DIRECT-CURRENT ELECTRICAL COUNTER-SHOCK IN THE TREATMENT OF ATRIAL ARRHYTHMIAS

EXPERIENCES IN 50 PATIENTS

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The course and prognosis of patients with heart disease are frequently altered by the onset of an arrhythmia which may cause a marked deterioration in the haemodynamic state or even congestive failure. The most frequently encountered arrhythmias are of the rapid ectopic type, and when the ventricular rate reaches 160/min. or more, cardiac output falls and coronary blood flow is compromised.[14] In patients with atrial fibrillation the ventricular output is diminished owing to the absence of the atrial systolic contribution to ventricular filling.[3]

Until recently, attempts at restoring sinus rhythm in patients with atrial fibrillation were confined to the administration of drugs, the most effective of which is quinidine.[5-7] However, the use of quinidine carries a well-recognized risk,[30] and it has been estimated that sudden death occurs in 1·8%[24] of patients receiving therapeutic doses of this drug. If congestive cardiac failure is present, quinidine is associated with an even greater danger, sudden death occurring in 4%.[2] Selzer and Wray[28] consider that paroxysmal ventricular fibrillation ensues in 3 - 5% of all patients on quinidine treatment. The ventricular fibrillation may be repetitive and it may occur after the patient has previously taken the drug in moderate doses without apparent ill-effect.[28] The treatment of quinidine-induced ventricular fibrillation is often difficult and may be unsuccessful.[25]

In 1962 Lown *et al.*[18] introduced an electrical method for the conversion of ectopic atrial arrhythmias to sinus rhythm. An under-damped direct-current discharge of 2·5 milliseconds duration is used. The current can be pre-set to be delivered at any part of the cardiac cycle, and the so-called 'vulnerable period' near the peak of the T wave on the electrocardiogram can therefore be avoided. The danger of inducing ventricular fibrillation is then negligible. The technique, now known as 'cardioversion', has been used extensively in the elective treatment of ectopic atrial arrhythmias.[9,10,13-17,19,21-23]

This paper describes our experience with the first 50 patients submitted to electrical cardioversion between October 1964 and April 1965.

MATERIAL AND METHODS

Of the 50 patients, 27 were males and 23 females. Their ages ranged from 6 months to 62 years, with an average of 40·4 years. Atrial fibrillation was present in 45 patients, the remaining 5 having atrial tachycardia without atrioventricular block (Table I). Cardioversion was performed electively in 43 patients and as an emergency in 7, the latter group including the 5 cases of paroxysmal atrial tachycardia. The vast majority of patients in the elective group had rheumatic heart disease (Table I). In the emergency group there were 4 patients with ischaemic and 1 with rheumatic heart disease, and 1 post-operative case.

TABLE I. DIAGNOSIS AND TYPE OF ARRHYTHMIA PRESENT IN PATIENTS SUBJECTED TO CARDIOVERSION

Arrhythmia	*Diagnosis*	*No. of cases*
Elective patients		
Atrial fibrillation	Post-mitral valvotomy	27
" "	Post-mitral & tricuspid valvotomy	1
" "	Mitral valve replacement	8
" "	Aortic valve replacement with mitral valvotomy	3
" "	Mitral valvuloplasty	1
" "	Closure of atrial septal defect	1
" "	Systemic hypertension	1
" "	Cardiomyopathy	1
	Total	43
Emergency patients		
Atrial fibrillation	Mitral and aortic valve disease	1
" "	Ischaemic heart disease	1
Paroxysmal atrial tachycardia	Ischaemic heart disease	3
" " "	Ebstein's anomaly	1
" " "	Lutembacher syndrome (postoperative)	1
	Total	7
	Grand total	50

All patients had been fully digitalized, but in about one-half digitalis was discontinued 24 hours before the attempt at cardioversion.

In the elective group the patients were maintained on adequate anticoagulant therapy for at least 2 weeks. After testing

for sensitivity they were given 0·2 G of quinidine sulphate 8-hourly on the preceding day, and 0·3 G 1½ hours before the procedure. After successful conversion a dose of 0·2 G, 3 times a day, was maintained. It should be noted that these doses are well below those used therapeutically for the conversion of atrial fibrillation to sinus rhythm. Quinidine was not given to all the emergency cases and none of these received a maintenance dose. Light general anaesthesia with sodium pentothal was used in all instances.

Counter-shock was administered with the Lown Cardioverter*: 1 - 4 shocks were given per session, with increasing energies of 100 - 400 watt-seconds (3,000 - 7,000 volts). One electrode was placed at the cardiac apex and the other at either the second right interspace or below the left scapula. The impulse was delivered synchronously with the downstroke of the R wave of the electrocardiogram (or upstroke of the S wave if the QRS complex on the oscilloscope was dominantly negative).

