THE AMERICAN JOURNAL OF THE MEDICAL SCIENCES

SEPTEMBER, 1963

ORIGINAL ARTICLES

CARDIOVERSION OF ECTOPIC TACHYCARDIAS*

By Bernard Lown, M.D.
ASSISTANT PROFESSOR OF MEDICINE, DEPARTMENT OF NUTRITION
HARVARD SCHOOL OF PUBLIC HEALTH
ASSOCIATE IN MEDICINE, PETER BENT BRIGHAM HOSPITAL

Sami Kaid Bey, M.D.
RESEARCH TRAINING FELLOW, DEPARTMENT OF NUTRITION
HARVARD SCHOOL OF PUBLIC HEALTH

Mark G. Perlroth, M.D.
NATIONAL HEART INSTITUTE RESEARCH FELLOW IN CARDIOVASCULAR LABORATORY
DEPARTMENT OF NUTRITION, HARVARD SCHOOL OF PUBLIC HEALTH

AND

Tadaaki Abe, M.D., Ph.D.
RESEARCH FELLOW, MASSACHUSETTS HEART ASSOCIATION

(From the Department of Nutrition, Harvard School of Public Health and the Peter Bent Brigham Hospital, Boston, Massachusetts)

Cardiac arrhythmias are usually terminated by means of drugs. Treatment has remained essentially unaltered for the past 45 years since the introduction of quinidine by Frey[1]. Recently a new method was described which no longer depends on drugs (Lown, Amarasingham and Neuman[4,5]). This method, designated as "Cardioversion" has been based on 3 findings: 1) the majority of sustained ectopic tachycardias in man can be terminated by transient depolarization of the entire heart; 2) depolarization of the heart can be effectively accomplished across the intact chest by brief direct current (DC) electrical discharge; 3) there is a brief interval within each cardiac cycle when the heart is susceptible to ventricular fibrillation (King[2], Lefemine *et al.*[3]). This vulnerable period of 20 to 30 milliseconds coincides with the apex of the T wave of the surface electrocardiogram (Lown *et al.*[6]). Synchronization of DC shocks to avoid this period, protects against ventricular fibrillation, a major hazard in the use of electrical discharge.

*Presented before the Association of American Physicians, May 1, 1963, at Atlantic City, New Jersey.

Supported by grants in aid from the John A. Hartford Memorial Fund; Nutrition Foundation, New York City; the Fund for Research and Teaching, Department of Nutrition, Harvard School of Public Health.

The present report summarizes the initial experience in the use of cardioversion at the Peter Bent Brigham Hospital.

Material and Methods. The method of cardioversion was employed to treat 148 episodes of arrhythmia in 114 patients. The abnormal mechanisms treated up to April 15, 1963, are presented in Table 1. Atrial fibrillation constituted 69.6% of the arrhythmias. A number of patients had recurrences and were therefore treated several times. One patient with paroxysmal ventricular tachycardia refractory to drugs, was reverted 12 times in the course of 2 years.

TABLE 1.—CLINICAL EXPERIENCE WITH CARDIOVERSION

	Patients	*Episodes*
Ventricular Tachycardia	11	25
Atrial Fibrillation	85	103
Atrial Flutter	15	15
Supraventricular Tachycardia	3	5
	114	148

The procedure followed was similar for all reversions. In patients with atrial fibrillation, maintenance quinidine therapy (0.3 gm. orally every 6 hours) was started on the previous day. One hour before the procedure the patient received 100 mg. of pentobarbital sodium. Reversions were accomplished in the surgical recovery room. Intravenous sodium thiopental was employed for inducing transient anesthesia. Muscle relaxant drugs were not used. Anticoagulant drugs were given for 2 to 3 weeks prior to reversion to those patients who suffered previous embolism and to those with mitral stenosis.

The instrument employed has been arbitrarily designated as a "cardioverter"* and consisted of 4 electronic components:

1) A DC defibrillator which delivers a single monophasic pulse of 2.5 milliseconds duration with sufficient energy to depolarize the heart within the thoracic cage. It is calibrated in energy units ranging from 0 to 400 watt seconds.
2) A synchronizer to permit discharge of the electrical pulse in any preselected phase of the cardiac cycle which is employed to avoid the vulnerable period.
3) A cardiometer to monitor the patients electrocardiogram and provide an R wave as a reference for the synchronizer.
4) A cardioscope for continuous display of cardiac activity.

