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A Prospective Comparison of Harmonic Transthoracic and Transesophageal Echocardiography for Identifying Left Atrial Thrombi in Patients with Atrial Flutter and/or Fibrillation Prior to Cardioversion

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Objective: To compare the value of current harmonic transthoracic and transesophageal echocardiography for assessing echocardiographic markers of thromboembolic risk and identify left atrial thrombi in patients with atrial fibrillation and atrial flutter prior to cardioversion and/or overdrive stimulation. Transesophageal echocardiography has been suggested for guiding cardioversion in patients with atrial fibrillation and atrial flutter, because of its high accuracy for identifying left atrial thrombi. More recent studies have demonstrated that harmonic echocardiography may allow transthoracic detection of left atrial thrombi and assessment of left atrial appendage function. Setting: Tertiary cardiac referral centre. 172 Patients with atrial fibrillation and/or atrial flutter who were scheduled for cardioversion and/or overdrive stimulation were examined both by harmonic transthoracic and multiplane transesophageal echocardiography by independent observers to assess left atrial chamber and appendage size and peak emptying velocities. In addition, the presence of thrombi was determined. All patients were followed for 4 weeks after the procedure to assess for thromboembolic complications. Harmonic transthoracic echocardiography allowed imaging of the left atrial appendage and recording of its velocities in 83 % and 74 % of cases, respectively. Transthoracic and transesophageal echocardiographic measurements of peak left atrial appendage velocities did not differ significantly (0.4 (0.14) versus 0.35 (0.17) m/s; P = 0.14). Overall 11 thrombi were detected by transthoracic echocardiography. Transesophageal echocardiography confirmed the presence of all thrombi. One additional thrombus was diagnosed in a patient with a negative transthoracic echocardiographic study. Thus, the sensitivity and specifity of harmonic transthoracic echocardiography for identifying a thrombus were 92 % and 91 %, respectively. Logistic regression analysis revealed that a peak left atrial appendage velocity > 0.25 m/s was the only independent transthoracic parameter for the exclusion of left atrial thrombi with an odds ration of 4.4 (95 % CI 1.4 to 14.5). None of the study patients had a thromboembolic complication after cardioversion or overdrive stimulation. Modern echocardiographic systems with harmonic transthoracic echocardiography allow the identification of large left atrial appendage thrombi with a high degree of confidence. Because the specificity of identifying left atrial appendage thrombi is very high for harmonic transthoracic echocardiography, transesophageal echocardiographic examinations may be omitted in patients with the transthoracic diagnosis of thrombi. If transthoracic recording of left atrial appendage velocities is feasible, it may be possible to identify a thrombogenic milieu by transthoracic echocardiography prior to cardioversion. *J Clin Basic Cardiol 2002; 5: 93–99.*

Key words: atrial fibrillation, atrial flutter, cardioversion, transthoracic echocardiography

Thromboembolism is a feared complication of cardioversion of atrial fibrillation (AF). More recent studies have shown that thromboembolism may also occur in patients with atrial flutter (AFL) after cardioversion and/or overdrive stimulation procedures [1–3]. Transesophageal echocardiography (TEE) may be used to exclude left atrial (LA) chamber and appendage thrombi and assess the LA appendage function. It has been suggested when thrombi are absent on TEE, cardioversion may be safely performed in patients with AF [4–5].

Generally TEE is claimed to be superior to transthoracic echocardiography (TTE) for assessing the LA appendage morphology due to the higher resolution of TEE transducers and the close proximity of TEE transducers to the LA appendage [6–7]. However, we have recently shown that a new generation echocardiographic system allows for the transthoracic detection of LA thrombi and accurate determination of LA appendage function in patients with a neurological deficit [8]. The development of harmonic imaging has further improved resolution and image quality [9–12]. The aim of this study was to compare the value of harmonic transthoracic and transesophageal echocardiography for the evaluation of LA appendage morphology and function in patients scheduled for cardioversion and/or overdrive stimulation.

Methods

Study patients

The study group consisted of 42 consecutive adult patients with AFL and 130 patients with AF who were scheduled for cardioversion and/or overdrive stimulation. Both TTE and TEE were performed after written informed consent was obtained from all patients. In patients with TEE exclusion of thrombi, cardioversion and/or overdrive stimulation was performed after the institution of effective anticoagulation therapy within 48 hours. Whereas in patients with TEE detection of LA thrombi, cardioversion was postponed and echocardiographic examinations were repeated after 4 weeks of treatment with phenprocoumon. All patients were followed up for 4 weeks in our outpatient department to determine the presence of thromboembolic complications after the restoration of sinus rhythm.

