

# Cardiac Output After Direct Current Conversion of Atrial Fibrillation

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There is scant agreement regarding the effect on cardiac output of conversion of atrial fibrillation to sinus rhythm. Some workers have reported a considerable increase in resting cardiac output; others have found no change. The interval between conversion and the repeat measurement of cardiac output has varied widely. In general, measurements made within a few hours of conversion have shown little change from the resting value, while those made after longer intervals have shown an increase (Table I). In previous work reported from this laboratory (Halmos and Patterson, 1965), an average rise of 53 per cent in cardiac output was demonstrated one week after direct current (DC) conversion. The present work was undertaken to study the changes in cardiac output occurring in the same patient at different intervals after restoration of sinus rhythm.

## PATIENTS AND METHODS

Studies were carried out on 16 patients: 9 with rheumatic heart disease, 3 with controlled thyrotoxicosis, 3 with ischaemic heart disease, and one with idiopathic atrial fibrillation. There were 11 men aged between 35 and 67 (mean 53 years), and 5 women aged between 41 and 60 (mean 53 years). All patients had previously been on digitalis, but none had evidence of cardiac failure at the time of DC conversion. Seven patients had had mitral valvotomy from three weeks to several years before conversion.

The patients were in hospital for at least 24 hours before output studies were made, and remained for at least 4 days after conversion. Digoxin was stopped 48 hours before attempted conversion. The procedure was explained to the patients on the evening before conversion, and they were fasted overnight. All conversions were performed in the morning.

Cardiac output was measured by the dye dilution technique, using indocyanine green. Dye dilution curves were obtained by withdrawing blood from the femoral artery through a cuvette densitometer which

was linked to a cardiac output computer (Gilford 104). The cardiac output was taken as the average of 2 estimations. The heart rate was obtained from an electrocardiogram recorded at the time of each output estimation.

After the insertion of catheters into the median cubital vein and the femoral artery, each patient was rested for 20 minutes. Two measurements of resting cardiac output were made. A comparison of the two initial resting measurements of cardiac output in the 16 patients showed a mean difference of 0.03 l./min. (range +0.57 - 0.59 l./min.).

The patient was anaesthetized by the intravenous injection of a short-acting barbiturate, methohexitone sodium (Brietal Sodium, Eli Lilly and Co. Ltd.) in a dose of 1 mg./kg. A direct current shock of 50 watt seconds was applied across the chest wall, the electrodes being placed over the mid-sternum and the back of the chest.

Ten patients reverted to sinus rhythm. A further shock of 150 watt seconds was given to the 6 patients who were still in atrial fibrillation and a further 4 reverted to sinus rhythm. In the 2 remaining patients, sinus rhythm was obtained in 1 after a shock of 400 watt seconds, and the other remained in atrial fibrillation even after 2 shocks of 400 watt seconds. The 15 patients who were converted maintained sinus rhythm throughout the period of the study.

Within 5 minutes of the restoration of sinus rhythm two measurements of cardiac output were made. These

TABLE I  
EFFECT OF DC CONVERSION ON CARDIAC OUTPUT AS RECORDED BY OTHER AUTHORS

Reference	Interval after DC conversion	Cardiac output after conversion
Oram <i>et al.</i> (1963)	3-16 days	Increased
Kahn <i>et al.</i> (1964)	12 hours	Increased
Graettinger <i>et al.</i> (1964)	1-2 hours	Unchanged
Halmos and Patterson (1965)	7 days	Increased
Duchelle (1966)	1 hour	Unchanged
	1 day	Increased
Morris <i>et al.</i> (1965)	3 hours	Slightly increased
Rodman <i>et al.</i> (1966)	Immediate	Unchanged
	3 hours	Slightly increased

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TABLE II  
EFFECT OF DC CONVERSION ON CARDIAC OUTPUT AND STROKE VOLUME

