

Section of Medicine

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Management of Cardiac Arrhythmia

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The Treatment of Cardiac Arrhythmias by Direct-current Shock

The subject of the treatment of cardiac arrhythmias by means of a DC shock now has a vast literature. Not all of it is very critical unfortunately, and there is no doubt that many problems remain unsolved. To borrow a title from a popular radio quiz game – 'Twenty Questions' – we might review some of them (Table 1).

My paper will be confined to the question of terminology, the present-day indications and contraindications for DC shock therapy, the use of DC shock therapy in acute cardiac infarction, and to the peculiar phenomenon of late 'spontaneous' reversion to sinus rhythm.

Before dealing with these matters I wish to make a plea for greater discretion in the use of DC shock therapy, particularly in the treatment of atrial fibrillation. There is no doubt that this mode of treatment constitutes a therapeutic advance in cardiology of some importance. There is equally no doubt that it is being used too enthusiastically. Too many papers are being published claiming a high percentage of 'success' in reverting atrial fibrillation to sinus rhythm without defining what precisely is meant by 'success'.

Manufacturers claim that these high success rates are due to the superiority of their particular brand of apparatus but the cardiologist himself seems to imply that it is something more to do with his superior manipulative skill, and curiously neither the manufacturer nor the cardiologist give any credit to luck! Surely in discussing the success of a method it is mandatory to ask whether

Table 1
'Twenty Questions'

- (1) What is the correct terminology?
- (2) How is 'successful' reversion defined?
- (3) Is DC preferable to AC shock?
- (4) What is the optimum level of energy and shape of the impulse?
- (5) What is the most effective position and polarity of the electrodes?
- (6) Is anaesthesia necessary?
- (7) Which is preferable, valve or solid state synchronizer?
- (8) Is synchronization necessary?
- (9) Is a paired impulse preferable?
- (10) What are the indications for DC shock?
- (11) Is DC shock indicated and safe in acute cardiac infarction?
- (12) What are the contraindications to DC shock?
- (13) Are anticoagulants indicated?
- (14) What is the place of digitalis?
- (15) How much influence have drugs, metabolic and electrolyte disturbances, and hypoxia?
- (16) How may post-reversion arrhythmias be avoided?
- (17) Can pulmonary oedema be prevented?
- (18) How may the risk of embolism be reduced?
- (19) How may sinus rhythm be maintained?
- (20) What is the explanation of late 'spontaneous' reversion of atrial fibrillation?

the treatment benefited the patient and, if so, in what way.

It is surprising how rarely authors define what they mean by success in reversion. Usually they imply merely that the patient was removed from the room in which the reversion was carried out in a state of sinus rhythm. Rarely is mention made of the persistence of normal rhythm. It is difficult to see how the appearance of sinus rhythm for a few beats or for a few minutes, hours, or even days, necessarily can help most patients except in the rare acute emergency.

Terminology

There is lack of uniformity and the terms most commonly used are 'defibrillation', 'cardioversion', 'countershock' and 'conversion'. We would suggest that a preferable term is 'reversion'.

'Defibrillation' should, of course, be restricted to either ventricular or atrial fibrillation, and which of these is meant should be clearly stated. This is not always done and the term is frequently used as an omnibus one. The term is inappropriate if arrhythmias other than these two are implied.

'Cardioversion' is popular in the United States but to where is the heart turned? 'Countershock' is also in common use but counter to what?

'Conversion' is more acceptable but we feel that 'reversion' is better. If a change is made from an original state to a different state, then certainly conversion is the correct term. For example, if a heathen adopts Christianity one would rightly say that he had been converted. On the other hand, surely if from his converted state he went back to his original heathenism, one would not then say that he had been converted but that he had reverted to his old bad habits. Certainly there is authority for the term:

Revert: 'To return to a former condition' (The Shorter Oxford English Dictionary on Historical Principles, 3rd ed.)

Revert: 'Restore the status quo';

Reversion: 'Back where one started' (Roget's Thesaurus of English Words and Phrases)

Indications for DC Reversion of Arrhythmias

The two main indications are where the arrhythmia itself threatens life or where the cause of the arrhythmia has been abolished or at least alleviated.

Over the past four years we have gradually reduced our indications for DC reversion to those listed in Table 2.

