

4 Result

4.1. Standard echocardiographic results

Transmitral and transtricuspid inflow velocities before and after PFO closure in all patients group are shown in Table 1.

There was no significant difference before and after PFO closure regarding the peak velocity of the early diastolic E-wave of transmitral valve inflow ($0.76\pm 0.17\text{m/s}$ vs $0.73\pm 0.09\text{m/s}$) and the peak velocity of the transtricuspid valve inflow ($0.62\pm 0.12\text{m/s}$ vs $0.63\pm 0.13\text{m/s}$). In addition, the A wave of transmitral valve inflow velocity ($0.57\pm 0.12\text{m/s}$ vs $0.54\pm 0.10\text{m/s}$) and transtricuspid valve inflow velocity ($0.44\pm 0.13\text{m/s}$ vs $0.44\pm 0.76\text{m/s}$) showed no significant changes before and after PFO closure ($p>0.05$). Furthermore, the E/A ratio of mitral valve inflow (1.34 ± 0.23 vs 1.39 ± 0.33) and of the tricuspid valve inflow (1.47 ± 0.34 vs 1.46 ± 0.34 velocity) also showed no significant changes before and after PFO closure ($p>0.05$).

Table 1. Pulsed Doppler derived diastolic parameter before and after PFO closure across the mitral and the tricuspid valve.

	MK			TK		
	E (m/s)	A (m/s)	E/A	E (m/s)	A (m/s)	E/A (m/s)
Pre-inter	0.76 ± 0.17	0.57 ± 0.12	1.34 ± 0.23	0.62 ± 0.12	0.44 ± 0.13	1.47 ± 0.34
Post-inter	0.73 ± 0.09	0.54 ± 0.10	1.39 ± 0.33	0.63 ± 0.13	0.44 ± 0.76	1.46 ± 0.34
p-value	0.37	0.27	0.42	0.77	0.88	0.95

MK: transmitral valve inflow velocity; TK: transtricuspid valve inflow velocity, E: early diastolic velocity; A: late diastolic velocity.

4.2. Tissue Doppler and strain rate imaging results

The regional cardiac performance derived from tissue Doppler and strain rate imaging before and after PFO interventional closure in all patients are shown in Tables 2 and 3.

At the atrial septal annulus and roof TVI E peak and SR peak E peak were significantly decreased ($p < 0.05$) in PFO patients after closure compared to before interventional closure (Figures 1, 2). In contrast, neither TVI S, A peaks nor SR S, A peaks at these locations showed significant changes before and after PFO closure ($p > 0.05$).

All the tissue Doppler and strain rate derived parameters at the mitral and tricuspid annuli after intervention did not significantly differ when compared to the pre-closure conditions.

Table 2. The regional cardiac performance assessed by tissue Doppler imaging TVI before and after PFO interventional closure in all the patients.

TVI parameters(cm/s)		Pre-intervention (n=50)	Post-intervention (n=50)	p-value
Mitral annular	E	8.77± 2.82	8.97± 2.86	NS
	A	7.42± 3.09	7.29± 2.70	NS
	S	7.36± 2.15	7.85± 2.35	NS
Tricuspid annular	E	9.78± 3.10	9.33± 2.43	NS
	A	9.38± 3.34	9.88± 3.23	NS
	S	9.56± 2.10	9.42± 2.07	NS
Septal annulus	E	7.95± 2.19	7.15± 2.23	0.0003
	A	7.22± 2.01	7.13± 1.77	NS
	S	6.85± 1.48	6.66± 1.23	NS
Roof of septum	E	3.31± 1.2	2.63± 1.1	0.0001
	A	2.60± 0.8	2.92± 1.0	NS
	S	3.39± 1.3	3.43± 1.1	NS

A: TVI late diastolic wave peak, E: TVI early diastolic wave peak, S: TVI systolic wave peak.