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Echocardiographic studies

Patients were first investigated by TTE and then examined by a second, blinded investigator using TEE. All studies were conducted with commercially available equipment (System V®, GE Vingmed Ultrasound, Norway and HDI 5000®, ATL). To allow off-line quantitative assessment of the echocardiographic data, studies were recorded on VHS videotape with selected cine-loops and velocity spectra digitally transferred to an external computer for subsequent analysis as described previously [6].

For TTE a 3.4 MHz transducer was used with a harmonic frequency at 1.7 MHz. All patients were examined in the left lateral, decubitus position. A one-lead electrocardiogram was recorded continuously. The M-Mode LA dimension was measured at end-systole in the parasternal long-axis view and left ventricular ejection fraction was determined according to the recommendations of the North American Society of Echocardiography [13].

The LA was imaged as previously reported [8]. First, we achieved a standard parasternal short axis view at the aortic valve level. Then the imaging plane was angulated superiorly and laterally until the LA appendage appeared (Fig. 1). The sample volume of the pulsed Doppler was placed 1 cm into the orifice of the LA appendage. If necessary, angle correction between the LA appendage blood flow and the Doppler beam was performed. In addition, the LA appendage was imaged by using a transthoracic apical plane. Therefore, the transducer was rotated between the two chamber view and the four chamber view. The LA appendage was visualized to the lateral border of the LA (Fig. 1).

TEE was performed with a 6.7 MHz multiplane transducer as previously reported [8]: The oropharynx was anaesthetized with lidocaine spray and a viscous lidocaine solution was used to cover the tip of the transesophageal probe. When needed, 2.5 to 5 mg midazolam was injected for sedation. The probe was placed in the midesophagus behind the LA and a transesophageal four chamber view was then employed. To obtain optimal images of the LA appendage, the probe was rotated anticlockwise until the LA appendage appeared and the left atrial appendage was examined for the presence of thrombi using different planes. The imaging plane and gain settings were adjusted to achieve optimal visualization of the appendage and of spontaneous echo contrast. The maximal left atrial appendage area was determined in a 45° view, which compares to a parasternal short axis view of the left atrial appendage. The sample volume of the pulsed Doppler was placed 1 cm into the orifice of the LA appendage, similar to the transthoracic measurement. Selected flow spectra and Cineloops of the LA chamber and appendage were stored.

Echocardiographic data analysis

Echocardiographic evaluations were performed in a single-blinded manner with the results confirmed by two independent observers following the original examination. The data was analyzed by means of the evaluation software provided by the manufacturers. The feasibility of imaging the LA appendage itself, thrombi within the appendage, and spontaneous echo contrast in the LA chamber was assessed by both methods. Inadequate transthoracic echogenicity was defined as previously reported by our study group [8]. A thrombus was defined as an echodense mass in the LA chamber or appendage with a well-defined border to the endocardium. LA appendage area was measured before cardioversion by tracing a line starting from the top of the limbus of the left upper pulmonary vein along the appendage's endocardial border. Maximal appendage area was determined during five heart cycles and averaged. The pattern of the LA appendage velocity profile was described and peak emptying and filling wavelets were measured during seven consecutive cycles each, and maximal velocities then averaged. Since peak emptying and filling velocities did not differ significantly, only emptying velocities are presented. The intra- and interobserver variability of our echocardiographic laboratory for transthoracic measurements of left atrial appendage size and velocities has been recently reported to be low [8, 14].

Electrical cardioversion and overdrive simulation

Patients with AF and atypical AFL underwent external electrical cardioversion. For external cardioversion fasting patients received intravenous anaesthesia with propofol or etomidate (1–2 mg/kg or 0.1–0.2 mg/kg bodyweight). We used a PhysioControl (Lifepak) direct current cardioverter in all patients. Direct current electrical shocks were delivered at 200–360 Joule. Cutaneous patch electrodes were placed in anteroposterior position on the patients' chests.

Patients with typical AFL underwent overdrive stimulation from the high right atrium with a maximum of 400 beats per minute to interrupt AFL. Typical AFL was defined as the presence of a saw-tooth like pattern with positive flutter waves in precordial leads II, III, aVF.