Table 2
Indications for DC reversion of arrhythmias

<i>Arrhythmia threatens life</i>	
(1) Ventricular rate uncontrollable	} Ventricular fibrillation } Paroxysmal ventricular tachycardia ● } Paroxysmal atrial tachycardia ●
(2) Emboli	
<i>Cause of arrhythmia eliminated or alleviated</i>	
(1) Acute myocardial infarction	
(2) Mitral valve surgery if sinus rhythm before operation	
(3) Mitral valve disease insufficiently severe to justify operation	
(4) Following treated thyrotoxicosis, medical or surgical	
(5) Acute toxic cardiomyopathies, e.g. pneumonia	
(6) Repair of atrial septal defect	} Including atrial fibrillation } before operation
(7) Pericardiectomy	

● Provided not induced by digitalis

Ventricular fibrillation is, of course, often an absolute indication as, untreated, the patient dies; even so it is wrong to treat all such patients in this manner particularly if the ventricular fibrillation is known to have been present for more than a few minutes or where the prognosis in the untreated patients is virtually hopeless – the so-called secondary type of fibrillation. Even when ventricular fibrillation is successfully reverted to sinus rhythm by DC shock the patient commonly dies subsequently.

Ventricular tachycardia, provided it has not been induced by digitalis, gives perhaps the most dramatic response especially if the patient is very ill as a result of it. Electrical reversion is so simple and so frequently successful that intravenous lignocaine or procainamide seem hardly worth while if a machine is to hand.

Paroxysmal atrial tachycardia is often benign, short and self-limiting; if not, the well-known methods of vagal stimulation are commonly effective. If they fail, then the cholinergic effect of digitalis or the beta-adrenergic effect of propranolol may be utilized. If these methods fail, and provided the arrhythmia is not itself due to digitalis, then a DC shock is usually effective. However, as far as acute cardiac infarction is concerned, our experience is that supraventricular tachycardias are far from benign and require urgent DC shock therapy. This is mentioned below.

Atrial flutter is the easiest arrhythmia to revert electrically and the unpleasantness of the heavy digitalization usually required to convert flutter to sinus rhythm is avoided by using a DC shock.

Atrial fibrillation is the commonest clinical problem and the most difficult to decide. There is no doubt that many fibrillating patients are being wrongly treated by DC shock. Many should not be treated at all, either because they relapse so soon that little or nothing is gained at some risk. Others are not treated at the right time. For example, we used to carry out reversion in the operating theatre immediately after mitral valvotomy, repair of an atrial septal defect or pericardiectomy in order to avoid two anaesthetics. Now we wait for at least two weeks as very early reversion is apt to be followed by relapse to atrial fibrillation or other arrhythmia.

If an arrhythmia persists after its cause has been got rid of then DC reversion would seem ideally indicated. Even so, persistence of sinus rhythm, once achieved, is by no means invariable. This is not altogether surprising when one

remembers patients who have been rendered euthyroid by operation, drugs or radioactive iodine, and yet their fibrillation has persisted for the rest of their days although the thyrotoxicosis has not recurred. Some of these patients may have been reverted to sinus rhythm by quinidine but often only temporarily so.

Usually, if patients with acute toxic cardiomyopathy develop an arrhythmia, it spontaneously reverts as the disease process remits, but this is not invariably so, especially in the elderly, and in such patients reversion is good therapy.

After mitral valve surgery reversion is worth while only if sinus rhythm has been present prior to operation, or at most if pre-operative atrial fibrillation is known to have been of recent origin.

On the other hand, atrial fibrillation preceding operation for atrial septal defect and constrictive pericarditis is not a contraindication even if it has been present for many years. The results are extremely satisfactory.

A few patients, usually young, are found to be fibrillating at a stage when their degree of mitral valve disease is not sufficient to warrant operation. Reversion of these is worth while as it may last for a few years.

Patients with an arrhythmia which has been induced as a result of acute cardiac infarction constitute, in our view, one of the strongest indications for DC shock therapy.

Contraindications to DC Reversion of Arrhythmias

Unlike our indications for DC shock therapy, which have grown smaller, our contraindications have increased although admittedly some are relative and only temporary (Table 3).

As in most other types of therapy, each patient must be judged individually but, in general, if sinus rhythm is unlikely to persist, then unless the atrial fibrillation *per se* is threatening the life of the patient it is pointless to revert the patient for a few beats or even for a few days. The technical ease with which sinus rhythm can be achieved does not justify such therapy; only the benefit the patient may derive vindicates the method.

In effect, if the atrial fibrillation is known to be longstanding or considerable cardiac enlargement is present, and commonly both co-exist, then there must be very strong reasons indeed for imposing DC shock therapy.

The only two absolute contraindications are digitalis toxicity, especially paroxysmal atrial tachycardia with block and the much rarer digitalis-induced ventricular tachycardia, and tight mitral stenosis.