Table 3. Regional septal performance assessed by strain rate before and after PFO interventional closure in all patients

SR parameter(cm/s)		Pre-intervention (n=50)	Post-intervention (n=50)	P value
Septal annulus	E	3.41 ± 1.2	2.68 ± 1.0	0.0035
	A	2.35 ± 1.4	2.61 ± 1.6	NS
	S	2.09 ± 0.9	2.44 ± 1.1	NS
Roof of septum	E	3.30 ± 1.2	2.58 ± 1.1	0.0003
	A	3.24 ± 1.2	3.33 ± 1.5	NS
	S	2.83 ± 1.1	3.15 ± 1.2	NS

A: SR late diastolic wave peak, E: SR early diastolic wave peak, S: SR systolic wave peak.

4.3. Comparison between the effect of different devices on the regional cardiac performance

There was no difference regarding the patients' characteristics among the three groups (Table 4).

Table 4. Patients' characteristics in the three interventional PFO groups

Variable	Amplatzer	Cardioseal	Helex	P value
Device size	23.7 ± 2.9	25.7 ± 2.5	25 ± 4.5	0.68
Procedure time (min)	60.8 ± 17.6	77.7 ± 31.2	85.6 ± 30.6	0.08
Heart rate	65 ± 5.4	67 ± 4.3	64 ± 4.8	0.38
Propofol (mg/kg)	2.2 ± 1.7	2.9 ± 1.9	2.6 ± 1.4	0.75
Age (year)	41.5 ± 13.4	43.6 ± 16.2	40.8 ± 13.8	0.13

The regional atrial septal performance before and after PFO closure by the three different devices (Amplatzer, Helex and Cardioseal) assessed by tissue Doppler and strain rate imaging are shown in Table 5 and 6, respectively.

In the Amplatzer group, TVI E peak and SR E peak at the atrial septal annulus and roof were significantly decreased ($p < 0.05$) after PFO closure when compared to pre-closure condition (table,5,6). In contrast, among the Cardioseal and Helex groups, TVI E and SR E peaks at septal annulus level had a tendency of reduction after interventional PFO closure, but this tendency did not reach significance (table 5, 6).

The TVI A, S peaks and SR A, S peaks showed no significant changes before and after PFO closure in any of the three interventional groups.

Table 5. The regional atrial septum performance measured by TVI before and after PFO closure in Amplatzer, Helex and Cardioseal groups respectively.

TVI parameter(cm/s)		Pre-intervention	Post-intervention	P value
Amplatzer group (n=20)	septal annulus	7.623±2.011	6.418±1.714	0.006
	roof of septum	3.389±1.476	2.575±1.554	0.041
Cardioseal group (n=14)	septal annulus	6.609±1.167	5.473±1.275	0.059
	roof of septum	3.184±1.067	2.661±0.914	0.062
Helex group (n=16)	septal annulus	6.544±1.183	5.902±1.155	0.069
	roof of septum	3.350±0.804	2.660±1.025	0.051

E: early diastolic velocity, TVI: tissue velocity imaging, SR: strain rate

Table 6. The regional atrial septum performance measured by SR before and after PFO closure in Amplatzer, Helex and Cardioseal groups respectively.

SR parameter(cm/s)		Pre-intervention	Post-intervention	P value
Amplatzer group (n=20)	septal annulus	3.62±1.54	2.78±1.35	0.004
	roof of septum	3.12±1.56	2.47±1.24	0.021
Cardioseal group (n=14)	septal annulus	3.29±1.05	2.65±1.09	0.083
	roof of septum	3.32±1.04	2.48±1.20	0.092
Helex group (n=16)	septal annulus	3.33±0.91	2.60±1.29	0.094
	roof of septum	3.44±0.92	2.76±1.21	0.139