RESULTS

Successful conversion was achieved in 84% of cases. The success rate in the emergency group was 100% and all 7 patients have remained in sinus rhythm. We have analysed the ease of conversion in terms of the number of shocks required, because the energy used for the initial shock was electively higher in larger patients or in those with a thick chest wall (Table II). Only 1 patient in the emergency group required

TABLE II. EASE OF CARDIOVERSION

	No. of cases	*No. of shocks*
Elective patients	14	1
	14	2
	6	3
	3	4
	Average	1·6
Emergency patients	6	1
	1	2
	Average	1·1

more than 1 shock for cardioversion—a man with multivalvular rheumatic heart disease. The 34 patients who showed no circulatory embarrassment did not require significantly fewer shocks (mean 1·2) than the 10 with raised pulmonary or systemic venous pressure (mean 1·5). The same number of shocks were required with either position of the electrodes.

Neither the patient's age nor the length of time that trial fibrillation had been present influenced the ease of cardioversion. Patients who had had open-heart surgery, 11 of whom had prosthetic valve replacements, were no more difficult to convert than those who had had a closed valvotomy.

Arrhythmias were common immediately after the procedure and were observed in 62% of the patients. They were always transient, usually lasting only a few minutes; the maximum duration was 3 hours. A wide variety of arrhythmias occurred (Table III). The commonest were atrial and ventricular ectopic beats. Transient atrioventricular block occurred twice; in 1 patient it was 1st degree and in the other 2nd degree. The over-all incidence of arrhythmias did not appear

TABLE III. POST-CARDIOVERSION ARRHYTHMIAS

Arrhythmia	*No. of cases*
Atrial ectopics	12
Nodal or low atrial ectopics	1
Atrial flutter	4
Varying atrial pacemakers	3
AV block	2
Ventricular ectopics	9

*Manufactured by the Optical Instrument Co.

to be related to the number and energy of the shocks (Table IV). There was no difference in the incidence or nature of arrhythmias between fully digitalized patients and those in whom digitalis had been discontinued 24 hours previously.

TABLE IV. RELATIONSHIP OF NUMBER AND ENERGY OF SHOCKS TO THE PRODUCTION OF POST-CARDIOVERSION ARRHYTHMIAS

	Average energy (watt-seconds)	*Average no. of shocks*
With arrhythmia	189	1·7
Without arrhythmia	199	1·9

Eight failures of cardioversion occurred in the elective group. There is probably a relationship between the duration of atrial fibrillation and the rate of success of cardioversion. Most of the failures were in cases of long standing. However, a long history of atrial fibrillation did not necessarily preclude a successful result, and in one such instance the patient had had the arrhythmia for at least 14 years. The presence of congestive cardiac failure in patients in this series did not significantly affect the success rate of cardioversion.

At the present time 10 patients successfully converted have relapsed into atrial fibrillation; 8 of these had been taking maintenance doses of quinidine—4 relapsed within 10 days after conversion. Congestive cardiac failure, post-conversion arrhythmias, or the ease of cardioversion did not influence the relapse rate. There were no serious complications as a result of cardioversion.

Illustrative Cases

Case 1. A 65-year-old polycythaemic man developed paroxysmal atrial tachycardia (Fig. 1) after his second myocardial infarct. He was shocked and required metaraminol intravenously to maintain an adequate blood pressure. Left- and right-sided cardiac failure were present, and attempts to con-

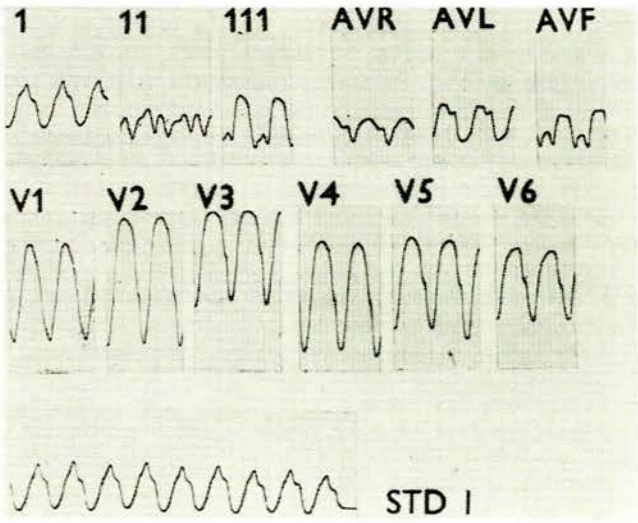

Fig. 1. Electrocardiogram in case 1 before cardioversion. Paroxysmal atrial tachycardia with aberrant conduction. The similarity of this to ventricular tachycardia is clear. Cardioversion is safe and effective with either atrial or ventricular tachycardia, eliminating the need for critical diagnosis.

trol the arrhythmia with quinidine and digitalis were unsuccessful. The arrhythmia was converted to a sinus rhythm (Fig. 2) with the first shock (200 watt-seconds). The blood pressure immediately rose to normal, and signs of cardiac failure disappeared after 30 minutes.