The cardiometer is connected to the patient by means of two monitoring leads which are attached to the right arm and left leg and a neutral ground lead which is connected to the right leg. The electrical discharge is applied by means of heavily insulated electrode paddles. These are covered with thick layers of conductive paste and applied to the chest wall. One electrode is positioned in the right pectoral area immediately adjoining the sternum at the level of the third intercostal space while the other is positioned in the left mid-axillary line at the level of the 5th intercostal space. Before each reversion, the electronic synchronizer is preset to deliver the discharge in the terminal portion of the QRS complex. The accuracy of synchronization is checked several times before application of the actual shock to the patient. A single twitch of thoracic muscle signals the passage of current. In case of failure to revert, the energy of successive discharges is progressively increased from 50 watt seconds up to a discharge level of 400 watt seconds. The patient is awake within 2 to 5 minutes. The entire procedure from the time of arrival in the recovery area to completion of cardioversion generally consumes 20 to 30 minutes.

Results. VENTRICULAR TACHYCARDIA. All 25 episodes of ventricular tachycardia were successfully reverted. A typical example is shown in Fig. 1. The duration of arrhythmia in this group of patients ranged from 1 to 33 days. Four of the 11 patients were in the early stages of acute myocardial infarction. In 7 patients antiarrhythmic drugs failed although employed in massive and frequently toxic doses. Cardioversion resulted in no immediate or late untoward effects. Serum glutamic-oxalacetic transaminase and lactic dehydrogenase levels showed no post-treatment deviation from control. Restoration of effective cardiac action characterized by a rise in blood pressure and return of compensation was apparent immediately upon reversion to normal sinus rhythm. Patients with recurrent ventricular tachycardia who previously required weeks of hospital-

*The one used in the present study is available from the American Optical Company, Buffalo, New York as the Lown Cardioverter.

ization were now controlled on an outpatient basis.

ATRIAL FIBRILLATION. The clinical background of the 103 episodes of atrial fibrillation in the 85 patients is illustrated in Table 2. All but 16 had rheumatic valvular disease. They ranged in age from 32 to 77 years. The mean duration of atrial fibrillation for the entire group was 2.6 years. It was somewhat longer for those with mitral stenosis. Twenty-two of 80 patients on whom data is available had been in

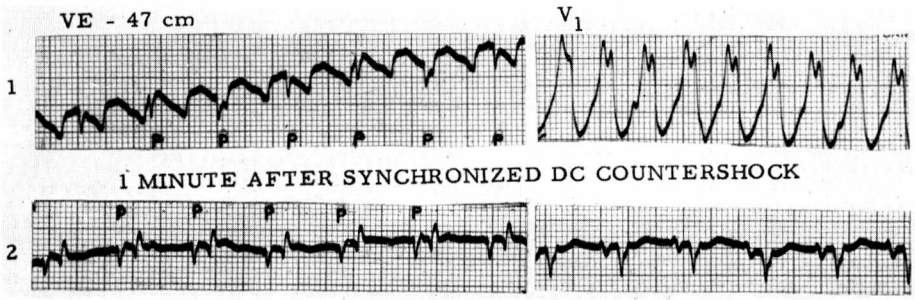

Fig. 1.—Ventricular tachycardia of 17 days' duration in a 32-year-old man refractory to all drugs. Patient in shock, pulmonary edema and appearing moribund before cardioversion. Esophageal and V1 leads are compared immediately before and one minute after restoration of sinus rhythm.

continuous fibrillation in excess of 5 years. The longest duration of documented arrhythmia was 30 years. Attempts at quinidine reversion were carried out in 38 patients. The refractoriness of the arrhythmia is indicated by the fact that only 6 of the 38 or 15.8% were transiently reverted with quinidine. In 3 patients severe toxic reactions resulted before full therapeutic doses were reached.

TABLE 2.—CLINICAL BACKGROUND OF 85 PATIENTS WITH ATRIAL FIBRILLATION

Etiology of Heart Disease	
Mitral Stenosis	31
Mitral Regurgitation	16
Mixed Lesions	22
Nonrheumatic	16
Duration of Atrial Fibrillation (80)	
Up to 1 year	33
1 to 5 years	25
5 to 10 years	14
Over 10 years	8
Quinidine	
Attempts	38
Success	6
Idiosyncrasy	3

Sinus rhythm was restored in 94 of the 103 episodes of atrial fibrillation (91%). One example is illustrated in Fig. 2. The electrical discharge is delivered within the terminal portion of the QRS complex. There then follows a brief electrical artefact lasting from 2 to 4 seconds. The resumption of sinus rhythm may be preceded by several ectopic atrial or nodal premature beats. The electrically quiescent period immediately following the cardioversion shock is not associated with cardiac standstill. This is illustrated in Fig. 3 where both systemic pressure and electrocardiographic activity during the reversion were monitored. Delivery of a DC discharge within the QRS complex like a ventricular extrasystole produces a compensatory pause.

