Original articles

Transesophageal electrical cardioversion of persistent atrial fibrillation: a new approach for an old technology

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Key words:
Atrial fibrillation; Cardioversion.

Background. **Low energy intracardiac cardioversion may be considered the elective, alternative method for the acute restoration of sinus rhythm when direct current cardioversion fails or is contraindicated. Transesophageal cardioversion is a further alternative method for the recovery of sinus rhythm and obviates the potential complications of the low energy intracardiac cardioversion venous approach.**

Methods. **The present prospective study including 30 patients (21 males, 9 females, mean age 65.1 years, range 52-76 years), with persistent atrial fibrillation (mean duration 4.3 months), was undertaken in order to further evaluate, with regard to transesophageal cardioversion: 1) the acute efficacy, 2) the patient acceptance of the procedure, 3) the preferable choice among direct current cardioversion, low energy intracardiac cardioversion and transesophageal cardioversion, 4) the time required to perform the procedure, 5) the incidence of complications, and 6) the persistence of sinus rhythm after 1 month.**

Results. **Sinus rhythm was acutely restored in 29 patients (96.7%). Discomfort induced by the electrical shock was minimal or mild in most patients (75.8%). Transesophageal cardioversion was usually preferred by patients who had been previously submitted to direct current cardioversion or low energy intracardiac cardioversion. The mean total time required to perform the procedure was 107.9 min. No complications related to the procedure occurred. In spite of adequate pharmacological prophylaxis of atrial fibrillation only 41.4% of patients were in sinus rhythm 1 month after successful transesophageal cardioversion.**

Conclusions. **Transesophageal cardioversion may be considered a very effective, well accepted and non-time consuming procedure for the short-term restoration of sinus rhythm. The incidence of complications is low.**

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Introduction

Atrial fibrillation is a widespread arrhythmia, rarely life-threatening but often significantly compromising the patient's quality of life. In fact, the clinical implications including stroke, angina, heart failure and cardiomyopathies are relevant. The management of patients with atrial fibrillation often involves attempts to restore sinus rhythm. This can be frequently achieved pharmacologically. Unfortunately, this approach is sometimes ineffective or contraindicated for clinical reasons. External direct current cardioversion (DCC) is the alternative method most frequently used to restore sinus rhythm. The procedure has been recognized as safe and effective, particularly when a biphasic shock is delivered[1,2]. Non-randomized studies report variable success rates, but the estimated average is around 80% when monophasic shock is utilized and over 90% when the biphasic waveform is used. When DCC fails and restoration of sinus rhythm is strongly indicated on clinical grounds, low energy intracardiac cardioversion (LEIC) may be attempted[3-6]. This procedure was introduced a few years ago for the treatment of both acute and chronic atrial fibrillation[7-18]. The efficacy of this technique in restoring sinus rhythm is estimated to range between 95 to 100% of cases. On the other hand, the need of a transvenous approach to introduce the defibrillator electrodes implies the risk of bleeding or of hematoma formation at the site of puncture of the blood vessel. Such events are favored by mandatory anticoagulation. Venous or cardiac trauma is also possible. Finally, the procedure is expensive. The transesophageal electrical cardioversion (TEC) is an alternative method for the restoration of sinus rhythm and obviates the potential

complications of the venous approach employed in LEIC when DCC fails or is contraindicated. The purpose of the present prospective study is therefore to establish the efficacy of this method in comparison to LEIC and to evaluate: 1) its efficacy in acutely restoring sinus rhythm; 2) the acceptance of the procedure by patients with mild sedation only, thus avoiding general anesthesia; 3) the preferable choice among DCC, LEIC and TEC; 4) the time required to perform TEC in comparison to LEIC; 5) the incidence of complications; and 6) the persistence of sinus rhythm after 1 month.

Methods

Our study group consisted of 30 consecutive patients (21 males, 9 females, mean age 65.1 years, range 52-76 years) who underwent TEC for persistent atrial fibrillation (mean duration 4.3 months, range 1-24 months) from December 2000 to December 2001.