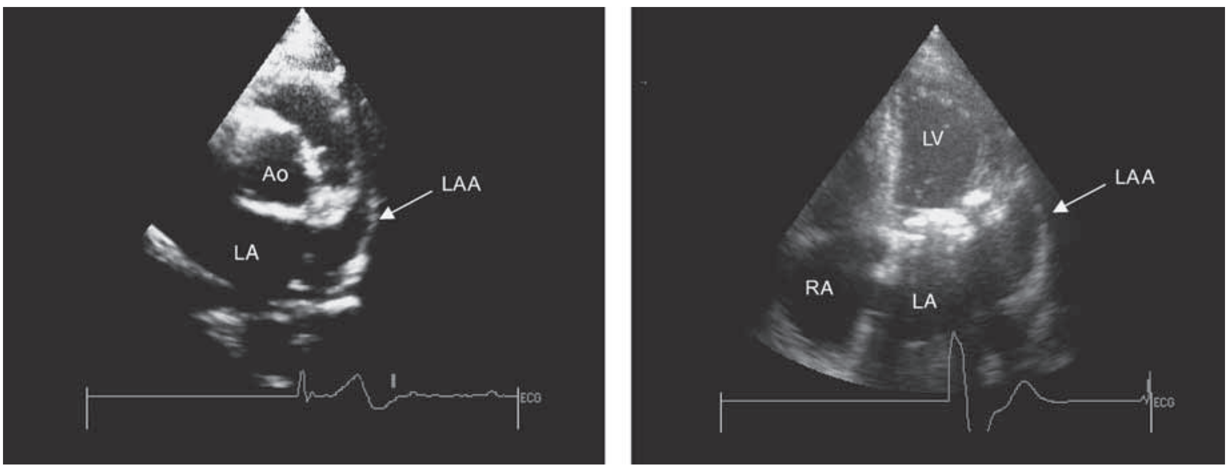

Figure 1. Transthoracic imaging of the LA appendage using a parasternal view (A) and apical view (B). Arrow indicates LA appendage.

Anticoagulation

All patients who presented without anticoagulation therapy to our department were anticoagulated with i. v. Heparin for at least 48 h prior to cardioversion and/or overdrive stimulation. They received intravenous weight-adjusted heparin in a dosage of 17 U/kg body weight per h. The dosage of heparin was adjusted to achieve an activated partial thromboplastin time ratio of 1.5 to 2.5 times the control value. In AF patients who were anticoagulated with phenprocoumon, cardioversion was performed if the INR level was > 2. Otherwise intravenous weight-adjusted heparin was administered for at least 2 days prior to the cardioversion procedure. Anticoagulation was continued after cardioversion for a minimum of 4 weeks.

Statistical analysis

Descriptive data are presented as the mean (SD). Continuous variables between groups were compared by student t-test and Wilcoxon sign rank test for unpaired observations. Nominal data were compared by the Fisher's exact test. A p value = 0.05 was considered statistically significant. (StatView 4.0®, Abacus Inc., Berkeley, California, USA). Logistic regression was performed to identify independent transthoracic echocardiographic parameters for the exclusion of thrombus formation.

Results

Patients

The age of the patients with AFL was mean 65 (9) years and 57 (15) years for patients with AF. 87 patients were male. 30 patients had typical AFL and 12 patients had atypical AFL. The mean duration of the last episode was 49 (60) days in patients with AFL and 61 (97) days in patients with AF. None of the patients with AFL had a history of thromboembolism, in contrast, five patients with AF had a history of thromboembolism. 38 patients had coronary heart disease, 17 had dilatative cardiomyopathy, 11 had valvular heart disease, 22 had myocarditis, 12 had hypertensive heart disease, 6 had thyreotoxicosis, 8 had other underlying heart disease and 45 had idiopathic AF or AFL.

None of the AFL patients were anticoagulated. Of the 130 patients with AF, 64 patients were anticoagulated with phenprocoumon. The INR level was > 2 in 56 of the latter patients.