E: early diastolic velocity, TVI: tissue velocity imaging, SR: strain rate

n=50

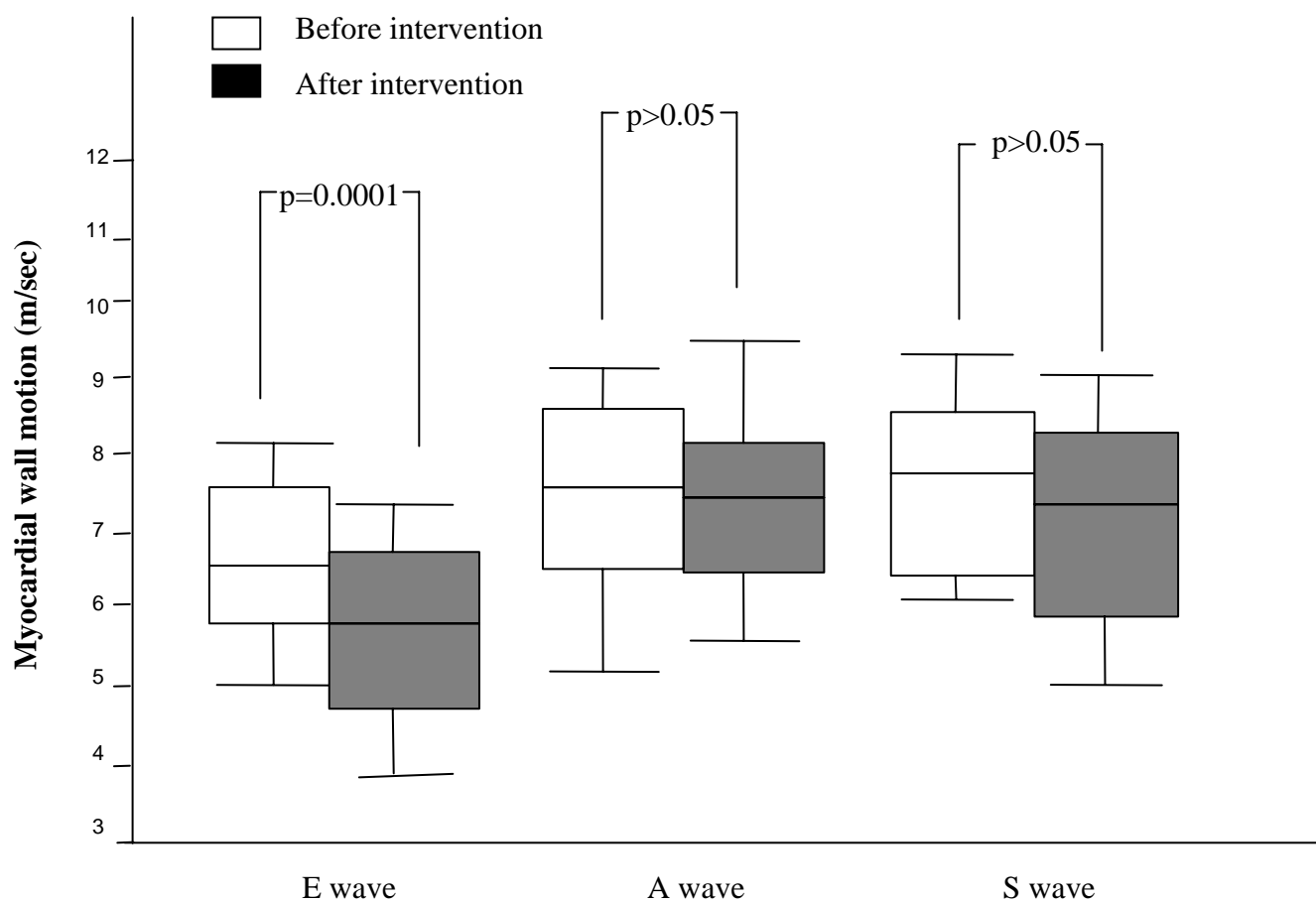


Figure 5: Regional atrial septum performance at the annulus level assessed by TVI in PFO patients before and after the intervention.
S: systolic peak, E: early diastolic peak, A: late diastolic peak, TVI: tissue Doppler velocity imaging, PFO: patent foramen ovale.