Thirteen patients had systemic hypertension, 3 ischemic heart disease, 1 dilated cardiomyopathy, 6 mitral valve disease, 1 hypothyroidism whereas 6 had no other signs of cardiac pathology except for atrial fibrillation (lone atrial fibrillation, Table I). Only patients meeting the following criteria were enrolled: 1) atrial fibrillation lasting at least 1 month as documented at 12-lead ECG; 2) written informed consent to TEC as the preferred choice or as an alternative procedure to conventional external cardioversion or LEIC. In order to avoid uncertainties and bias in the interpretation of the results, all antiarrhythmic drugs were stopped.

Patients were instructed to suspend oral therapy (antiarrhythmics, digitalis, or beta-blockers) at least 48 hours before the procedure. Thirteen patients were allowed to continue with oral amiodarone therapy.

Each patient had to be correctly anticoagulated with INR values ranging between 2 and 3 for at least 1 month before the procedure. In no case was anticoagulant therapy stopped before the procedure.

The TEC procedure consists of a few sequential steps. An Esoflex 10 nasal lead (FIAB, Vicchio-FI, Italy) which is a newly designed decapolar esophageal polyurethane catheter (diameter 7F, 2.3 mm; stainless steel electrodes with an interelectrode distance of 20 mm between the two distal electrodes and of 10 mm between the other electrodes, for a 5.7 cm^2 total electrode area; depth markers at different distances) with a non-traumatic silicone 7.3 mm tip, was indifferently inserted via the right or left nostril and pushed down. To facilitate the introduction and the sliding down of the catheter, its tip was first manually gently curved and then a lubricant anesthetic cream was applied over the distal part. The patient was maintained in a sitting position with his head slightly bent forward. He was instructed to swallow a sip of water while the catheter was being pushed down so as to avoid that it slides into the trachea. A quick radioscopic control was then performed to check that catheter was correctly positioned inside the esophagus against the left atrial curve just superior to the diaphragmatic silhouette. A precordial adhesive patch electrode was placed on the anterior chest wall over the inferior part of the breastbone (Fig. 1). The Physiocontrol Lifepack 12 defibrillator support device was used allowing selection of designated energy levels with biphasic truncated exponential asymmetric waveforms and ranging from 2 to 360 J. The shocks were delivered between the esophageal electrodes as cathode and the precordial patch as anode according to the following programmed increasing energy sequence: 20, 50, 70 and 100 J. The procedure was stopped as soon as sinus rhythm or the maximal programmed energy was reached. The decision to start the protocol with a set energy of 20 J was taken on the basis of a previous experience with the same method[19]. In that paper efficacious cardioversion was obtained with a mean energy of 50.6 ± 34 J.

The total duration of the procedure was calculated from the time of admission of the patient to the electrophysiologic laboratory to the time when he was discharged from hospital. We also calculated the following times: 1) from the admission of the patient to the electrophysiologic laboratory to the time when the esophageal

Table I. Underlying heart disease.

	No.
Systemic hypertension	13
Ischemic heart disease	3
Dilated cardiomyopathy	1
Mitral valve disease	6
No heart disease	7