In 7 patients reversion could not be accomplished by this method. In 2 other patients reversion was not possible when attempted at the completion of a mitral valve operation, however, both were successfully treated later in the postoperative period. Thus 9 of 103 episodes of atrial fibrillation could not be restored to sinus rhythm,

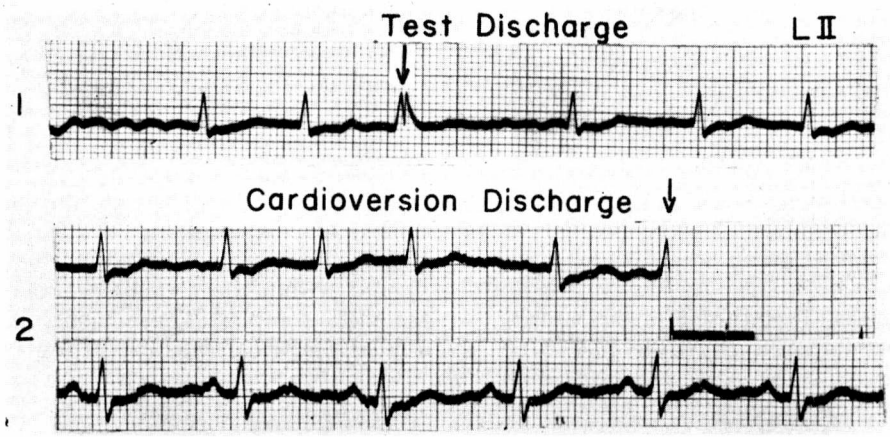

Fig. 2.—Atrial fibrillation reverted with a single DC discharge. In strip 1, the synchronizer is tested, the electrical shock falls within the QRS complex. The actual reversion discharge occurs in exactly the same point within the cardiac cycle.

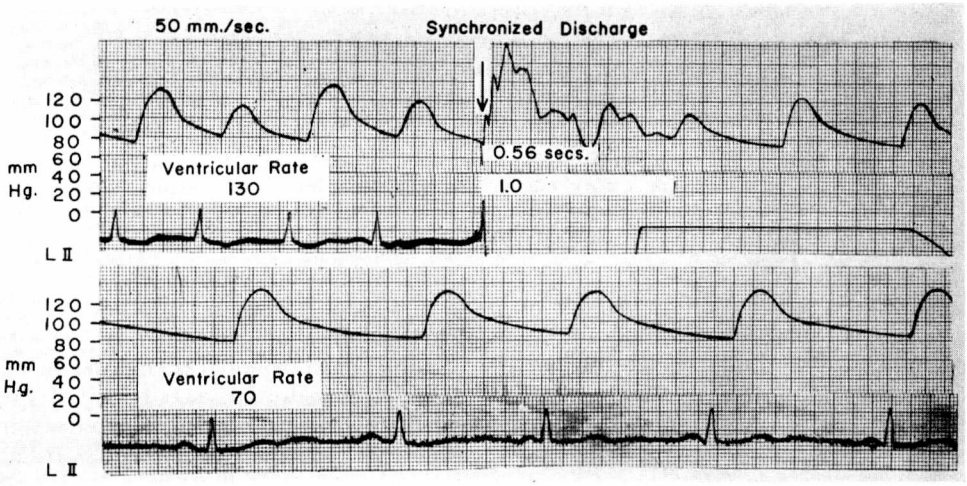

Fig. 3.—Simultaneous arterial pressure and electrocardiographic monitoring during reversion to sinus rhythm of an episode of atrial fibrillation. While the electrocardiogram reveals no activity immediately after the shock, a pressure pulse is evident within 0.56 second. Note the disappearance of mechanical alternation immediately after restoration of sinus rhythm as well as the marked reduction in ventricular rate.

an incidence of failure of 9%. Some clinical characteristics of the unsuccessfully treated group are presented in Table 3. Of note was the high incidence of mitral regurgitation, the long duration of continuous fibrillation, and the fact that in the majority reversion was carried out at the completion of mitral valvular operation.