Echocardiographic measurements

The LA diameter was 4.5 (0.8) in patients with AF and 4.4 (0.6) cm in patients with AFL, respectively. The corresponding values for left ventricular ejection fraction were 47 (16) %

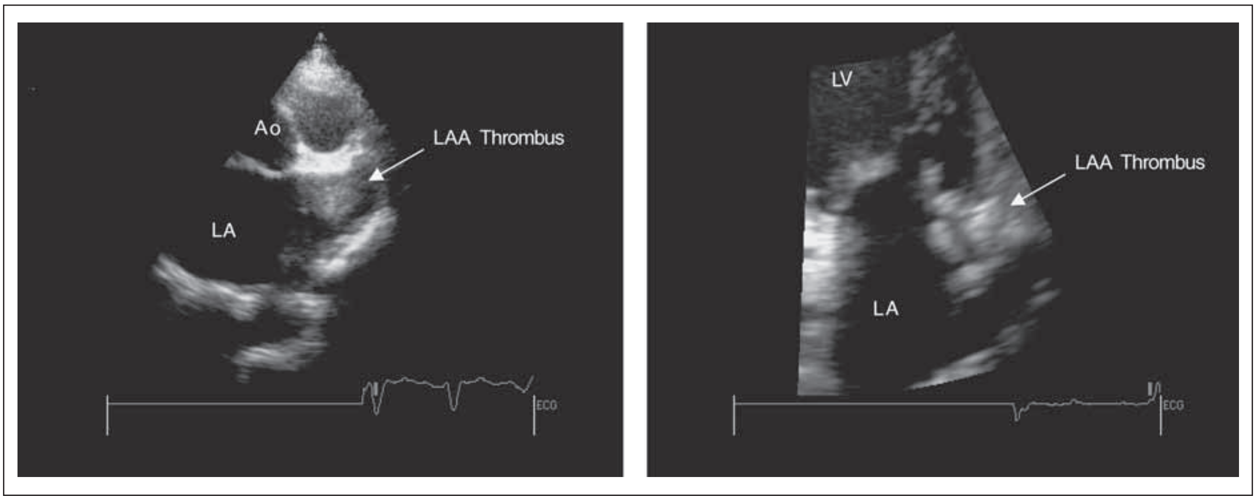

Figure 2. Transthoracic recording of the velocity profile over the LA appendage in a patient with AF (A) and AFL (B).

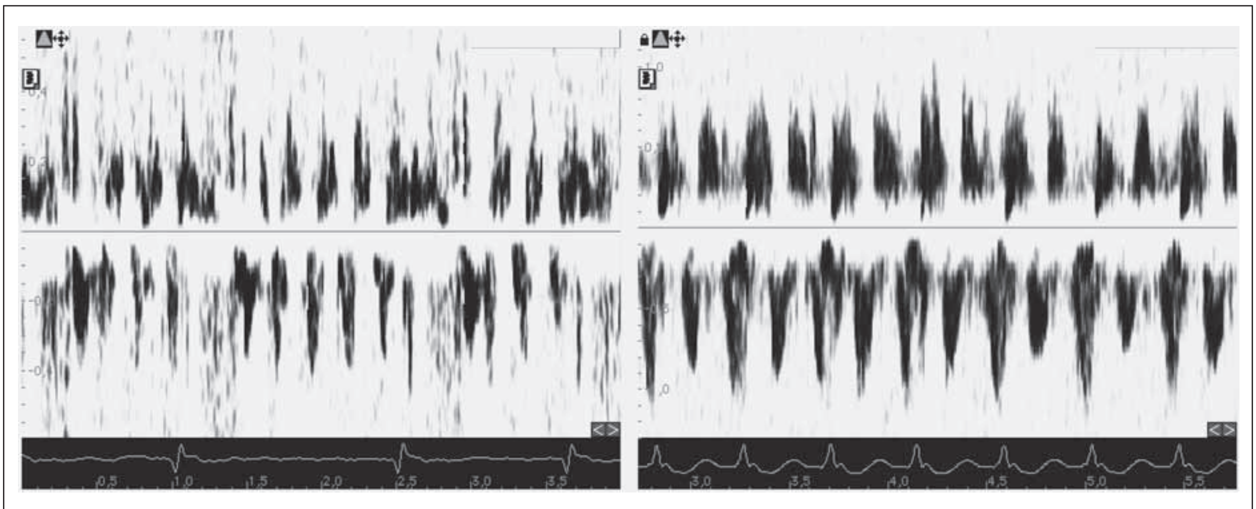

Figure 3. Transthoracic visualization of an LA appendage thrombus using a parasternal (A) and apical view (B). Arrows indicate thrombi.

and 53 (10) %. Tables 1 and 2 give the remaining harmonic TTE and TEE measurements for patients with AFL and AF. The overall feasibility of imaging the LA appendage by means of TTE was 83 % (n = 142). The LA chamber and appendage were adequately visualized in 132 patients from a parasternal approach and in 98 patients from an apical window, respectively. In 87 cases the LA appendage was visualized from both transducer positions. Recording of peak LA appendage velocities was feasible in 98 patients from a parasternal plane (74 %), in 65 patients (49 %) from an apical plane and in 57 patients from both views (43 %). In 26 of those cases, where flow LA appendage velocities could not be measured by harmonic TTE, TEE revealed LA appendage flow velocities below 0.25 m/s. Only 3 patients with AFL had LA appendage flow velocities < 0.25 m/s.