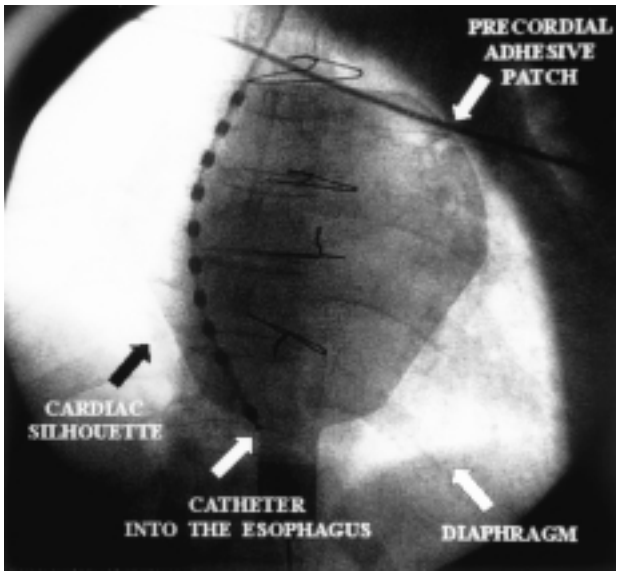

Figure 1. *Radioscopic view of the transesophageal catheter into the esophagus.*

catheter was considered to have been correctly positioned, 2) the time from the correct positioning of catheter to the last shock, 3) the time from the moment of delivery of the last shock to discharge from hospital.

The fluoroscopic time necessary to check the proper position of the catheter was not calculated because it was in the order of a few seconds.

The same cardiologist with adequate electrophysiological expertise and with the support of trained registered nurses performed all procedures.

When necessary, mild sedation with diazepam (3-5 mg i.v.) was administered at the beginning of the procedure, before the insertion of the catheter; depending on the patient's anxiety and on his acceptance of the procedure this drug was or was not re-administered. Five minutes prior to the first shock, each patient received propafenone (1.5 mg/kg i.v.) when not contraindicated. As soon as sinus rhythm was restored an i.v. infusion with a fixed dose of 70 mg of propafenone was started and completed in 1 hour. Propafenone treatment was used to prevent the early recurrence of atrial fibrillation.

In order to determine the serum levels of potassium and the INR, each patient had a blood sample taken and analyzed before the procedure. In 8 consecutive patients, the serum levels of troponin I and of creatine phosphokinase (CPK)-MB were determined before and 4, 8 and 12 hours after the procedure.

The ECG was monitored until the patient was discharged. At that time, the patient underwent a final standard 12-lead ECG.

Furthermore, before discharge, the patient was asked to describe his level of discomfort caused by the intraesophageal shock using a four grade scale: grade 1 minimal or no discomfort, grade 2 mild, grade 3 moderate, grade 4 severe discomfort. The level of discomfort was graded at the time of discharge so as to avoid any bias related to the sedation itself at the end of the procedure.

Patients who had been previously submitted to DCC (14 patients), LEIC (1 patient) or both (3 patients) were also asked to indicate the procedure of preference.

Statistical analysis. Data were analyzed by two-way analysis of variance. The factorial component "sample" is fixed while the "subject" is a random factor. The interaction of the two factors was considered to be the estimated error of the model. The null hypothesis was tested using the Fisher F test for variance. The variability was also expressed as the SD and percentage of the mean. When necessary, data were also analyzed using the χ^2 test.

Results

A successful cardioversion was achieved in 29 patients (96.7%). The mean number of shocks delivered to each patient was 1.8 (range 1 to 4). Sinus rhythm was restored at the first attempt with a set energy of 20 J in 11 patients (36.7%), in 15 patients (50%) at the second attempt with a set energy of 50 J, and in 3 patients (10%) at the third attempt with a set energy of 70 J. In 1 patient (3.3%), in spite of a fourth attempt at 100 J, sinus rhythm was not restored. The mean energy required was 64.3 J (range 20-100 J).

In no case did ventricular arrhythmias occur. The maximum asystolic pause after shock delivery and before the restoration of sinus rhythm was 1.7 s.

The mean dose of diazepam used during the procedure was 7 mg (range 5-10 mg).

The mean length of time elapsing from the admission of the patient to the electrophysiologic laboratory to electrode positioning was 22.7 min (range 15-45 min); that between the achievement of the correct position of the catheter to the last shock was 14.7 min (range 5-25 min). The time elapsing between the last shock to discharge from the hospital (72.5 min; ranging from 40 to 130 min) and that necessary to complete the whole procedure (107.9 min; ranging from 75 to 180 min) were calculated in 22 patients only. In fact, for the other 8 patients, hospital discharge was delayed because of serial blood sampling reasons only.