Case 2. A 52-year-old male had been in atrial fibrillation owing to rheumatic heart disease for 6 years. Mitral valvotomy had been performed 2 years previously, resulting in mild mitral

incompetence. Residual moderate pulmonary arterial hypertension was present. In December 1964 he was subjected to cardioversion, and after 2 shocks (100 and 200 watt-seconds) sinus rhythm was established. He has remained in sinus rhythm for more than 7 months. His effort tolerance is markedly improved and he volunteered that he now has a 'feeling of calm in the chest'.

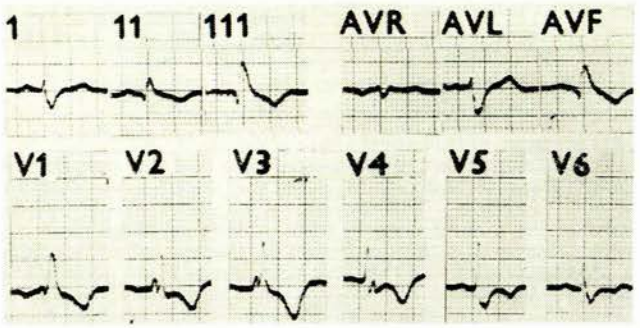

Fig. 2. Electrocardiogram in case 1 after successful cardioversion showing sinus rhythm with right bundle-branch block.

DISCUSSION

There is often justification for converting atrial fibrillation to sinus rhythm. It has been stated[7] that 30% of patients with atrial fibrillation from rheumatic valvular disease have at least one major embolic episode. Furthermore, Askey and Bernstein[1] estimated that 25 - 30% of deaths in adult patients with chronic rheumatic valvular disease are due to arterial embolism.

It appears that the most striking benefits from cardioversion are experienced by those patients in whom acute paroxysmal atrial tachycardia is converted to sinus rhythm. In the group of patients with chronic atrial fibrillation, cardiac efficiency is subnormal even with controlled ventricular rates. A return to sinus rhythm is associated with an increase in cardiac output;[15,20] probably because the 'booster pump' action of the atria becomes available.[3,9] Our experience is in accord with that of Hurst,[9] who found an improved effort tolerance in patients having had successful cardioversion of chronic atrial fibrillation.

There is experimental evidence[11,14,29] that a modified direct current is superior to alternating current for the electrical treatment of arrhythmias, and that less myocardial damage is produced. Cardioversion is now widely employed, and has even been used on newborn infants.[5] The only serious complications that we have found in the literature are 1 fatal case of ventricular fibrillation,[27] and the occurrence of transient pulmonary oedema in 4.[26]

We have administered anticoagulants to all of the elective cases because of the possibility of systemic embolism occurring after conversion. However, some authors[13,16] regard the routine administration of anticoagulants as unnecessary unless previous systemic embolism has occurred.

Our immediate success rate of 84% compares favourably with that in most reports. Slightly higher success rates have been achieved when there is a smaller proportion of rheumatic cases with atrial fibrillation.[9,13,19] In atrial flutter the success rate of cardioversion is even higher,[4,21] and in paroxysmal atrial tachycardia it is also very high.

A major problem after successful conversion of atrial fibrillation is the maintenance of sinus rhythm.[17,21] Eight of the 10 patients who relapsed had strictly adhered to their maintenance dose of quinidine. The relapse rate is probably not related to dosage since our figures do not differ significantly from others[19] where much larger maintenance doses of quinidine were used.

Arrhythmias are commonly observed after the first 3 seconds of electrical blackout which follow cardioversion. It has been claimed[10,13] that electrical defibrillation unmasks latent digitalis intoxication or the effects of potassium depletion, and that post-conversion arrhythmias are at least partly due to this. We found that the nature (though not the incidence) of post-conversion arrhythmias was related to the energy of the preceding shock. Thus the 4 patients who developed atrial flutter did so after low-energy shocks (average 200 watt-seconds). This experience is similar to that of Lemberg *et al.*,[12] and is probably caused by incomplete electrical depolarization of all the atrial fibres. High-energy shocks, on the other hand, were associated with the production of multiple arrhythmias and atrioventricular block. The development of transient multiple atrial pacemakers is not infrequent and is probably related to temporary suppression of the sino atrial node by the counter-shock.[4]

In our experience with cardioversion no serious complications were encountered, confirming the safety of this technique. We regard cardioversion as the treatment of choice for the conversion of atrial fibrillation to sinus rhythm. It is also strongly indicated in other ectopic arrhythmias which have not responded to safe anti-arrhythmic drugs. The use of potentially dangerous agents, such as quinidine and intravenous procaine amide, is now seldom justified.