Thrombi and Spontaneous Echo Contrast

Overall 11 thrombi were imaged by harmonic TTE. Spontaneous echo contrast was detected in 13 cases by TTE. TEE confirmed the presence of all thrombi. One additional thrombus was diagnosed in a patient with a negative TTE study. Thus, the overall positive predictive value of harmonic TTE for diagnosing a thrombus was 100 %. The sensitivity and specifity were 92 % and 91 %, respectively.

In patients with atypical AFL, harmonic TTE detected one thrombus in the LA appendage. The thrombus was 1.5 x 1.6 cm in size and was confirmed by TEE. Spontaneous echo contrast was detected in 3 patients by TTE and in seven patients by TEE. Spontaneous echo contrast was graded 2+, 2+, 1+ by TTE 2.3 (1.2) by TEE. TTE underestimated the severity of spontaneous echo contrast in all cases and was only able to detect spontaneous echo contrast in those cases where TEE diagnosed severe = grade 3+ echo contrasts.

In the AF group, 10 thrombi were detected by TTE. All thrombi were confirmed by TEE. Furthermore, one additional thrombus was diagnosed by TEE in a patient with a negative TTE study. The thrombus measured 3 x 4 mm and was situated in the tip of the LA appendage. TTE was not able to separate this thrombus from surrounding trabecular structures. The average size of thrombi in the AF group was 20 (15) x 9 (5) mm. TTE and TEE measurements of thrombi length and width did not differ significantly (tab. 1). TTE classified 8 thrombi as mobile and 3 thrombi as immobile. TEE findings were concordant in all cases.

TEE detected spontaneous echo contrast in 46 patients out of 130 patients with AF, whereas TTE was able to visualize spontaneous echo contrast in only 10 cases (8 %, p > 0.001). The latter patients had dense spontaneous echo contrast in the TEE study. In patients with AFL, TEE visualized spontaneous echo contrast in 7 cases, whereas TTE depicted spontaneous echo contrast only in 3 of the latter cases (P = 0.02).

Table 1. Transthoracic and transesophageal echocardiographic measurements in patients with atrial fibrillation

Variable	TTE	TEE	P Value
Feasibility of imaging LA appendage [%]	105 [81 %]	129 [99 %]	
LA appendage area [cm^2]	5.7 (2.7)	5.0 (2.5)	0.0001
LA appendage velocity [m/s]	0.4 (0.14)	0.35 (0.17)	0.14
SEC [n]	10	46	< 0.0001
Thrombi [n]	10	11	0.76
Length of thrombus [cm]	2 (1.35)	2 (1.52)	0.55
Width of thrombus [cm]	0.81 (0.6)	0.85 (0.5)	0.31

LA, left atrial; SEC, spontaneous echo contrast

Table 2. Transthoracic and transesophageal echocardiographic measurements in patients with atrial flutter

Variable	TTE	TEE	P Value
Feasibility of imaging LA appendage [n, %]	37 [88 %]	42 [100 %]	
LA appendage area [cm^2]	5,9 (1.8)	5.4 (2.3)	0.14
LA appendage velocity [m/s]	0.54 (0.2)	0.58 (0.24)	0.11
SEC [n]	3	7	0.02
Thrombi [n]	1	1	

LA, left atrial; SEC, spontaneous echo contrast

Table 3. Comparison of transthoracic measurements in patients with and without thrombi

Variable	Thrombi	Without thrombi	P Value
LA diameter [cm]	4.8 (0.7)	4.5 (0.7)	0.15
LA appendage area [cm^2]	5.4 (1.2)	5.1 (2.5)	0.57
LA appendage velocity [m/s]	0.35 (0.16)	0.45 (0.17)	0.05
SEC [n]	11	0	0.0002
LVEF [%]	43 (16)	49 (15)	0.12

LA, left atrial; SEC, spontaneous echo contrast

Comparison of patients with atrial fibrillation and atrial flutter

Patients with AF had significantly lower peak LA appendage velocities (0.36 [0.17] m/s vs. 0.52 [0.21 m/s], p < 0.001, 95 % CI 0.16 to 0.38) and an increased incidence of spontaneous echo contrast (p = 0.04). The groups did not differ in LA diameter (4.54 [0.76] cm vs. 4.47 [0.64] cm, p = 0.73), left ventricular ejection fraction (47 [15] % vs. 53 [10] %, p = 0.13) or maximal LA appendage areas (5.5 [2.32] cm^2 vs. 5.01 [2.32] cm^2, p = 0.78).