The patients were asked to report their level of discomfort during delivery of the intraesophageal shock/s. Among the patients in whom sinus rhythm was achieved at the first attempt, 3 reported minimal discomfort, 7 mild, none moderate, and none severe discomfort. Among the patients receiving more than one shock, 6 reported minimal discomfort, 6 mild, 4 moderate, and 3 complained of severe discomfort. For 1 patient this information was not available.

The level of discomfort did not statistically differ between patients who were or were not on amiodarone therapy.

Fourteen patients who had been previously submitted to DCC were asked to indicate a preference between the two procedures: 11 preferred TEC, 1 DCC, and 1 had no preferences; this information was not available for 1 patient. The patient who had been previously submitted to LEIC only, manifested his preference for TEC. Among the 3 patients who had been submitted to all three procedures, 2 reported that they tolerated TEC better and one that he preferred DCC.

No major complications were observed; it was possible to introduce the lead in all patients although some difficulty was encountered in the presence of a deviated nasal septum or polyposis (5 patients). In 2 cases, mild nasal bleeding was induced but did not necessitate any clinical interventions. No symptoms possibly related to local damage of the esophageal mucosa (pain, swallowing, etc.) were referred after the shock or during follow-up. However, endoscopic evaluation was not included in our protocol.

The serum levels of potassium and the INR were within the required range in all patients. The serum levels of troponin I and of CPK-MB were not significantly modified during the follow-up (Tables II and III).

Table II. Troponin I and creatine phosphokinase (CPK)-MB values of the four samples.

	1	2	3	4	p
Troponin I	0.046 ± 0.033	0.045 ± 0.031	0.053 ± 0.044	0.048 ± 0.039	NS
CPK-MB	1.85 ± 1.04	1.86 ± 0.88	2.00 ± 1.14	1.69 ± 0.73	NS

Table III. Results of the two-way analysis of variance.

	Mean ± SD	% of the mean	p
Troponin I			
Subject	0.048 ± 0.035	73	< 0.001
Sample	0.048 ± 0.003	6.8	NS
Error	0.014		
CPK-MB			
Subject	1.85 ± 0.85	46	< 0.001
Sample	1.85 ± 0.13	6.9	NS
Error	0.52		

CPK = creatine phosphokinase.

Clinical follow-up gave the following results: at 1 month, 17 patients (58.6%) had recurrence of atrial fibrillation in spite of adequate pharmacological treatment with amiodarone (200 mg daily in 6 patients) or propafenone (mean dose of 640 mg daily in 8 patients) or flecainide (mean dose of 175 mg daily in 2 patients). Among these 17 patients one presented with early recurrence after 10 sinus beats and 12 presented with atrial fibrillation 7 days after the procedure.

The patients on chronic amiodarone therapy required a mean energy dose of 69.2 J to restore sinus rhythm, in comparison to the 50.6 J necessary for those patients who were not on amiodarone (p = NS).

The patient in whom sinus rhythm was not achieved and the one who presented with early recurrence of atrial fibrillation were not on chronic amiodarone.

Discussion

Since its introduction in 1962 DCC has become the first choice approach in the treatment of atrial fibrillation in emergency or elective cases, when pharmacological cardioversion is not indicated or has failed to restore sinus rhythm. LEIC has been introduced a few years ago into clinical practice and permits restoration of normal sinus rhythm in difficult cases when neither pharmacological nor external cardioversion have been successful. LEIC is generally well accepted by the patients[16-18,20].

TEC of atrial arrhythmias was introduced into clinical practice in 1966[21]. Other authors have since then occasionally used this technique to treat either atrial or, in animals, ventricular tachyarrhythmias[22-25]. In spite of these sporadic reports, the technique has not yet gained widespread acceptance. This is probably due to the lack of suitable esophageal electrode systems and to the necessity of high energy levels to achieve cardioversion. Such energy levels are not well tolerated by the patients; therefore general anesthesia was required.