SUMMARY AND CONCLUSIONS

1. Forty-five patients with atrial fibrillation and 5 with paroxysmal atrial tachycardia were treated by electrical counter-shock using the Lown Cardioverter.

2. Conversion to sinus rhythm was achieved in 84%. We were unable in this small series to establish any definite factors which predisposed to failure to convert. However, it is probable that in patients with long-standing atrial fibrillation the success rate of cardioversion will be less.

3. The ease of cardioversion in successful cases (i.e. the number of shocks required) was uninfluenced by electrode position, patient's age, duration of arrhythmia, presence of cardiac failure, or type of previous cardiac surgery.

4. A wide variety of transient arrhythmias followed cardioversion in 62% of cases; none had serious consequences.

5. The relapse rate was 20% and bore no relation to the presence of cardiac failure, post-conversion arrhythmias or the ease of cardioversion.

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REFERENCES

1. Askey, J. M. and Bernstein, S. (1960): Prog. Cardiovasc. Dis., **3**, 220.
2. Askey, J. M. (1946): Ann. Intern. Med., **24**, 371.
3. Braunwald, E. (1964): Amer. J. Med., **37**, 665.
4. Castellanos, A. jnr., Lemberg, L., Gosselin, A. and Fonesca, E. J. (1965): Arch. Intern. Med., **115**, 426.
5. Conn, H. L. and Luchi, R. J. (1964): Amer. J. Med., **37**, 685.
6. Goldman, M. J. (1960): Prog. Cardiovasc. Dis., **2**, 465.
7. *Idem* (1951): Amer. J. Med. Sci., **222**, 382.
8. Hassenrück, A., Chojnaki, B. and Barker, H. J. (1965): Amer. J. Cardiol., **15**, 726.
9. Hurst, J. W., Paulk, E. A. jnr., Proctor, H. D. and Schlant, R. C. (1964): Amer. J. Med., **37**, 728.

10. Killip, T. (1963): J. Amer. Med. Assoc., **186**, 1.
11. Kuhn, L. A. (1964): Amer. Heart J., **67**, 709.
12. Lemberg, L., Castellanos, A. jnr., Swenson, J. and Gosselin, A. (1964): Circulation, **30**, 163.
13. Lown, B. (1964): Mod. Conc. Cardiov. Dis., **33**, 869.
14. Lown, B., Amarasingham, R. and Neuman, J. (1962): J. Amer. Med. Assoc., **182**, 548.
15. Lown, B., Bey, S. K., Perlroth, M. G. and Tadaaki, A. (1963): Amer. J. Med. Sci., **246**, 257.
16. Lown, B., Kleiger, R. and Wolff, G. (1964): Amer. Heart J., **67**, 282.
17. McDonald, E. L. and Resnekov, L. (1965): *Resuscitation and Cardiac Pacing*. London: Cassell.
18. McIntosh, H. D., Kong, Y. and Morris, J. J. (1964): Amer. J. Med., **37**, 712.
19. Meltzer, L. E., Aytan, N., Yun, D. D., Ural, M. E., Palmon, F. P. jnr. and Kitchell, J. R. (1965): Arch. Intern. Med., **115**, 537.
20. Morris, J. J., Entman, M., North, W., Kong, Y. and McIntosh, H. (1965): Circulation, **31**, 670.
21. Morris, J. J., Kong, Y., North, W. C. and McIntosh, H. D. (1964): Amer. J. Cardiol., **14**, 94.
22. Oram, S., Davies, J. P. H., Weinbrenn, I., Taggart, P. and Kitchen, L. D. (1963): Lancet, **2**, 159.
23. Pantridge, J. F. and Halmos, P. B. (1965): Brit. Heart J., **27**, 128.
24. Parkinson, J. and Campbell, L. (1929): Quart. J. Med., **22**, 281.
25. Rainier-Pope, C. R., Schrire, V., Beck, W. and Barnard, C. N. (1962): Amer. Heart J., **63**, 582.
26. Resnekov, L. and McDonald, L. (1965): Lancet, **1**, 506.
27. Ross, E. M. (1964): Arch. Intern. Med., **114**, 811.
28. Selzer, A. and Wray, H. W. (1964): Circulation, **30**, 17.
29. Yarbrough, R., Ussery, G. and Whitley, J. (1964): Amer. J. Cardiol., **14**, 504.
30. Zion, M. M. and Bradlow, B. A. (1962): S. Afr. Med. J., **36**, 497.