Transesophageal low-energy cardioversion of atrial fibrillation without fluoroscopy outside the electrophysiology laboratory

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Atrial fibrillation; Cardioversion.

Background. **Low-energy internal cardioversion (LEIC) is a safe and effective procedure for the restoration of sinus rhythm in patients with atrial fibrillation refractory to external cardioversion. However, the procedure needs fluoroscopy and the use of the electrophysiology laboratory, even when the esophageal approach is utilized. The aim of this study was to assess the efficacy, safety and tolerability of a new simplified procedure of esophageal LEIC performed without fluoroscopy, outside the electrophysiology laboratory.**

Methods. **Thirty consecutive patients (23 males, 7 females) with persistent atrial fibrillation were submitted to LEIC using a step-up protocol (by steps of 50 V, starting from 200 V). Twenty (66%) were resistant to external cardioversion. A large surface area lead (cathode) was positioned within the esophagus, 45 cm from the nasal orifice. A second large surface area lead (anode) was positioned in the right atrium via the right internal jugular vein without fluoroscopic control. Synchronization of delivery of the shock with the QRS was achieved by means of two cutaneous electrodes positioned on the thoracic wall.**

Results. **Sinus rhythm was restored in 28 patients (93%) with a mean delivered energy of 15.2 ± 7.5 J (range 5-27 J) and a mean impedance of 48.3 ± 5.6 Ohm. No complication occurred during and after the procedure that was well tolerated under sedation.**

Conclusions. **This new technique of performing esophageal LEIC is effective and seems to be safe and well tolerated. In this way internal cardioversion can be performed without fluoroscopy, outside the electrophysiology laboratory.**

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Introduction

Low-energy internal cardioversion (LEIC) is now regarded as a safe and effective method for the restoration of sinus rhythm in patients with atrial fibrillation[1-6]. The procedure is indicated after the failure of conventional external cardioversion or in patients with contraindications to general anesthesia[6].

Despite such significant advantages, the spread of this new methodology in clinical practice has been limited by the need of an electrophysiology laboratory with fluoroscopy and of a specific technical competence for lead positioning, either in the coronary sinus or in the left pulmonary artery, which are both in direct contact with the left atrium, allowing a significant reduction of the atrial defibrillation threshold[4].

We have previously described a new method of performing LEIC positioning a catheter in the esophagus, another anatomical structure in direct contact with the left atrium[7]. Using this approach, LEIC was performed positioning another lead in the right atrium, while a third one placed in the right ventricular apex allowed synchronization of delivery of the shock with the QRS. This new technique of performing LEIC was demonstrated to be effective and safe and allowed us to avoid positioning a lead in the coronary sinus or in the left pulmonary artery, thereby simplifying the procedure, although the use of fluoroscopy and the utilization of the electrophysiology laboratory in the hospital were still necessary. However, in the mentioned study[7], the atrial lead was positioned in the right atrium under echocardiographic control in a significant percentage of patients (40%); fluoroscopy was just subsequently used to confirm the correct position of the lead in the atrium. Such an approach proved to be effective in all cases and a precise lead positioning was achieved in all patients without any kind of

complication. In fact, the straight course of the jugular vein towards the superior vena cava and the right atrium allows a simple approach for lead positioning and does not require any specific skilled maneuvers.

After this experience, we hypothesized that internal cardioversion using the esophagus-right atrium configuration could be performed without the use of fluoroscopy.

Therefore, the aim of the present study was to verify the safety, effectiveness and tolerability of transesophageal cardioversion, performed without fluoroscopy and outside the electrophysiology laboratory, by introducing a second lead in the right atrium via the right internal jugular vein and achieving the synchronization of the delivery of the shock with the QRS by resorting to external cutaneous electrodes.

Methods

Patient selection. The study included 30 consecutive patients with persistent atrial fibrillation. Even those patients who were at their first cardioversion attempt were included in this research protocol. All patients gave their written informed consent. Of the 30 patients, 20 (66%) were resistant to a monophasic direct current shock (200-300-360 J), although they were all receiving an antiarrhythmic drug (14 amiodarone and 6 propafenone).

The diagnosis of atrial fibrillation was based on the surface ECG, with the following criteria: the presence of a fluctuating baseline without regular P or F waves and with totally irregular RR intervals. Thyroid dysfunction had been previously ruled out in all patients. Significant liver disease had been previously excluded in all patients by history, clinical assessment and blood chemistry.