Two different approaches to the esophageal cardioversion of atrial sustained arrhythmias have more recently been introduced:

• a "hybrid" intracardiac-extracardiac technique in which a large surface area lead (cathode) is introduced into the esophagus through the nasal orifice and a second large surface area lead (anode) positioned transvenously within the right atrium. A third quadripolar lead may also be positioned within the right ventricular apex for ventricular synchronization and back-up pacing[26];

• an esophageal-precordial technique in which electric energy is applied between the electrodes of an esophageal catheter (cathode) and a paddle or a precordial adhesive patch electrode (anode)[19,22]. This last technique was introduced in our Institution in order to establish the efficacy, feasibility and cost-effectiveness of TEC in comparison to LEIC.

In our experience, even if LEIC was highly effective (97.6% of cases) in acutely restoring normal sinus rhythm in persistent atrial fibrillation[27], complications are generally of slight clinical significance but are sometimes potentially relevant (atrioventricular fistula, hematoma, etc.). Moreover, LEIC must be performed by a skilled electrophysiologist and necessitates the availability of a catheterization room. Another important aspect is the significant cost of LEIC. In our experience, the mean cost of just three catheters is around 1110 vs 885 Euro for the TEC catheter and patch. The single catheter LEIC technique is not less expensive.

For these reasons we decided to attempt a different low-risk and cost-effective approach in the hope that its efficacy would be similar to that of LEIC. The time necessary to perform the procedure was also less than that employed during DCC.

In our group of patients with persistent atrial fibrillation lasting > 1 month, the acute cardioversion of atrial fibrillation was achieved in 96.7% of cases. In about 36.7% of the patients, a single shock was sufficient for restoration of a normal sinus rhythm; in 50% of cases, two shocks were required. Most of the patients (75.8%) accepted the procedure without major subjective complaints and described the discomfort caused by the electrical shock as minimal or mild. Most patients who had been previously submitted to LEIC or DCC or both clearly showed a preference for TEC. This, for different reasons, including its effectiveness, their fear of gener-

al anesthesia, the length of hospitalization, the fear of inguinal puncture and of possible hemorrhage or hematoma formation and, finally, the necessity of temporarily limited exercise after the procedure. Interestingly, almost every patient who felt more discomfort during the transesophageal shock as compared to the intracardiac one, would still prefer TEC if it were necessary to repeat the electric cardioversion.

Even though we performed TEC in the catheterization room, we feel this is not absolutely mandatory since the procedure is feasible in any other adequate environment. The proper position of the catheter in the esophagus can also be established by means of esophageal electrocardiograms[19]. However, in our experience, this technique may be misleading owing to the emission of similar electric signals from different levels of the esophagus. The assessment of the correct position by calculating the distance from the teeth to the gastroesophageal junction (average 40-45 cm) could be more useful even if sometimes insufficient owing to the different chest dimensions or because the catheter tip can become abnormally curved during introduction. In our opinion, a quick check of the catheter position by X-rays renders the procedure less time consuming. Another important aspect to be considered is the possibility of performing TEC with mild sedation only (mean 7 mg i.v. of diazepam). This is in disagreement with other authors who prefer to perform the procedure in general anesthesia or with the patient deeply sedated[19,22] but in agreement with others[26]. We believe that an adequate psychological preparation and relational behavior before and after the shock/s can help to make the procedure more acceptable to patients. We decided to start with a 20 J shock so as to try to reduce the number of shocks and render the procedure more tolerable. This study seems to suggest that to start with a 50 J shock could be a better choice if the best results in the restoration of sinus rhythm in patients with atrial fibrillation lasting > 1 month are to be achieved. Chronic amiodarone therapy did not significantly increase the defibrillation threshold in our series; at any rate, the aims of this study did not include the specific analysis of the cardioversion thresholds with different drugs.