There were no immediate complications ascribable to cardioversion. Atrial premature beats were noted in half the patients. These generally abated within one minute. Transient nodal rhythm lasting about 30 seconds was noted in less than 10% of reversions. In 6, AV dissociation with sinus bradycardia and periodic nodal capture was noted. A

TABLE 3.—CARDIOVERSION FAILURES IN 7 OF 85 PATIENTS WITH ATRIAL FIBRILLATION

Mitral Regurgitation	6
During Valvular Operation	5
Two Valvular Operations	3
Mean Duration of Arrhythmia	10.8 years

single late complication consisting of a splenic embolus occurred 48 hours after reversion. This was in a patient with mitral stenosis who had not been receiving anticoagulant drugs.

rhythm, but it in no way facilitates the maintenance of a normal sinus mechanism.

ATRIAL FLUTTER. Only those patients with atrial flutter, who exhibited resistance to reversion with the usual therapeutic doses of either digitalis or quinidine were treated. All of the 15 patients were easily restored to normal sinus rhythm by means of the cardioverter. A typical example is illustrated in Fig. 4.

SUPRAVENTRICULAR TACHYCARDIA. Only

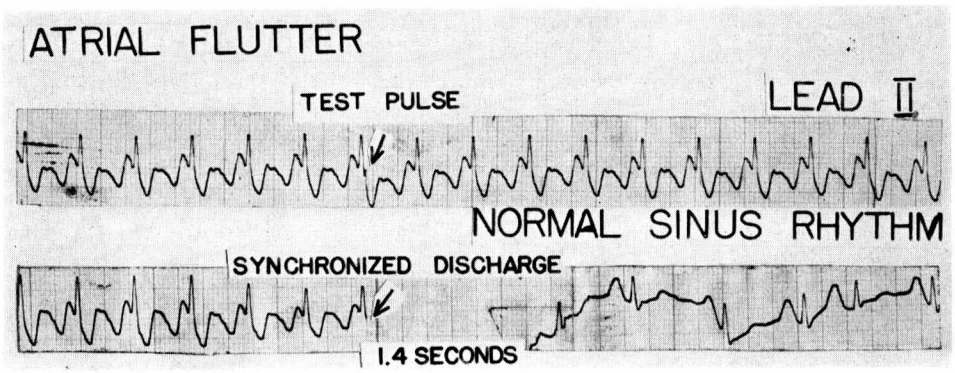

Fig. 4.—Atrial flutter resistant to drugs, reverted to sinus rhythm by means of cardioversion. Note test and discharge shocks fall within the same point of the QRS complex

The ease of electrical reversion in no way assured maintenance of sinus rhythm. Recurrence of atrial fibrillation was common notwithstanding prophylactic doses of quinidine. Resumption of atrial fibrillation generally followed if reversion was carried out at the close of a mitral valve operation and in the presence of significant mitral regurgitation. Atrial fibrillation was also favored in those patients who demonstrated frequent atrial premature beats, especially if they occurred in showers or persisted for a minute after reversion. The presence of a prolonged PR interval with a duration in excess of 0.24 second or the patients' inability to tolerate a daily dose of 1.2 gm. of quinidine were also unfavorable signs. Cardioversion is the most effective method yet devised for restoring sinus

5 episodes of supraventricular tachycardia were treated. These occurred in patients who were refractory to vagal maneuvers and digitalis drugs. All 5 episodes were instantly reverted with cardioversion. One example illustrating the entire process is shown in Fig. 5. In this particular patient the nature of the mechanism was uncertain. It was surmised to be ventricular tachycardia. Upon restoration of sinus rhythm it was evident that the arrhythmia was due to a combination of nodal and atrial tachycardia with dissociation.

The results in the 148 episodes of ectopic arrhythmias are summarized in Table 4. The only failures were encountered among the patients with atrial fibrillation who had multivalvular disease or significant degrees of mitral valve regurgitation. All of the 31 pa-

tients with predominant mitral stenosis were successfully reverted. These results attest to the high degree of effectiveness of cardioversion in depolarizing the heart and permitting resumption of sinus rhythm. This procedure is furthermore associated with little hazard to the patient. In this experience, 352 electrical discharges were employed yet there was not a single episode of ventricular fibrillation, ventricular tachycardia or cardiac standstill. Though a number of patients treated were in a critical state, there was not a single death during or immediately following this procedure.