Sixteen patients were on amiodarone, 6 on propafenone, and 8 in therapeutic washout. As a rule, the patients in washout were treated with intravenous propafenone (2 mg/kg) after sinus rhythm restoration. All patients were placed on full dose oral anticoagulation therapy for at least 3 weeks before the procedure. The dose of the anticoagulant was reduced 2 days before the procedure to achieve an INR value approximating 2. Full oral anticoagulation was restarted after cardioversion and was continued for at least 30 days in case of persistence of sinus rhythm. Heparin was contemporaneously administered for the first days and discontinued when therapeutic INR values (2.5-3) were again reached.

Lead position. The procedure was performed outside the electrophysiology laboratory, in the room usually utilized for external cardioversion. No fluoroscopic procedure was used.

Two catheters were used for each patient. One custom-made decapolar large active surface area (520 mm^2) lead (FIAB, Vicchio-FI, Italy) was introduced into the right or left nostril and advanced into the esophagus with the patient's cooperation, to a depth between 40 and 45 cm and until the distal pair of electrodes recorded a large ventricular electrogram and the proximal pairs recorded the fibrillating atrial activity. A second lead with a distal defibrillating coil having a large active surface area (420 mm^2) (Rhythm Technologies, Jackstone Ville, FL, USA) was positioned in the right atrium via the right internal jugular vein without fluoroscopy for a length of about 22-25 cm, in accordance with the results of our previous experience[7]. The correct position of the atrial lead was confirmed by the recording of an atrial signal > 0.5 mV with the pacing-sensing analyzer.

A schematic example of the lead configuration is shown in figure 1.

Cardioversion. The two catheters were connected to a Telectronics 4510 implant support device, combining features of a pacing-sensing system analyzer and those of a cardioverter/defibrillator, provided with a 150 μF capacitor. A truncated, biphasic (3+3 ms) exponential waveform was used. The lead in the esophagus was used as the cathode and that in the right atrium as the anode.

Synchronization of shock delivery with the QRS was achieved by connecting two cutaneous electrodes positioned on the thoracic wall with the Telectronics implant support device utilized for shock delivery. Ap-

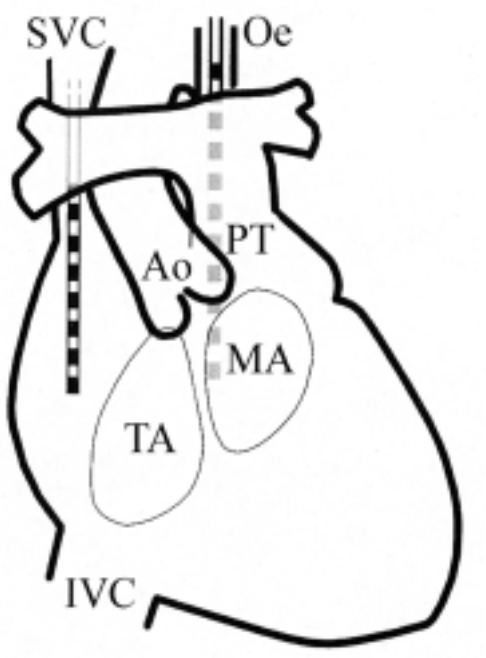

Figure 1. *Schematic representation of the catheter position: a decapolar lead (cathode) is positioned within the esophagus, whereas a second lead with a large active area coil (anode) is introduced through the internal jugular vein into the right atrium. The two leads embrace a large part of the atrial mass, including the septum. Ao = aorta; IVC = inferior vena cava; MA = mitral annulus; Oe = esophagus; PT = pulmonary trunk; SVC = superior vena cava; TA = tricuspid annulus.*

propriate recognition of all QRS complexes was assumed to be present when at least one ventricular signal > 0.5 mV was recorded. In case of a lower signal amplitude, the position of the cutaneous electrodes on the thoracic wall was changed until an adequate signal was found.

Beginning from 200 V, the voltage was progressively increased by 50 V until restoration of sinus rhythm or an energy of 27 J was reached. All shocks were separated by an interval of at least 1 min. The voltage, both the total and delivered energy, and the impedance of each shock were automatically measured by the device. All patients were sedated with diazepam (standard dose 5 mg in 2 min) before shock delivery.

