameter to assess regional myocardial function. It calculates velocity gradients between two distinct points along the ultrasound beam and is less affected by heart translation and tethering effects than tissue velocity. Therefore, it is potentially superior to TVI in regional myocardial function assessment (70,71).

In the study by Hanseus et al (35), the authors used parameters derived from tissue Doppler imaging to assess cardiac function before and after surgical and Amplatzer device closure of ASD. They observed that systolic velocity of the septum decreased significantly in the surgical group, whereas no changes were seen in the device group. Lange and colleagues reported that percutaneous ASD occlusion by an Amplatzer septal device reduces longitudinal diastolic septal annular motion (99). Dhillon et al (95) found that septal measurements of M-mode echocardiography were reduced in ASD closure procedure, indicating that the septal function was impaired by the device. However it is not clear whether such reductions are related to the haemodynamic change after ASD closure or directly to the interventional procedure itself.

In the present study , the TVI and SR peak E wave at the annulus and the roof of atrial septum regions were decreased after device closure of PFO (Tables 5, 6 and Figures 3, 4). This may be related to the mechanical impact of the device on the longitudinal septal deformation. A hard device across the atrial septum has the potential to increase the atrial stiffness and deformation. This, however, does not have haemodynamic significance, since the atrial E wave is only a reflection of the ventricular relaxation which was not significantly altered after device closure.

The mechanical impact of the device on the atrial deformation was more obvious in the Amplatzer group compared to the Helex and Cardioseal groups. The latter two devices are more softer compared to the Amplatzer, the soft device may not distort the atrial septum and may reduce stress between the device and the heart.

Associated atrial aneurysm can also contribute to the reduced atrial septal deformation after device closure using Amplatzer, since four patients in the Amplatzer group had an associated aneurysm and only one patient in the Cardioseal and Helex groups had respectively an aneurysm.

6 Conclusions:

(1) Transcatheter closure of PFO does not affect the left ventricular function or right ventricular function. (2) Transcatheter closure of PFO may affect septal early diastolic motion and deformation. (3) Whether there is a difference between the results with the Amplatzer, Helex and Cardioseal occluder could not be proved by this study (because of different group sizes).

7 Summary

Background: The patent foramen ovale (PFO) is the most common congenital heart disease in adults. It permits interatrial right-to-left shunt which has been demonstrated to be related to paradoxical embolism. Paradoxical embolism through a patent foramen ovale has been recognized as a potential cause of transient ischemic attack (TIA) and cryptogenic stroke. Percutaneous transcatheter closure of PFO is now used as an alternative to surgery or long-term anticoagulation for the treatment of patients with paradoxical embolism and PFO. It has a high success rate, low incidence of hospital complications, low frequency of recurrent systemic embolic events and avoids some of the disadvantages of open-heart surgery. Although many studies