Discussion. The use of drugs for terminating chronic ectopic disorders of rhythm has a number of disadvantages. The effective dose in any one patient cannot be predicted. A time-consuming titration, requiring incremental doses at frequent intervals, is the only safe method. Days and even weeks are at times necessary to achieve reversion. There is therefore need of intensive patient observation and frequent electrocardiographic monitoring. The three most effective drugs used for this purpose are the digitalis glycosides, quinidine and procaine amide. These drugs frequently induce serious toxic reactions. Furthermore, they are not always effective even when given in large doses. Thus when every patient with atrial fibrillation was treated irrespective of the clinical findings, the reported rate of success was 47% (Rokseth and Storstein[7]). The incidence of reversion was still less when the arrhythmia had lasted 2 or more years, when the

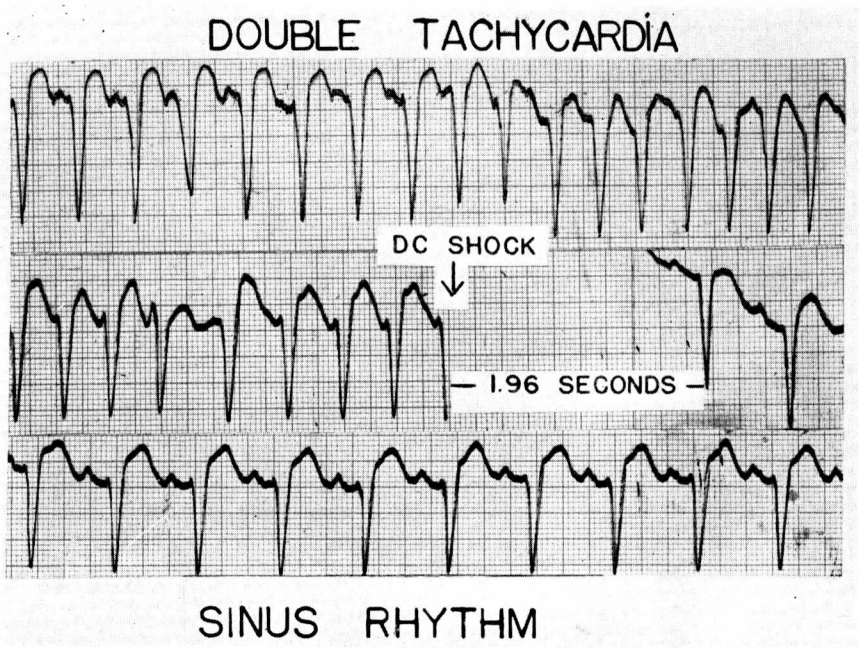

Fig. 5.—The complete process of reversion of complex tachycardia is illustrated.

TABLE 4.—RESULTS OF CARDIOVERSION IN 148 EPISODES OF ARRHYTHMIA

	No.	*Reverted*
Ventricular Tachycardia	25	25
Atrial Fibrillation	103	94
Atrial Flutter	15	15
Supraventricular Tachycardia	5	5

heart condition was due to mitral valve disease and when there was significant cardiomegaly, especially involving the left atrium.

The method of cardioversion has none of these disadvantages. It is simple and direct. It can be accomplished within several minutes. The entire process can be monitored by the physician. There is a higher success rate than with any current method of treatment. There are no complications ascribable to the method itself. It does not require frequent electrocardiographic monitoring, being applicable for both ventricular and supraventricular tachycardia, differentiation between these disorders ceases to be an important factor for effective therapy. Such distinction, which is at times difficult, is necessary when drugs are to be employed. Cardioversion does not depress cardiac contractility or excitability, common complications after large doses of antiarrhythmic drugs. Finally, the features of safety and simplicity permit the use of cardioversion by clinicians less experienced in the recognition and treatment of arrhythmias.

Cardioversion consists of two procedures: depolarization of the heart and establishment of the sinus node as pacemaker. Even when it is possible to depolarize the heart electrically, resumption and maintenance of sinus rhythm are not assured. There are several reasons for failure. If the factors originally precipitating the abnormal mechanism are still operating, this method will probably not prove successful. Failure may also occur when the sinus node is injured or depressed by drugs, inflammation, infiltration or infarction. There are also instances where sinus rhythm is restored but the abnormal mechanism recurs within minutes. This represents a problem in maintenance therapy that may be resolved by the use of adequate doses of antiarrhythmic drugs prior to cardioversion.