Comparison of thransthoracic and transesophageal echocardiographic measurements

The results are given in tables 1 and 2. In the AF group, TTE and TEE measurements did not differ for peak LA appendage velocities or the measurements of length and width of the thrombi. However, transthoracic measurements of maximum LA appendage areas were higher than TEE measurements. In patients with AFL, TTE and TEE measurements of LA appendage velocities and areas did not differ.

Cardioversion and overdrive stimulation

130 patients underwent cardioversion after TEE exclusion of LA thrombi. 30 patients underwent overdrive stimulation. The remaining 12 patients with a TEE diagnosis of LA thrombi were anticoagulated and followed up for 4 weeks. In patients without thrombi, cardioversion was successfully performed in 69 % (n = 90) cases. Overdrive stimulation resulted in restoration of SR in 87 % (n = 26). During the follow-up period, none of the patients experienced thromboembolic complications. In patients with thrombi, two strokes occurred during the follow-up period of 4 weeks. TTE demonstrated disappearance of thrombi in 6 of 12 cases. Of the remaining patients with thrombi, TTE demonstrated a reduction in thrombus size in 4 out of 6 patients. TEE confirmed the presence of thrombi as diagnosed by TTE. However, in those patients with negative findings on TTE, TEE revealed 2 small thrombi, which were not diagnosed by TTE. In both cases dense spontaneous echo contrast was present in the LA appendage. Thus, the sensitivity and specificity of detecting thrombi were 75 % and 33 %, respectively.

Transthoracic echocardiographic predictors for TEE exclusion of thrombi

Table 3 shows the comparison of transthoracic echocardiographic measurements in patients with and without thrombi. LA diameter, left ventricular ejection fraction and maximal LA appendage area did differ significantly between those groups. However, patients with thrombi had lower peak LA appendage velocities and more often spontaneous echo contrast. Furthermore, 8 patients of those in whom recording of the LA appendage velocities was not feasible had LA appendage thrombi. Of the patients with thrombi, 11 patients had spontaneous echo contrast on TTE. Logistic regression analysis revealed that a peak LA appendage velocity > 0.25 m/s, as measured by TTE, was the only independent parameters for predicting the absence of thrombi on TEE with an odds ratio of 4.4 (95 % CI 1.4 to 14.5).

Discussion

Previous studies have shown that TEE has a much higher sensitivity for detecting and excluding LA chamber and appendage thrombi than TTE. Because of the high accuracy of TEE for excluding LA thrombi, guiding cardioversion of AF by TEE has been suggested: If thrombi are absent on TEE, cardioversion may be performed safely [4–5]. However, TEE has its own risks and is a least invasive procedure [15]. To the best of our knowledge this is the first study to systematically compare the value of current harmonic TTE and multiplane TEE for detecting and excluding LA thrombi prior to cardioversion of AF and/or AFL.

TEE for the assessment of LA chamber and appendage morphology and function

TEE is regarded as the standard method for assessing LA chamber and appendage morphology and function. TEE is claimed to be superior to fundamental TTE because the TEE transducer may be placed within the esophagus close to the body of the LA, thereby allowing an unrestricted view of the LA appendage. In addition, TEE transducers are known to have a higher resolution than transthoracic transducers. However, recent developments in ultrasound technology have improved transthoracic image quality. In particular, harmonic imaging has been shown to reduce side lobe artefacts and to improve signal the to noise ratio [9, 12]. Thus, transthoracic imaging of LA thrombi may be improved. Recently it has been shown that a new generation echocardiographic system allows for the transthoracic detection of LA appendage thrombi and accurate determination of LA appendage function in most patients with a neurological deficit [8]. In this study imaging of the LA appendage was feasible in 75 % of the patients by transthoracic and in 95 % by transesophageal echocardiography. The overall feasibility of imaging the LA appendage by harmonic TTE was 83 % and was slightly higher than in our previous study, investigating patients with neurological deficits. However, patients with neurological deficits are often difficult to examine and harmonic instead of fundamental TTE was employed in the present study. The results of our study show that the parasternal approach was more effective for imaging the LA appendage (77 %) than the apical window (57 %). A possible explanation for this finding is the closer proximity of the LA appendage to the parasternal transducer position, as compared to the apical transducer position. Interestingly, imaging of the LA appendage was feasible in 51 % of cases from both windows. Another finding of the present study was that transthoracic echocardiographic measurements of the maximal LA appendage area were higher than the corresponding measurement by TEE. It is possible that harmonic TTE overestimates the size of the LA appendage due to the lower lateral resolution of harmonic TTE, as compared to TEE. However, because the LA appendage is usually a multilobed structure, it is often difficult to obtain adequate measurements of its size from one transducer position [16, 17]. Thus, attempts to quantitate LA appendage size by different planimetric methods may vary [18].

