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Clinical Research

# Study of Atrial Function Using Echocardiographic Automatic Boundary Detection Following External or Internal Cardioversion for Idiopathic Atrial Fibrillation

Athanasios Kranidis, Konstantinos Kappos, Ioannis Lekatsas, Ilias Karabinos, Spyridon Koulouris, Georgios Andrikopoulos, Tania Bouki, Athanasios Kotsakis, Nikolaos Exadaktylos

*A′ Cardiology Department, "Evangelismos" General Hospital, Athens, Greece*

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*Address:*
Athanasios I. Kranidis

*71 Thiseos St.,*
*152 34 Halandri*
*Athens, Greece*
*e-mail:*
***kranidis@internet.gr***

**Introduction:** The aim of this study was to evaluate the validity of an echocardiographic method of automatic boundary detection (ABD) in the assessment of the degree of atrial dysfunction in patients who had undergone external or internal cardioversion for idiopathic atrial fibrillation.

**Methods:** The study population included 31 patients (mean age 48 ± 6.5 years) with idiopathic atrial fibrillation. The patients were randomised into two groups: Group 1 (14 patients, 8 ± 3.13 joules), where internal cardioversion was applied, and Group 2 (17 patients, 200-360 joules), where external cardioversion was used for restoration of sinus rhythm. During the following 24 hours the ABD method was used in both groups to assess the following functional indices for both the left and the right atrium: a) total fractional change of atrial area (Δ1), b) passive change of atrial area (Δ2), c) change of atrial area due to atrial contraction (Δ3) and d) index of % atrial expansion (Δ4).

**Results:** All patients in both groups were successfully cardioverted (100%, p: NS). Post-cardioversion indices Δ1-Δ4 for both left and right atria did not differ between the 2 groups (p:NS). A negative correlation was found between left atrial function as assessed by ABD and the mean energy in joules delivered through the catheter in each patient for successful cardioversion (r =-0.55 to r=-0.67 and p=0.04 to p=0.01). However, no relevant correlations were found for the right atrium (p:NS).

**Conclusions:** 1) The atrial dysfunction which follows the cardioversion of idiopathic atrial fibrillation (atrial stunning) is not related to the type of cardioversion (internal or external). 2) The higher the amount of energy delivered during internal cardioversion, the greater the degree of left atrial dysfunction observed.

The echocardiographic method of automatic boundary detection (ABD) provides a direct measurement of the area and the estimated volume of the left atrium in real time. The results are depicted as a waveform, allowing observation of the changes in the measurements at each time point in the cardiac cycle. The method has been used for the evaluation of the function of both the left ventricle and the left atrium.[1] In particular, studying left atrial function is of practical importance in various clinical conditions, among which is the phase following the cardioversion of atrial fibrillation (AF), an arrhythmia responsible for most of the admissions to a hospital's cardiology department.[2]

The purpose of this study was to use ABD to investigate the affect on atrial function of external and internal electrical cardioversion for idiopathic AF.

## Material and methods

The study material comprised 31 patients (16 men, 15 women, mean age 48 ± 6.5 years) with idiopathic AF. The duration of AF was 6.9 ± 7.9 weeks. All patients had been taking anticoagulants for at least 4 weeks prior to cardioversion (INR: 2.5-3.5) and none had an intra-chamber thrombus on the transoesophageal echocardiographic examination carried out on the day before cardioversion. No patient had a history of thromboembolism.

The patients were randomised into two groups: Group 1 (14 patients), where internal cardioversion was applied, and Group 2 (17 patients), where external cardioversion was used for restoration of sinus rhythm. Internal, low-energy cardioversion was applied using the "Alert" method, which involves a single-catheter electrode system whose electrodes are placed in the lower right atrium and the left pulmonary artery, guided by a Swan-Ganz balloon catheter. Successful cardioversion using this method required a mean energy of 8.03 ± 3.13 J.

External cardioversion in the 17 patients of Group 2 involved the transthoracic application of a monophasic shock. In 3 of these patients cardioversion was achieved with the application of 200 J, while in the remaining 14 a 200 J shock was unsuccessful and a further shock with 360 J was necessary for the restoration of sinus rhythm.

In all patients a complete transthoracic echocardiographic study was carried out within the 24 hour periods both before and after cardioversion, using an HP Sonos 2500 echocardiograph device. Left and right atrial function were assessed using the ABD method, by two independent and experienced echocardiographers, within the first 24 hours following cardioversion. No patient needed to be excluded from the study because of poor quality imaging or the inability to obtain measurements via ABD.