To date, a limitation of this method has been the use of anesthesia. This has added a small risk to an elective procedure and has required hospitalization with its attendant inconvenience and cost. The need for anesthesia has never been certain (Lown, Amarasingham and Neuman[4]). Recently Stock has demonstrated that cardioversion can be done with the patient awake without undue discomfort. We have confirmed this finding. The elimination of anesthesia will further simplify the cardioversion of arrhythmias and add to its safety.

Summary and Conclusion. 1. Ectopic arrhythmias can be terminated by transthoracic depolarization of the heart by means of direct current discharge. Synchronization of the electrical discharge to fall outside the vulnerable period of the cardiac cycle assures the safety of this procedure.

2. This method has been designated as cardioversion and has been employed to treat 148 episodes of arrhythmia in 114 patients.

3. All episodes of ventricular tachycardia, atrial flutter and supraventricular tachycardia were successfully reverted. Failures were encountered only in patients with atrial fibrillation. The majority of the patients with atrial fibrillation had rheumatic valvular disease, were resistant to quinidine and had the arrhythmia for over 2 years; nevertheless, 91% were restored to normal sinus rhythm.

4. No immediate complications were encountered. One patient with atrial fibrillation sustained a splenic embolism 48 hours after reversion.

5. This method has many advantages over the use of drugs in terminating chronic disorders of heart rhythm.

REFERENCES

1. **Frey, W.:** Berlin klin. Wchnschr., **55,** 417, 450, 1918.

2. **King, B. G.:** Effect of Electric Shock on Heart Action with Special Reference to Varying Susceptibility in Different Parts of Cardiac Cycle. Columbia University Doctoral Thesis, New York, N.Y.: Aberdeen Press, 1934.
3. **Lefemine, A. A., and others:** Defibrillation by Direct and Alternating Currents at Normal and Reduced Temperature. Unpublished data.
4. **Lown, B., Amarasingham, R.,** and **Neuman, J.:** J. Am. Med. Assn., **182,** 548, 1962.
5. **Lown, B., Amarasingham, R., Neuman, J.,** and **Berkovits, B. V.:** Use of Synchronized Direct Current Countershock in Treatment of Cardiac Arrhythmias. Presented before the 54th Annual Meeting, Am. Soc. Clin. Invest., April 30, 1962.
6. **Lown, B., Kaidbey, S., Perlroth, M.,** and **Abe, T.:** Comparative Studies of Ventricular Vulnerability to Fibrillation (abstract), 55th Annual Meeting, Am. Soc. Clin. Invest., April 29, 1963.
7. **Rokseth, R. J.,** and **Storstein, O.:** Arch. Int. Med., **111,** 184, 1963.
8. **Stock, R.:** Personal communication, May 6, 1963.

SUMMARIO IN INTERLINGUA

Cardioversion de Tachycardias Ectopic

1. Arrhythmias ectopic pote esser terminate per depolarisation transthoracic del corde effectuate per medio de un discarga de currente directe. Synchronisation del discarga electric de maniera que illo cade foras del periodo vulnerabile del cyclo cardiac assecura le salvitate de iste manovra.

2. Le methodo es designate como cardioversion, e illo ha essite empleate in le tractamento de 148 episodios de arrhythmia in 114 patientes.

3. Omne le episodios de tachycardia ventricular, de flutter atrial, e de tachycardia supraventricular esseva revertite successosemente. Non-successo esseva incontrate solmente in patientes con fibrillation atrial. Le majoritate del patientes con fibrillation atrial habeva rheumatic morbo valvular, esseva resistente contra quinidina e habeva le arrhythmia depost plus que 2 annos. Nonobstante, 91% esseva restaurate a normal rhythmos sinusal.

4. Nulle immediate complicationes esseva incontrate. Un patiente con fibrillation atrial experientiava un embolismo splenic 48 horas post le reversion.

5. Iste methodo ha multe avantages in comparation con le uso de pharmacos in le termination de chronic disordines del rhythmo cardiac.

SUMMARIO IN INTERLINGUA

(See page 289 for original article)

Observationes in Re le Inhibition del Sedimentation de Erythrocytos per Dextrano de Basse Peso Molecular

Il ha essite demonstrate que dextrano de basse peso molecular (Rheomacrodex) produce un significative relentation del sedimentation del erythrocytos tanto in vitro como etiam in vivo. Observationes de controlo suggere que iste effecto inhibitori super le sedimentation del erythrocytos es non simplemente un resultato de dilution del proteinas de plasma. Il pare, per consequente, que le uso del rapiditate del sedimentation es ben possibilemente un utile guida in establir efficace nivellos sanguinee de dextrano de basse peso molecular pro applicationes clinic.