n=50

□ Before intervention
■ After intervention

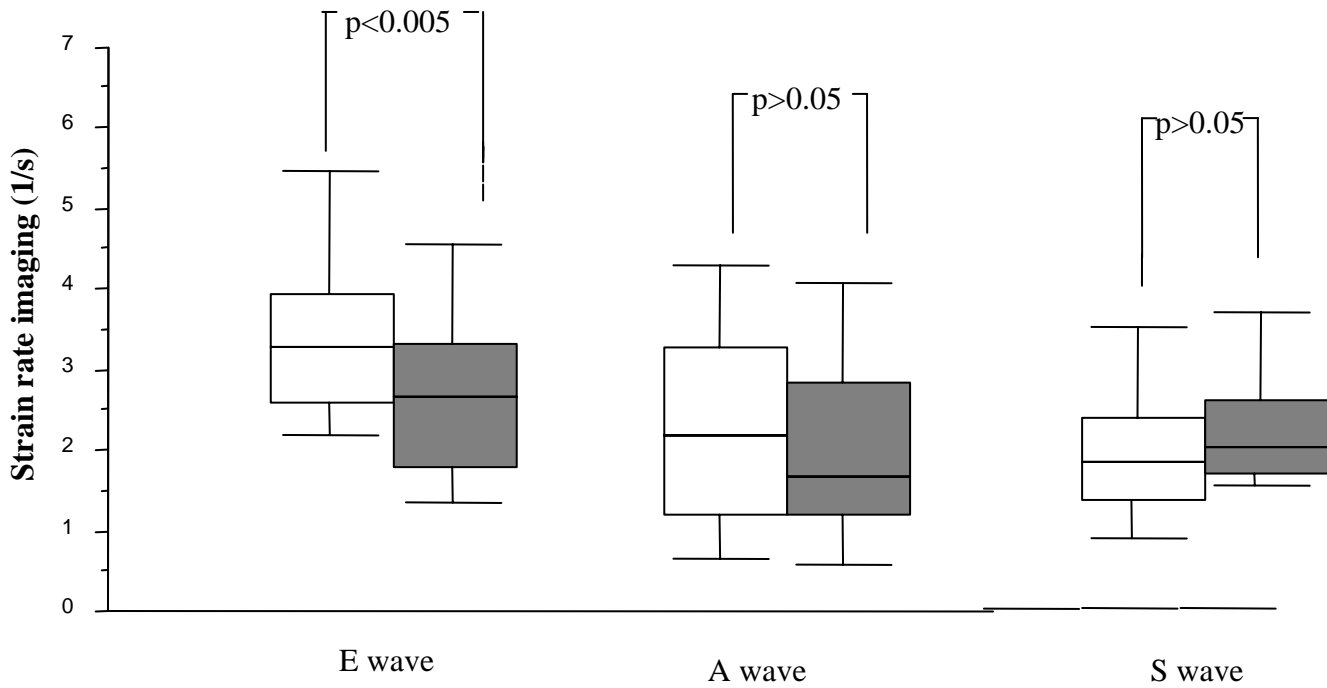


Figure 6: Regional atrial septum performance at the annulus level assessed by strain rate imaging in PFO patients before and after the intervention. S: systolic peak, E: early diastolic peak, A: late diastolic peak, PFO: patent foramen ovale, SR: *strain rate imaging*.