No patient complained of any symptoms possibly related to damage of the esophageal mucosa. This is in agreement with the results of Santini et al.[26] who systematically performed endoscopy in all their patients after the transesophageal shock. Their study showed that damage of the esophageal mucosa is rare and heals spontaneously not requiring any specific therapeutic intervention. This was also reported by McKeown et al.[22] in patients who were submitted to repeated 100 J shocks. Lukoseviciute and Peculiene[25] reported no adverse effects despite the administration of shocks equivalent to delivered energies in excess of 300 J. McKeown et al.[22] encountered esophageal mucosal injury in 1 of 5 patients who received a transesophageal shock of 200 J.

In our experience, no significant asystolic pause occurred after the shock/s. However, the esophageal lead we used allows atrial pacing in case of sinus arrest. In our previous experience with LEIC[20], ventricular pacing at a programmed rate of 40 b/min was required in 9 of 41 patients because of asystolic pauses due to complete heart block in 3 cases and to sinus pauses in 6. In 1 case, the asystolic pause due to complete heart block, lasted 51 s. Our results with TEC seem to suggest that this procedure could interfere less with sinus node activation or with atrioventricular node conduction.

After TEC, the troponin I and CPK-MB serum levels were not significantly modified. This suggests that no relevant myocardial cell damage had occurred.

The patients were discharged < 2 hours after the procedure. The total duration of the procedure is significantly shorter than that we observed in our previous experience with LEIC[20] in which the mean time necessary to complete the whole procedure was 40.1 min followed by 4-6 hours of patient monitoring. Another potential advantage of TEC in comparison to LEIC is the easier management of the patients with an undesirably elevated INR at the time of the procedure. In fact, an increased INR could sometimes increase the risks of LEIC and thus prompt postponement of the procedure, with obvious disappointment of the patient. A further advantage of the procedure could be its use in paroxysmal or persistent atrial fibrillation refractory to drugs or DCC in patients in whom a permanent cardiac pacemaker had been recently implanted. In such cases, LEIC is not recommendable owing to the high risk of displacement of the endocardial leads. TEC can also be useful during electrophysiological evaluation or radiofrequency transcatheter ablation procedures, to overcome undesirable anesthesia (required by DCC) or to avoid further intracardiac catheter manipulation (LEIC).

At our Institution, DCC is still more time consuming than LEIC due to the need of general anesthesia and longer patient monitoring before discharge. In 33 consecutive patients the mean total procedure time calculated for DCC between admission and discharge was 9.08 hours.

We believe that the esophageal-precordial approach we are presently reporting could be less invasive than that suggested by Santini et al.[26] in which two further endocardial leads are required with potential venipuncture- and intracardiac-catheter-positioning-related problems. Furthermore, the totally non-invasive technique we have used allowed us to achieve cardioversion with shock energies and doses of diazepam similar to those used by Santini et al. Finally, in our study, the fluoroscopic time was in the range of a few seconds, in comparison to the 4 min reported in the study by Santini et al. and to the 7.3 min in our previous report on LEIC.

In conclusion, the results of our study confirm that TEC is a safe and very effective procedure for the acute restoration of sinus rhythm in patients with persistent

atrial fibrillation lasting > 1 month. The percentage of successful cardioversions is almost the same as that reported for LEIC. The discomfort induced by the shock/s was described as minimal or mild by most patients who seemed to prefer TEC when they had been previously submitted to LEIC or DCC. In comparison to LEIC and, at our Institution, even to DCC, TEC is a time saving procedure. The complication rate is negligible while the cost of the electrodes is significantly lower than that of those used in LEIC. The high recurrence of atrial fibrillation at 1 month after TEC is similar to that observed following DCC or LEIC.

Moreover, we feel that the present approach should be considered as a first choice in the cardioversion strategies of atrial fibrillation when DCC fails or is not recommended.

However our study was not randomized and a control group was not available; the interpretation of the results can also be difficult because the dimensions of the left atrium were not available. In fact, the dimensions of the left atrium could be useful for a better understanding of the results.

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