There is good evidence that DC shock therapy potentiates the toxic effects of digitalis, possibly due to transient cellular damage. Digitalis intoxication may become manifest in sinus rhythm when not evident in atrial fibrillation. If paroxysmal atrial tachycardia with block is already present there is very considerable danger of death, and fatalities due to this have been recorded. On the other hand of course, if the paroxysmal atrial tachycardia is not due to digitalis, DC shock therapy may well be life saving, particularly in cardiac infarction. It is of interest that experimentally DC shock occasionally transforms digitalis-induced ventricular tachycardia into ventricular fibrillation.

With tight mitral stenosis, the risk of inducing acute pulmonary oedema if sinus rhythm is suddenly produced is so great that the method is contraindicated. The correct treatment of such patients is to increase the size of the valve orifice surgically and then, if the fibrillation is of recent origin, they can be defibrillated a few weeks after operation.

If mitral incompetence is dominant and severe, not only is it difficult to revert such hearts to sinus rhythm but even when reversion is successful the duration of sinus rhythm is so disappointingly short that we have given up treating such patients. If as a result of mitral valve operation atrial fibrillation has been pro-

Table 3
Contraindications to DC reversion of arrhythmias

<i>General - Sinus rhythm unlikely to persist - except emergency</i>	
(1)	Longstanding atrial fibrillation
(2)	Cardiomegaly
<i>Particular</i>	
<i>Absolute:</i>	
(1)	Heavy digitalization, especially paroxysmal atrial tachycardia with block and paroxysmal ventricular tachycardia
(2)	Tight mitral stenosis
<i>Relative:</i>	
(1)	Pure and severe mitral incompetence
(2)	Following mitral valve operation if preceded by longstanding atrial fibrillation
(3)	Cardiomyopathy, especially alcoholic
(4)	Chronic ischaemic and hypertensive heart disease
(5)	Lone fibrillators
(6)	Elderly with only moderate symptoms
(7)	Electrolyte imbalance especially hypokalaemia; acidosis; hypoxia

duced, then reversion is well worth while, but if atrial fibrillation has long been present prior to operation reversion is so unlikely to result in sinus rhythm of any beneficial duration that we now feel it is not worth attempting in most such patients. Even so, again each case must be judged on its merits and in one of our patients atrial fibrillation gave way to sinus rhythm at the exact moment that the surgeon split the mitral valve digitally. Later, atrial fibrillation returned and we thought it worth reverting this patient and she has remained in sinus rhythm now for more than two years.

Many of the chronic cardiomyopathies seem to end up with persistent atrial fibrillation whatever treatment is employed, and this is particularly so when alcohol is the cause. Whether, after several years' abstinence from alcohol, DC reversion would prove more lasting remains to be seen.

Chronic ischaemic heart disease, unlike acute cardiac infarction, is disappointing and early reversion to atrial fibrillation is the rule. Similarly, hypertensive heart disease is both difficult to revert to sinus rhythm and even more difficult to maintain.

Lone fibrillators, which by definition are without demonstrable heart disease, we originally thought might prove ideal subjects although if they are symptom-free they are probably best left alone. 'Failed reversion', especially on several occasions, can have a depressing effect on young people as well as old. In view of our high failure rate with these patients one cannot help but wonder whether they have some defect, possibly microscopic, in the conducting tissue in or near the sinoatrial node.

Although as a rule it is not difficult to revert elderly patients, if they can manage a relatively restricted life commensurate with their age, reversion is not indicated as they are so unlikely to maintain their sinus rhythm.

A temporary contraindication is electrolyte imbalance, especially hypokalaemia; acidosis and hypoxia must also be corrected before DC shock therapy.

Acute Cardiac Infarction

If one includes sinus bradycardia, sinus tachycardia and ectopic beats, then over 90% of acute cardiac infarction patients develop an arrhythmia during the first seventy-two hours of the illness.

At first we were hesitant to send a high-voltage shock through heart muscle which was known to

be extensively and recently damaged. We thought that the fate of an already precariously ill patient might well be further jeopardized by such therapy. In this we were wrong, and with increasing experience we are confident that DC shock has an important role in the treatment of such patients.

We thought that the commonest arrhythmia which would need DC reversion in acute cardiac infarction would be ventricular tachycardia or possibly ventricular fibrillation. In this also we were wrong.