Follow-up. In all patients an ECG was recorded every 6 hours for 3 days after the procedure. After discharge, ECG and physical examination were performed once a week for the first month and once a month thereafter. Patients were asked to come to the hospital for additional check-ups whenever symptoms recurred.

Statistical analysis. Data are presented as mean values ± SD. Differences in continuous variables were analyzed using the paired and unpaired Student's t-test or ANOVA as appropriate, and comparisons between groups were performed using the multiple Bonferroni test. Differences in categorical variables were analyzed using the χ^2 test, with Yates correction if needed. A p value of < 0.05 was considered statistically significant.

Results

The clinical data of the studied patients are reported in table I. Twenty-three patients were men and 7 women, with a mean age of 60.77 ± 7.65 years; the mean body weight was 79.53 ± 13.78 kg; the mean height was 167.00 ± 5.91 cm. The mean duration of atrial fibrillation was 286.50 ± 245.19 days (median 200 days, range 30-1040 days). The mean left atrial size, as measured at echocardiography, was 46.40 ± 4.67 mm (range 38-56 mm).

Table I. Clinical characteristics of patients.

Patient	Sex	Age (years)	Weight (kg)	Height (cm)	AF duration (days)	LA (mm)	Disease	Therapy
LF	F	59	88	167	220	46	Valvular	Amiodarone
PC	F	65	58	168	145	49	Valvular	Washout
LML	F	60	78	156	230	44	CAD	Amiodarone
PG	M	58	72	168	320	46	CAD	Amiodarone
DG	M	70	84	167	280	48	Hypertension	Propafenone
MA	M	66	72	166	120	44	Hypertension	Amiodarone
AA	M	72	80	172	240	40	CAD	Amiodarone
MD	M	48	82	170	280	45	Hypertension	Washout
AA	M	61	88	168	640	46	CAD	Amiodarone
PM	M	60	88	165	720	47	Valvular	Propafenone
AB	M	61	75	172	60	42	DCM	Amiodarone
PL	M	61	92	162	60	45	CAD	Amiodarone
FC	M	66	66	164	180	44	Valvular	Amiodarone
LL	F	57	74	172	120	38	Lone AF	Washout
LA	M	68	70	169	320	56	Valvular	Washout
TZ	M	74	90	170	1040	54	DCM	Amiodarone
SM	M	60	92	178	180	38	Lone AF	Propafenone
VC	M	59	66	154	30	42	Lone AF	Washout
AG	M	66	86	177	60	49	CAD	Amiodarone
AC	M	55	72	168	720	52	Valvular	Propafenone
ZL	M	49	76	172	50	53	DCM	Amiodarone
PM	M	64	88	168	720	48	CAD	Washout
TA	M	72	92	172	360	46	Hypertension	Propafenone
BF	M	67	122	164	120	42	Lone AF	Washout
CV	M	54	98	176	240	54	Hypertension	Amiodarone
ZE	F	45	60	158	90	44	Hypertension	Propafenone
MA	F	61	78	166	190	50	Valvular	Amiodarone
LB	F	54	53	160	320	46	CAD	Amiodarone
MN	M	45	80	162	360	52	CAD	Amiodarone
AI	M	66	66	159	180	42	Lone AF	Washout
Mean		60.77	79.53	167.00	286.50	46.40		
SD		7.65	13.78	5.91	245.19	4.67		
Median		62.5	77	163	200	44		

AF = atrial fibrillation; CAD = coronary artery disease; DCM = dilated cardiomyopathy; LA = left atrium.

The underlying heart diseases were as follows: valvular heart disease (7 patients), hypertension (6 patients), dilated cardiomyopathy (3 patients), and coronary artery disease (9 patients). Five patients had lone atrial fibrillation.

Response to cardioversion. Cardioversion was successfully achieved in 28/30 patients (93%) with a mean of 7.1 ± 2.5 shocks/patient (range 3-11). An example of a successful termination of atrial fibrillation is shown in figure 2.