LA appendage function may be assessed by recording LA appendage velocities [19]. Multiple studies have suggested that assessment of LA appendage function may allow the identification of patients with increased risk for thrombus formation and thromboembolic complications. Usually peak LA appendage velocities are recorded by TEE. However, previous studies have demonstrated that peak LA appendage velocities may also be recorded by TTE [8, 20]. In the present study, recording of peak LA appendage velocities was feasible in 62 % of all patients and in 81 % of patients with adequate transthoracic echogenicity. The feasibility of recording peak LA appendage velocities was higher from a parasternal approach than from the apical approach. Again, this phenomenon is most likely due to the closer proximity of the LA appendage to the parasternally placed transducer. In patients in whom recording of the LA appendage velocities was feasible from both transthoracic windows, there was not a significant difference between the two measurements. The results of our study not only demonstrated that transthoracic and transesophageal echocardiographic measurements do not differ significantly, but also show that transthoracic measurements of peak LA appendage velocities are reliable. An important finding of the present study is that it was not possible to record LA appendage velocities in 26 cases using a transthoracic approach despite adequate transthoracic visualization of the LA appendage. In those cases TEE revealed peak flow velocities < 0.25 m/s. Thus, the sensitivity of TTE is limited for the recording of low peak LA appendage velocities. The failure to record velocities in the latter cases may be explained by the fact that they were too low for the Doppler threshold.

Detection of LA chamber and appendage thrombi and spontaneous echo contrast

TTE is regarded as an inadequate imaging modality for identifying or excluding LA atrial thrombi [7]. In contrast, comparative intraoperative series have demonstrated the excellent sensitivity and predictive accuracy of TEE for the identification and exclusion of LA thrombi in patients undergoing valvular surgery [21–25]. Because of the high accuracy for identifying LA thrombi, TEE has been advocated to guide early cardioversion of AF [4, 5]. Because the cost effectiveness of TEE guided cardioversion is increased with the omission of a transthoracic examination, omission of TTE prior to cardioversion has been suggested [7]. However, more recent studies have shown that modern echocardiographic systems may allow for the transthoracic echocardiographic detection of LA appendage in a high number of patients. Our study group has recently shown that in patients with adequate transthoracic echogenicity, the specificity and sensitivity of detecting LA appendage thrombi is high [8]. In support of our findings, another study found a 74 % sensitivity of transthoracic echocardiography for detecting left atrial appendage thrombi in patients with mitral stenosis [26]. The sensitivity of detecting thrombi rose to 83 % in the latter study when patients with poor echogenicity were excluded.

The primary result of the present study is that harmonic TTE allows the detection and exclusion of LA thrombi prior to cardioversion and or overdrive stimulation in patients with

AF and/or AFL with a sensitivity and specificity of 92 % and 91 %, respectively. Of the 12 LA thrombi that were detected by TEE, only one thrombus was missed by harmonic TTE. The high accuracy of harmonic TTE may be partly explained by the fact that the thrombi were relatively large in our study group. In this respect it is worth noting that the thrombus that was missed by TTE measured only 3 x 4 mm and was situated in the tip of the appendage. Generally large LA thrombi are regarded to be associated with valvular disease. However, relatively large LA thrombi are also not uncommon in patients with non-valvular disease. One study reported a range of LA thrombus size from 5 to 20 mm in patients scheduled for cardioversion of nonrheumatic AF [27]. Another explanation for the high accuracy of detecting LA thrombi in our study may be that most of the thrombi were mobile. Movement of a thrombus enhances its detection. However, in the present study immobile thrombi were also correctly detected by harmonic TTE. In this respect it is interesting to note that harmonic TTE and TEE were concordant for classifying mobility of LA thrombi in all cases. The high specificity of our study for excluding thrombi is probably due to our strict criteria for the diagnosis of a thrombus.