Since setting up our Intensive Care Coronary Unit (ICCU) we have treated some 70 patients and have considered it necessary to attempt reversion in only 12 of these in the first seventy-two hours (Table 4). It is of interest that these have all had atrial arrhythmias, either fibrillation or paroxysmal tachycardia. We have, of course, attempted reversion in more than 12 acute cardiac infarction patients but these others have been dealt with either in the Casualty Department before reaching the ICCU, or in the general wards after discharge from the Unit. We have not as yet had to revert any patient with ventricular tachycardia or ventricular fibrillation whilst still in the ICCU.

Patients with ventricular tachycardia in the early stages of an infarct are quite common, but our experience is that the arrhythmia is often self-limiting and occurs in short salvos, or longer runs of up to perhaps a minute, and then spontaneously remits. If the run continues it can almost always be abolished by drugs such as procainamide, propranolol or lignocaine and DC shock has not so far been required. We thought that ventricular fibrillation would be a common indication for DC shock but it has not been so in the Unit.

We have come to regard ventricular fibrillation as of two types, primary and secondary. By primary is meant that the patient is not in failure or shock and is progressing well. The ventricular fibrillation appears unexpectedly and not necessarily very early in the disease. If it can be reverted quickly the prognosis may be excellent.

Unfortunately, partly due to pressure on beds, we keep our patients in the Unit for only seventy-two hours provided they are not too ill for transfer to a general ward. The danger of such a short period of intensive care is that primary ventricular fibrillation may occur after the patient has been removed from immediate access to electrical reversion. This has happened on several occasions.

By secondary ventricular fibrillation is meant an arrhythmia associated with circulatory failure in a very ill patient, often in severe shock. The fibrillation is commonly terminal. It is difficult to revert such patients although, if sufficient attention is paid to correcting the acidosis, DC shock may be successful if repeated. If in such patients the ventricular fibrillation has been known to be present for more than a few minutes it is doubtful whether DC shock therapy is justified. We recently had one such patient whom we reverted to sinus rhythm after about twenty minutes, throughout which time closed chest compression gave an excellent femoral pulse. To our surprise, after about a dozen unsuccessful shocks sinus

reversion was failure of the patient to improve, and in our patients consisted of persistent pain, hypotension, increasing breathlessness and frank left ventricular failure. The time from the onset of the infarct to the beginning of the arrhythmia varied from simultaneous onset to thirteen days, most being within a few hours. The interval between the onset of the arrhythmia and the application of DC shock varied from less than one hour to forty-eight hours, and 11 of the patients were shocked within twenty-four hours.

Short episodes of atrial fibrillation in acute cardiac infarction are not at all uncommon and usually remit spontaneously. Only 3 of our

Table 4
Supraventricular arrhythmias in acute cardiac infarction treated by DC shock

Sex	Age	Arrhythmia	Previous digitalis	Indication for reversion	Time from infarct to onset of arrhythmia	Time from onset of arrhythmia to DC shock	Result	Remarks
F	67	AF	Yes	Hypotension	Fibrillating before onset	—	Failed	Died in shock
M	64	AF	No	Persistent pain	<4 hours	12 hours	SR	Forty-eight hours after DC shock developed left hemiplegia and coma. Died four days later
M	57	AF	No	Increased breathlessness. No response to digitalis or propranolol	5 days	24 hours	SR	
M	49	PAT 2:1 block	No	Shock	13 days	4 hours	Failed	Death in asystole
F	67	PAT 2:1 block	No	Unconscious. Hypotension	<3 hours	1 hour	SR	Never recovered consciousness
M	50	PAT variable block	Yes	Hypotension	8 hours	16 hours	Failed	Death
M	59	PAT 2:1 block	No	Hypotension	10 days	12 hours	SR	Second episode forty-eight hours later. Again successfully reverted
F	55	PAT 2:1 block	No	Coma. Hemiplegia. Hypotension	2 hours	<1 hour	SR	Regained consciousness. Signs of hemiplegia disappeared
M	38	PAT 2:1 block	No	Hypotension	Simultaneous	1 hour	SR	
M	73	PAT 2:1 block	No	Hypotension	3 hours	1 hour	SR	
M	68	PAT 2:1 block	Yes	Left ventricular failure	24 hours	48 hours	SR	Forty-eight and seventy-two hours later developed arrhythmia again. Successfully converted each time
M	57	PAT 2:1 block	No	Left ventricular failure. Hypotension	<24 hours	<24 hours	SR	Old infarct. Pain for twenty-four hours

AF = atrial fibrillation. PAT = Paroxysmal atrial tachycardia. SR = Sinus rhythm

rhythm suddenly appeared and remained. At first we were delighted, but once he regained consciousness he remained decerebrate until he died.