The intracardiac cardioversion data of the successfully treated patients are reported in table II. The mean energy required for cardioversion was 15.21 ± 7.49 J (range 5-27 J), the mean voltage was 507.14 ± 128.89 V (range 350-700 V) and the mean impedance was 48.286 ± 5.62 Ohm (range 36-62 Ohm). The mean atrial signal amplitude was 1.3 ± 0.8 mV and the mean ventricular signal amplitude was 0.9 ± 0.4 mV. In all the patients a ventricular signal amplitude > 0.5 mV was recorded at the cutaneous electrodes. The mean duration of the procedure was 35.6 ± 7.4 min; of course there was no fluoroscopy time.

Under a light sedation the procedure was tolerated by all the patients and general anesthesia was never requested although offered before the procedure. The mean discomfort score (graded from 0 to 5) of the effective shock was 3.2 ± 0.5.

Safety of the procedure. A total of 221 esophageal shocks were delivered in the 30 patients. All the shocks

Table II. Intracardiac cardioversion data of the successfully treated patients.

Patient	Procedure time (min)	No. shocks	Joule	Volt	Ohm
LF	36	5	9	400	42
PC	38	11	27	700	36
LML	34	5	9	400	54
PG	35	7	14	500	48
DG	34	9	20	600	44
MA	40	9	20	600	50
AA	42	4	7	350	52
MD	38	7	14	500	40
AA	45	11	27	700	42
AB	42	10	24	650	52
PL	38	11	27	700	47
FC	40	5	9	400	48
LL	48	6	11	450	51
LA	30	5	9	400	47
TZ	31	7	14	500	43
SM	35	11	27	700	49
VC	45	9	20	600	45
AG	43	5	9	400	47
ZL	41	11	27	700	48
PM	43	9	24	650	55
TA	38	4	7	350	48
BF	36	4	7	350	62
CV	30	7	14	500	60
ZE	38	5	9	400	48
MA	37	3	5	300	48
LB	35	6	11	450	54
MN	35	7	14	500	44
AI	33	6	11	450	48
Mean	37.86	7.11	15.21	507.14	48.286
SD	4.62	2.54	7.49	128.89	5.62
Median	34.5	5.5	10	425	45

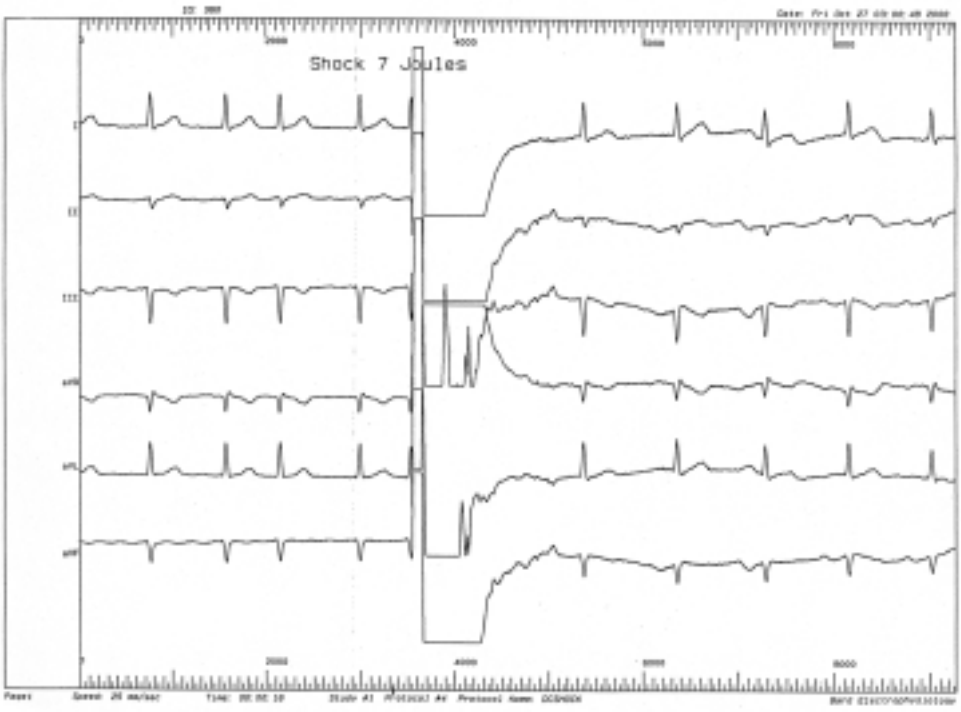

Figure 2. *An example of successful cardioversion obtained with the esophagus-right atrium configuration. A 7 J energy shock, synchronized on the QRS, restores the sinus rhythm.*

were properly synchronized with the QRS complex and no proarrhythmic effect was noted. No symptom related to an eventual esophageal lesion or dysfunction was reported.