Spontaneous echo contrast is regarded as an echocardiographic marker of thrombogenic milieu and is associated with an increased thromboembolic risk [28–31]. The findings of our study show that harmonic TTE depicted spontaneous echo contrast in only 13 patients, whereas TEE detected spontaneous echo contrast in 53 patients. Furthermore, all patients with transthoracic detection of spontaneous echo contrast had dense spontaneous echo contrast. Thus, the results of our study show that the feasibility of transthoracic detection of LA chamber spontaneous echo contrast is very low. However, if spontaneous echo contrast is present on harmonic TTE, it is likely that TEE reveals dense spontaneous echo contrast indicating an increased thrombogenic milieu in the LA. The low feasibility of imaging spontaneous echo contrast by TTE is probably due to the significantly lower transducer frequency of transthoracic transducers, as compared to transesophageal ones.

Comparison of patients with atrial flutter and atrial fibrillation

The results of our study show that patients with AF had significantly lower LA appendage velocities and an increased incidence of spontaneous echo contrast than those patients with AFL. However, both groups did not differ significantly for LA diameter, left ventricular ejection fraction and maximal LA appendage areas. The finding that peak LA appendage velocities were significantly higher in AFL patients than in AF patients is a potential explanation for the higher feasibility of recording peak LA appendage velocities in patients with AFL by means of transthoracic echocardiography. Furthermore, only 3 out of 42 patients with AFL had peak LA appendage velocities < 0.25 m/s on TEE examination. Another finding of our study is that patients with AFL had significantly less thrombi than patients with AF. Only one patient with atypical AFL had a thrombus in the LA appendage. Although, this result supports previous findings of a low rate of LA thrombi in patients with AFL, it is in contrast to a more recent study showing a high prevalence of LA thrombi in patients with AFL [32–34]. However, the incidence of heart failure was higher in the latter study.

Transthoracic echocardiographic parameters for excluding the presence of LA thrombi on TEE examination

Because the risk of cardioversion of AF and/or AFL is increased with the presence of LA thrombi, we have analyzed the predictive value of transthoracic echocardiographic parameters for excluding LA thrombi on TEE examination. The results of our study show that LA diameter, left ventricular ejection fraction and maximal LA appendage area were not significantly associated with the presence of LA thrombi on TEE examination. Whereas patients with thrombi had significantly lower peak LA appendage velocities and greater spontaneous echo contrast. Logistic regression analysis revealed that a peak LA appendage velocity > 0.25 m/s was the only independent transthoracic parameter for predicting the absence of thrombi on TEE with an odds ratio of 4.4. Thus, the results of our study indicate that the absence of thrombi on a harmonic TTE study and LA appendage velocities > 0.25 m/s are strong predictors of TEE exclusion of LA appendage thrombi.

However, another important finding of our study is that the sensitivity and specificity of TTE for excluding LA appendage thrombi decreased in those patients who underwent repeat echocardiographic examinations for the follow-up of known thrombi. The results of our study show that harmonic TTE was correct for showing disappearance of LA thrombi in 6 out of 12 cases. However, TTE presented a false negative in 2 cases in which TEE still depicted small thrombi. This finding is important, because it shows that TTE is limited for the detection of very small thrombi. On the other hand TTE was still highly specific for the detection of LA appendage thrombi on repeat examination.

Clinical Implications

Modern echocardiographic systems with harmonic TTE allow the detection and exclusion of large LA appendage thrombi with a high degree of confidence. Because the specificity of detecting and excluding LA appendage thrombi is very high for harmonic TTE, TEE examinations may be omitted in patients with the transthoracic diagnosis of LA thrombi. If transthoracic recording of LA appendage velocities is feasible, it may be possible to identify a thrombogenic milieu in the LA by TTE prior to cardioversion.

Study Limitations

The number of patients investigated was limited, however measurements were assessed on a prospective basis. Assessing the presence of spontaneous echo contrast is subjective, however it has been shown recently that interobserver variability in the diagnosis of spontaneous echo contrast is low [36]. The accuracy of transthoracic echocardiography for identifying atrial thrombi was compared to transesophageal echocardiography. However, despite the high accuracy of transesophageal echocardiography for detecting atrial thrombi, small thrombi may still be missed by transesophageal echocardiography.

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