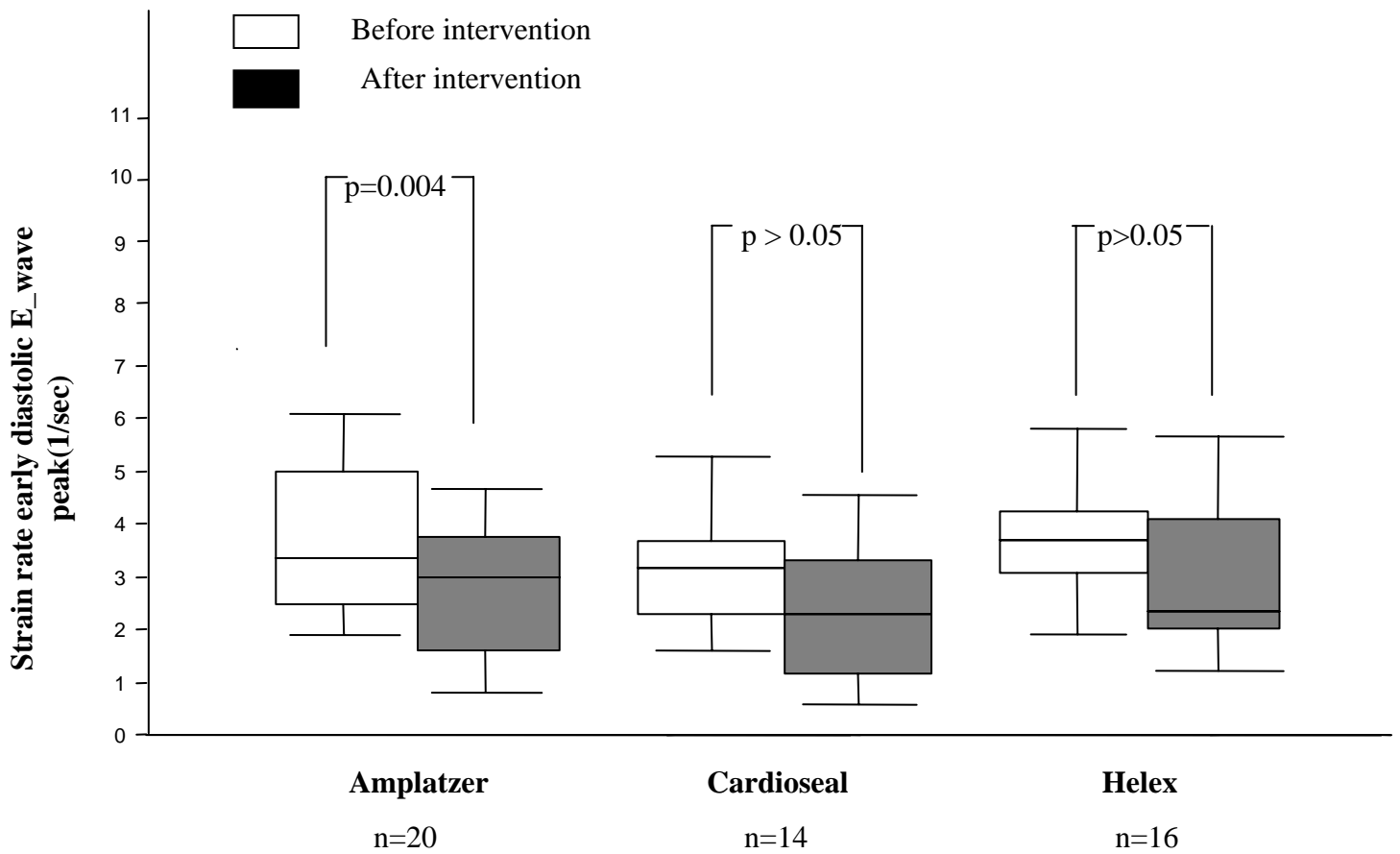


Figure 7 Regional atrial septum performance at the annuli level assessed by strain rate imaging in PFO patients before and after the intervention using three different devices.

E: early diastolic peak, PFO: patent foramen ovale, SR: *strain rate imaging*, .