The ABD method was used to generate a waveform representing the area of the left and the right atrium. For the assessment of left atrial function using this method the following indices were measured from the transthoracic echocardiographic 4-chamber apical view:

- the total fractional change of atrial area (Δ1), equal to end-systolic minus end-diastolic divided by end-systolic left atrial area;
- the passive change of atrial area (Δ2), equal to end-systolic minus mid-diastolic divided by end-systolic left atrial area;
- the change of atrial area due to atrial contraction (Δ3), equal to mid-diastolic minus end-diastolic divided by mid-diastolic left atrial area, and
- the index of atrial expansion (Δ4), equal to end-systolic minus end-diastolic divided by end-diastolic left atrial area and expressed as a percentage.

Areas were measured in $cm^2$. The end-systolic left atrial area was calculated at the maximum of the left atrial curve (descending branch on the ECG) and was provided automatically by the software of the echocardiograph. The end-diastolic left atrial area was calculated from the curve at the peak of the QRS on the ECG, while the mid-diastolic measurement was obtained before atrial systole (before the start of the P wave).

The same indices were obtained in the same way for the evaluation of right atrial function.

In every patient each index was calculated by two independent echocardiographers for each of three successive cardiac cycles and the average was used. The interobserver and intraobserver variability were obtained by applying one way analysis of variance (ANOVA) to all the index values calculated by both operators for all 31 patients. The within subject coefficient of variation was calculated in each case, as the ratio of the standard deviation (the square root of the ratio of the sum of the sums of the squares around the mean value in each sample to the degrees of freedom) to the mean value of the measurements, expressed as a percentage. The interobserver variability for each index was as follows: Δ1=4.8%, Δ2=4.7%, Δ3=4.9%, Δ4=4.8%. Intraobserver variability for one operator was Δ1=4.2%, Δ2=4.3%, Δ3=4.1%, Δ4=4.3%, and for the other operator Δ1=4.2%, Δ2=4.1%, Δ3=4.2%, Δ4=4.2%.

In the statistical analysis, the $\chi^2$ test was used for comparison of conversion rates between groups. Student's t-test was used for comparing the mean values of the various indices of atrial function between groups. Pearson's correlation coefficient was used to analyse the functional indices derived following cardioversion. A p value $<0.05$ was the criterion of statistical significance.

## Results

As Table 1 shows, there were no differences between Groups 1 and 2 as regards age, duration of AF or echocardiographic variables (p:NS). Internal cardioversion was successful in all patients of Group 1 (14, 100%) and external cardioversion was successful in all of Group 2 (17, 100%) (p:NS).

Table 2 shows the values of the indices of left atrial function derived using ABD after cardioversion in the 2 groups and Table 3 shows the same indices for the right atrium. There was no significant relationship between these indices for the left or right atrium and the cardioversion method employed (p:NS).

**Table 1.** Clinical and echocardiographic variables of patients who underwent internal (Group 1) and external (Group 2) cardioversion.

| | Group 1 (n=14) | Group 2 (n=17) | t | p |
|---|---|---|---|---|
| Age (years) | 47.41 ± 5.31 | 48.82 ± 7.21 | t=0.6, | p=0.55 |
| Duration of AF (weeks) | 6.52 ± 8.24 | 7.12 ± 6.91 | t=0.22, | p=0.82 |
| PW (cm) | 0.95 ± 0.09 | 0.93 ± 0.06 | t=1, | p=0.31 |
| IVS (cm) | 0.96 ± 0.06 | 0.94 ± 0.09 | t=0.68, | p=0.51 |
| EDD (cm) | 4.73 ± 0.24 | 4.71 ± 0.03 | t=0.36, | p=0.65 |
| ESD (cm) | 2.81 ± 0.14 | 3.92 ± 0.18 | t=1.75, | p=0.08 |
| EF (%) | 58.12 ± 4.41 | 57.32 ± 3.71 | t=0.55, | p=0.58 |
| LA (cm) | 4.26 ± 0.52 | 4.23 ± 0.87 | t=0.46, | p=0.66 |

AF – Atrial fibrillation, EDD – left ventricular end-diastolic diameter, EF – left ventricular ejection fraction, ESD – left ventricular end-systolic diameter, IVS – interventricular septum, LA – left atrium, PW – left ventricular posterior wall.