Of our 12 patients with arrhythmias resulting from acute cardiac infarction treated by DC shock in the Unit, 3 had atrial fibrillation, 9 had paroxysmal atrial tachycardia of whom no fewer than 8 had 2:1 block; in the other the block was variable (Table 4). The indication in general for

patients with atrial fibrillation required electrical reversion; of these, 2 died, one from persistent shock from which he never recovered and the other as a result of a hemiplegia. Of the 9 patients with paroxysmal atrial tachycardia with block 3 died. We failed to revert 2 of these to sinus rhythm. The third patient was admitted unconscious with hypotension, and although we shocked him within an hour of the onset of the paroxysmal atrial tachycardia, and he reverted to

sinus rhythm, he did not regain consciousness. Fortunately not all experience is so depressing, and of the 6 patients with paroxysmal atrial tachycardia who were successfully reverted and survived, one was a woman of 55 who was admitted in coma with hypotension and hemiplegia. We successfully reverted her in less than an hour from the onset of the paroxysmal atrial tachycardia, and she not only regained consciousness but the signs of her hemiplegia completely disappeared.

Paroxysmal atrial tachycardia is a well-recognized complication of digitalis therapy, but only 2 of our 9 patients were receiving it and neither in excessive dose.

It is our experience in the first seventy-two hours of acute cardiac infarction that it is the atrial arrhythmias, not the ventricular, which constitute the greater problem. Supraventricular

fibrillation took over again in a few seconds. In the other 3 there was no sign whatsoever of sinus rhythm on the cathode-ray oscilloscope or during the subsequent ten minutes or so.

None of them had received quinidine either before or after DC shock.

Of the 4, one has gone back to atrial fibrillation but the other 3 have so far remained in sinus rhythm (Table 5).

It is likely that we have missed several examples of this phenomenon because of our practice of treating many patients as day patients and allowing them to go home within a few hours of attempted reversion. Indeed, we have since been told by a general practitioner that he found his patient was in sinus rhythm after we had written to him apologizing for the fact that our attempted DC shock therapy had failed!

Table 5

Late 'spontaneous' reversion to sinus rhythm from atrial fibrillation following DC shock

Sex	Age	Etiology of atrial fibrillation	Pre-shock duration of atrial fibrillation	Heart size	Previous digitalis	Shocks and energy (joules)	Post-shock persistence of atrial fibrillation (maximum)	Duration of sinus rhythm	Comments
M	52	Idiopathic	3 years	N	Yes	100 200 300	6 hours	6 months	Atrial flutter preceded atrial fibrillation
M	58	Chest infection	8 weeks	N	No	100 200 300	3½ hours	Persists (1 month)	300 joules produced sinus rhythm for few seconds only
F	57	Atrial septal defect	Several years	2/4	Yes	100 200 300	7 hours	Persists (7 months)	Reversion performed one month after repair of secundum defect
M	46	Thyrotoxicosis	5 years	1/4	Yes	100 300	24 hours	Persists (2 years)	Reversion attempted two weeks after thyroidectomy

No patient had had a spontaneous remission to sinus rhythm
No patient had been receiving quinidine

tachycardia is by no means the benign arrhythmia that it is in patients without cardiac infarction. It may easily tip the balance against the patient's survival and in our view DC shock is urgently indicated.

Late 'Spontaneous' Reversion

On four occasions we have observed a curious phenomenon which we have not seen recorded elsewhere. Although it has surprised and delighted us we have no explanation for it. It is that at some time after apparent failure to revert atrial fibrillation the patient goes back, apparently spontaneously, to sinus rhythm. In all 4 patients we went up to 300 joules before abandoning the attempt. In all 4 the sinus rhythm appeared within a few hours, never more than twenty-four. In one of them sinus rhythm had been produced after a 300 joule shock had been reached, but atrial

To sum up, DC reversion of arrhythmias represents an important therapeutic advance in cardiology, but its ease of application and relative safety have led to enthusiasm for the method which is not warranted by the results. The strongest indication is, of course, ventricular fibrillation but arrhythmias resulting from acute cardiac infarction also constitute an important group. The most common arrhythmia requiring treatment is atrial fibrillation, but our view now is that the majority of patients with this arrhythmia are better not treated by DC shock.

The two commonest indications are, first, as an emergency measure, particularly when acute cardiac infarction has induced a persistent arrhythmia which is threatening life, and, secondly, when an arrhythmia remains after its original cause has been removed.