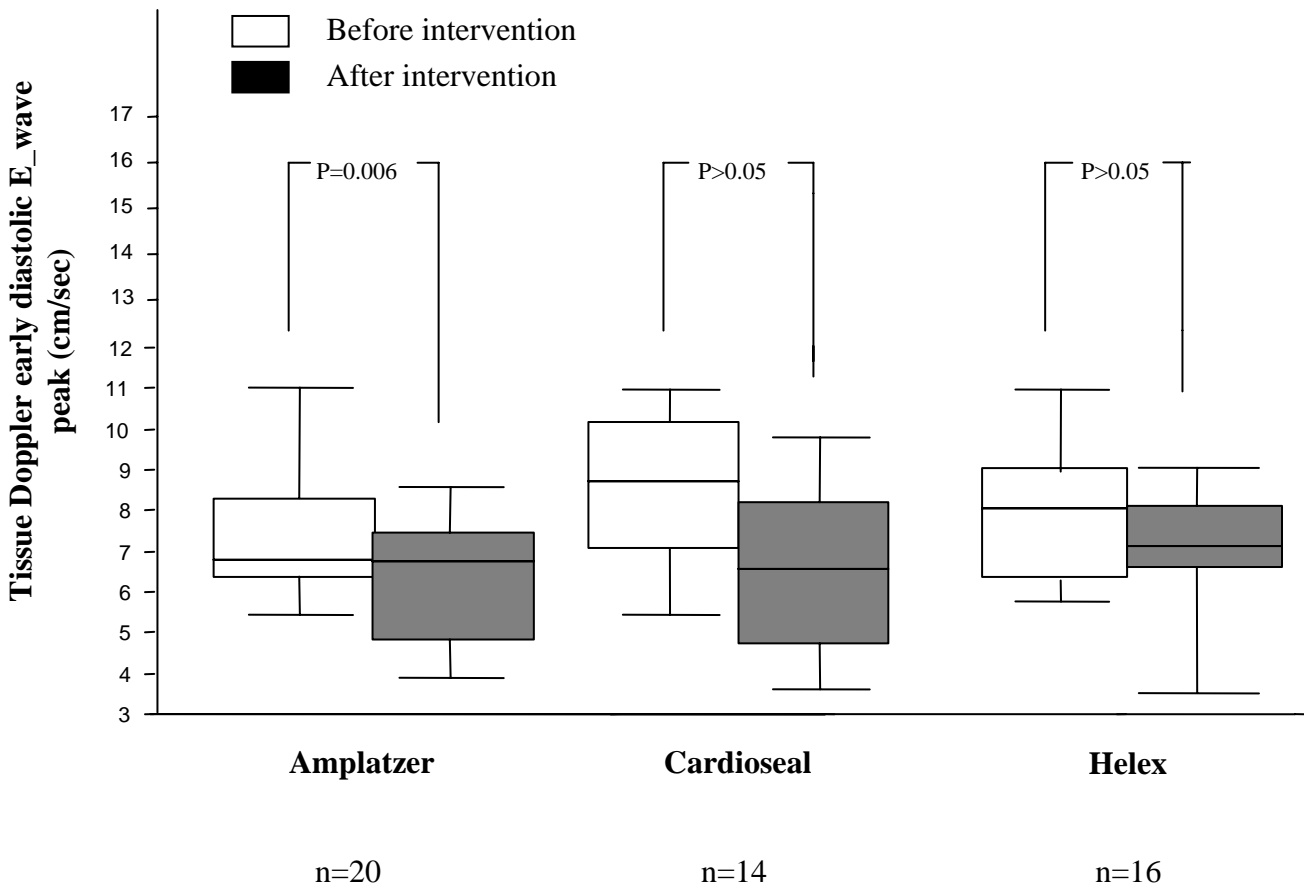


Figure 8: Regional atrial septum performance at the annuli level assessed by tissue velocity imaging in PFO patients before and after the intervention using three different devices.
E: early diastolic peak, PFO: patent foramen ovale, TVI: tissue velocity imaging..