**Table 2.** Indexes (Δ) of left atrial function derived by automatic boundary detection after internal (Group 1) or external (Group 2) cardioversion of atrial fibrillation.

| | Δ1 | Δ2 | Δ3 | Δ4 |
|---|---|---|---|---|
| Group 1 (n=14) | 0.45 ± 0.23 | 0.32 ± 0.21 | 0.21± 0.17 | 109.71 ± 96.50 |
| Group 2 (n=17) | 0.37 ± 0.11 | 0.22 ± 0.1 | 0.15 ± 0.04 | 63.52 ± 32.09 |
| t, p | t= 0.81, p=0.42 | t=0.96, p=0.35 | t=0.71, p=0.46 | t= 1.03, p=0.31 |

**Table 3.** Indexes (Δ) of right atrial function derived by automatic boundary detection after internal (Group 1) or external (Group 2) cardioversion of atrial fibrillation.

| | Δ1 | Δ2 | Δ3 | Δ4 |
|---|---|---|---|---|
| Group 1 (n=14) | 0.46 ± 0.16 | 0.32 ± 0.14 | 0.24± 0.11 | 111.01 ± 82.02 |
| Group 2 (n=17) | 0.40 ± 0.22 | 0.23 ± 0.15 | 0.23 ± 0.15 | 89.00 ± 71.02 |
| t, p | t= 0.75, p=0.45 | t=0.91, p=0.37 | t=0.22, p=0.8 | t= 0.57, p=0.57 |

In Group 1 there was a negative correlation between the values of the left atrial functional indices derived using ABD and the mean energy required for successful internal cardioversion. Specifically, the correlations were as follows: Δ1, r=-0.64 p=0.01; Δ2, r=-0.55 p=0.04; Δ3, r=-0.67 p=0.01; Δ4, r=-0.55 p=0.04. However, no such significant correlations were found for the right atrium (Δ1, r=-0.037 p=0.871; Δ2, r=-0.08 p=0.69; Δ3, r=-0.14 p=0.52; Δ4, r=-0.06 p=0.77).

No attempt was made to perform a similar analysis in Group 2, since only 3 patients were successfully cardioverted using a 200 J shock, whereas the remaining 14 required 360 J.

## Discussion

Atrial function is a complex matter, since the atrium functions as a reservoir, a conduit and a booster pump in the different phases of the cardiac cycle.[1] Assessment of atrial function is mainly achieved non-invasively using various techniques of Doppler echocardiography. Systolic pulmonary venous flow has been proposed as an index of left atrial function in its role as a reservoir.[3] In addition, the maximum velocity of transmitral flow and the amount of late filling in relation to total left ventricular filling (filling fraction) have found application as indices of left atrial function as a booster pump.[4,5] However, these two Doppler indices from the study of transmitral flow provide no information regarding the size of the left atrium or its regional function. Doppler can also be used to estimate the power of atrial ejection, if the area of the mitral ring is estimated first. However, this method assesses only the active contractile state of the left atrium.[4-8] One of the relatively recent echocardiographic techniques is ABD, which is a practical method for the rapid evaluation of the functionality of the atria, providing more than one index of atrial function.[1,3]

Assessment of atrial function is of particular importance in AF since, apart from anything else, it is linked to thromboembolic complications, which are not rare after conversion to sinus rhythm. Thromboembolic complications following cardioversion of AF are clearly related with the existence of atrial stunning.[9] Conversion of AF to sinus rhythm may be achieved with either external or internal electrical cardioversion,[10-13] of which the latter, more recent technique has certain advantages. Among them is the fact that it is unnecessary to have an anaesthesiologist present to administer anaesthesia during the procedure.[10] Furthermore, internal cardioversion is considered to be more effective than external, as we found in the present study. However, it is not associated with a reduction in the relapse rate to AF following the restoration of sinus rhythm.[7,9] Indeed, it has been reported that its use entails risks, although doubt has been cast on this aspect by the multicentre study of Adraghetti and Scalese.[12]