Follow-up. The mean follow-up period was 264 ± 84 days (range 92-360 days).

No late symptom possibly related to the shocks in the esophagus was reported by the patients.

Of the 28 cardioverted patients, 14 (50%) had an atrial fibrillation recurrence during the follow-up period. Ten of the 14 recurrences (71%) occurred within the first 2 weeks.

Discussion

Main findings. Transesophageal cardioversion without fluoroscopy and outside the electrophysiology laboratory, using a catheter in the esophagus and a second lead introduced within the right atrium via the right internal jugular vein, was found to be effective in restoring sinus rhythm in 93% of patients with persistent atrial fibrillation. The procedure seems to be safe and very effective.

Indications for low-energy internal cardioversion. Internal cardioversion is indicated for all the patients in whom external cardioversion failed, and should be attempted before considering atrial fibrillation as permanent. The procedure is also indicated for those patients in whom general anesthesia is hazardous, contraindicated or refused.

Despite these indications and despite the fact that the procedure is safe, effective and well tolerated under mild sedation, the spread of internal cardioversion in clinical practice is still limited. There are several reasons which may explain this phenomenon, but the most important is the overall complexity of internal cardioversion. In fact, internal cardioversion performed with the standard technique needs the introduction of a lead in the coronary sinus or in the left pulmonary artery. This requires specific skilled maneuvers. Moreover, an electrophysiology laboratory is available only in a minority of cardiological centers.

The advantages of transesophageal endocardial cardioversion. In a recent study[7] we have demonstrated that a simplified method to perform internal cardioversion is feasible by employing an esophageal lead, thus rendering the positioning of leads in the coronary sinus or in the left pulmonary artery unnecessary. This new approach is safe and effective and has simplified the procedure. However, with this approach the presence of an electrophysiology laboratory and the use of fluoroscopy are still mandatory.

In the present study we have proposed a new method that carries a further reduction in the overall complexity of internal cardioversion and that can be performed outside the electrophysiology laboratory, just by introducing the right atrial lead through the right internal jugular vein, without fluoroscopic control, and avoiding the need of a third catheter in the right ventricle for shock synchronization, which was easily achievable by means of surface electrodes.

Results of transesophageal endocardial cardioversion without fluoroscopy. In this series transesophageal cardioversion without fluoroscopy was found to be effective in restoring sinus rhythm in 93% of patients with persistent atrial fibrillation, with a mean energy similar to that reported for transesophageal cardioversion using fluoroscopy.

It is probable that the achievement of a correct position of the atrial lead (initial introduction of the atrial catheter for 22-25 cm followed, if necessary, by gentle adjustment until an atrial signal < 0.5 mV was recorded by the pacing-sensing analyzer) can account for this good result.

The procedure was found to be safe and well tolerated, as no patient complained of symptoms that could be related to esophageal trauma. Finally, it is possible that the use of one single effective shock (instead of the step-up increasing energy protocol) could further increase the tolerability of the procedure[8].

Study limitations. The role of internal cardioversion has been reduced because of the recent improvement in the success rate of external cardioversion using biphasic shocks[9], higher energy shocks[10] or pretreatment with antiarrhythmic drugs[11]. Nevertheless, the simplification of the procedure may be useful in specific situations allowing one to perform electrical cardioversion in out-patients and outside the electrophysiology laboratory.

If, in daily clinical practice, the success rate of external cardioversion increases, the utility of the technical simplification suggested in this paper, could be reduced; in fact, a small number of internal cardioversions could be performed only by skilled electrophysiologists in specialized centers.

Perspectives and conclusions. Transesophageal cardioversion without fluoroscopy represents, in our opinion, an important progress in the field of internal cardioversion. In fact, during the last years, internal cardioversion has improved thanks to the research aimed at increasing the success rate, safety and the tolerability of the procedure. Nevertheless, only a significant simplification of the procedure, such as that shown in this study, could allow its spread in clinical practice and render internal cardioversion a more competitive technique as compared to external cardioversion that remains all the same the first-choice treatment for the majority of patients with persistent atrial fibrillation.

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