In this study we found, using the ABD method during the first 24 hours after cardioversion of AF, that the degree of atrial stunning in both the left and right atrium did not differ significantly whether the cardioversion was internal or external. Omran et al,[14] in a study of 20 patients, measured the velocity of late transmitral flow and the emptying and filling velocities of the left atrial appendage, using transthoracic and transoesophageal echocardiography, respectively, for the assessment of left atrial and left atrial appendage function after restoration of AF to sinus rhythm using internal cardioversion. They obtained similar findings to ours, in that internal cardioversion caused stunning of the left atrium and left atrial appendage, which contributed to the appearance of automatic echo-contrast (prothrombotic state) and later thrombus within the left atrium. More specifically, during the early period following cardioversion they observed thrombus formation in one patient in the left atrial appendage, while another patient suffered a cerebrovascular episode. At first sight this is a striking finding, given that internal cardioversion uses only a small amount of energy.[10] However, it appears that when these few joules of energy are released during internal cardioversion they can cause a significant degree of stunning in the atrial tissue. It is likely that the endocardial shock creates an electrical field within the atria that can depress left atrial function to a similar degree to that seen in external cardioversion. Moreover, the left atrium is sensitive even to the low quantity of energy supplied in internal cardioversion.[14]

We found that the degree of left atrial stunning after internal cardioversion was related to the amount of energy needed for the restoration of sinus rhythm. This finding may appear to contradict in some way the hypothesis that AF itself causes left atrial dysfunction, which persists even after it is converted to sinus rhythm. The hypothesis is based on the fact that the duration of AF prior to cardioversion is related with the length of time the atrium is stunned after sinus rhythm is restored. Omran et al,[14] however, found no correlation between the degree of left atrial stunning and the total energy delivered during cardioversion of AF, although the latter was not exclusively idiopathic. Furthermore, the researchers used a different internal cardioversion system with large-surface electrodes (Elecath Inc.) that were placed in the right atrial appendage and the coronary sinus.

Our finding that internal cardioversion, like external cardioversion with monophasic shock, causes left atrial stunning somewhat decreases the value of this method of converting AF to sinus rhythm, since it is well known that left atrial stunning is associated with thromboembolic complications.[12-15] In addition, our finding that an increase in the energy supplied during internal cardioversion increases the degree of left atrial stunning is of particular interest, in that it could lead to a search for catheters with new technical characteristics that enable the successful internal cardioversion of AF while delivering fewer joules. Boriani et al,[13] applying internal cardioversion with one catheter in the coronary sinus and another in the right atrium, found that the use of a longer coil resulted in a reduction in resistance, a smaller amount of energy and necessary potential, as well as less discomfort during the procedure. The energy required for successful cardioversion decreased from $7.86 \pm 4.25$ to $6.75 \pm 4.25$ J.

Data concerning the effect of the conversion of AF to sinus rhythm on right ventricular function are scarce in the literature. However, what affects the left atrium must also affect the right. Atrial myopathy due to tachycardia and hibernating atrial myocardial tissue are probably related with biatrial stunning.[16] Quite recently, Omran et al[17] studied right atrial function after internal or external cardioversion of AF. They found stunning of the right atrium and its appendage following both methods of cardioversion. More specifically, in 2 of the 25 patients who participated in the study they found thrombi within the right atrium which were not there before cardioversion. It is interesting to note that the thrombus was located in the fossa ovalis. It seems likely that the placement of the catheter in the right atrium was itself responsible for the thrombus, or that the electrical energy released from the catheter caused damage to the atrial tissue, leading to thrombus formation.[17] As in our own study, these investigators found no difference in the severity of stunning in relation to whether the cardioversion was internal or external, as in the case of the left atrium. In the present study we did not see an increase in the degree of right atrial stunning with an increase in the energy delivered during cardioversion, as we did in the left atrium. This may have been due to anatomical differences between the right and left atria.

### *Study limitations*

The main limitation of this study is the rather small number of patients. In addition, based on our findings it is not clear whether atrial function was stunned as a result of the cardioversion (although this would be expected), since we do not know what the atrial function was like before. It would have been better if the atrial function had been reassessed after 1 and 3 weeks following conversion to sinus rhythm, during its period of "convalescence".

In conclusion, the findings of this study indicate that: a) although internal cardioversion of idiopathic AF is more efficient (requiring less energy in joules delivered), it has the same consequences with respect to atrial stunning as does external cardioversion with monophasic shock; b) only in the left atrium does the degree of stunning reflect the total quantity of energy used for successful internal cardioversion of idiopathic AF.

Taking into consideration the disadvantages of internal cardioversion of AF observed in this study and the fact that external cardioversion can also be performed with biphasic shock, so as to require fewer joules,[18] the internal cardioversion method must not only have no future, but also no present as regards its wide use. Conversion to sinus rhythm with internal cardioversion should be considered only when external cardioversion fails, or probably in emphysemic or obese patients, in patients with a pacemaker or defibrillator or drug infusion pumps, or when general anaesthesia is contraindicated.[19]

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