Patient	Before conversion			3 min. after conversion			3 hr. after conversion			3 days after conversion		
	Heart rate/min.	Cardiac output (l./min.)	Stroke vol. (ml.)	Heart rate/min.	Cardiac output (l./min.)	Stroke vol. (ml.)	Heart rate/min.	Cardiac output (l./min.)	Stroke vol. (ml.)	Heart rate/min.	Cardiac output (l./min.)	Stroke vol. (ml.)
P. McC	92	6.3	70	84	6.4	76	70	6.4	92	64	8.3	130
V.E.	74	3.6	49	72	3.4	48	80	3.4	42	73	3.6	49
H.B.	80	4.5	57	70	4.1	53	72	4.8	68	74	5.2	70
G.C.	110	6.3	57	86	5.6	65	86	6.6	77	68	6.2	72
A.C.	113	5.7	51	95	4.2	44	95	5.4	57	74	7.6	103
E. McC	80	4.7	54	72	4.5	63	75	5.8	77	65	6.1	94
M.H.	80	4.8	61	84	5.2	63	76	5.1	67	70	5.9	84
T.D.	72	5.6	78	83	6.0	76	72	6.2	86	72	7.0	98
P. McC	84	6.6	81	76	6.8	90	68	6.1	90	68	9.0	133
G.C.	84	5.5	65	76	4.9	65	66	6.8	103	66	6.0	92
E.I.	78	5.8	74	67	5.7	85	76	6.3	83	71	7.5	106
H.R.	104	4.0	38	100	4.5	45	102	4.7	46	92	7.6	83
J.D.	84	5.4	64	64	5.7	90	66	6.8	104	66	8.2	124
A.H.	118	3.1	26	86	3.1	36	82	4.4	53	72	4.1	57
J.G.	72	4.2	59	64	4.3	70	64	4.8	77	60	5.1	85
Mean	88.0	5.1	59.3	78.6	5.0	65	76	5.57	75.5	70	6.52	93.2

observations were repeated three hours after conversion, after which the catheters were removed. Three days later, under similar conditions, identical catheters were inserted into the opposite median cubital vein and femoral artery. Two estimations of resting cardiac output were made. No drugs apart from the anaesthetic agent were given during the period of the study.

In 6 of the patients undergoing cardiac output studies, and in a further 7 patients who had a successful DC conversion but in whom cardiac output studies were not made, the oxygen consumption was measured spirometrically before and at 3 hours and 3 days after conversion.

### RESULTS

Observations of heart rate, cardiac output, and the calculated stroke volume in the 15 patients who returned to sinus rhythm are shown in Table II.

The initial cardiac output ranged from 3.1 l./min. to 6.6 l./min. (mean 5.1 l./min.), and the stroke volume from 26 ml. to 81 ml. (mean 59.3 ml.). Immediately after conversion to sinus rhythm the cardiac output did not change significantly, the mean fall being 0.1 l./min. ( $0.4 > p > 0.3$ ). The mean rise in stroke volume was 5.7 ml. and the mean fall in pulse rate was 9.4 beats per minute.

Three hours after conversion 12 patients showed a slight increase in cardiac output, and 3 a slight decrease. The mean difference from the pre-conversion value was 0.4 l./min. and was not significant ( $0.2 > p > 0.1$ ). The stroke volume showed a mean increase of 16.2 ml. which is highly significant ( $p < 0.01$ ). There was a mean decrease in heart rate of 12 beats per minute.

Three days after restoration of sinus rhythm, the cardiac output was greater than before conversion in 13 patients. In 1 patient it was unchanged, and in 1 it was slightly reduced. There was a mean

increase of 1.4 l./min. which was highly significant ( $p < 0.01$ ). The mean increase in cardiac output between the third hour and the third day after conversion of 0.95 l./min. was also highly significant ( $p < 0.01$ ). The stroke volume increased in all but one patient in whom it remained unchanged. The mean increase was 33.9 ml. The mean increase in stroke volume between 3 hours and 3 days after conversion was 17.7 ml. and the mean decrease in heart rate over the same period was 6 beats per minute.

The percentage increases in mean cardiac output, stroke volume, and heart rate for each patient at 3 minutes, 3 hours, and 3 days after conversion are presented in the Figure. The cardiac output fell by 2 per cent immediately after restoration of sinus rhythm, but increased by 10 per cent after 3 hours and by 29 per cent after 3 days. The stroke volume increased by 10 per cent after 3 minutes, by 27 per cent after 3 hours, and by 57 per cent after 3 days.

In the 13 patients in whom serial measurements of oxygen consumption were made, the mean oxygen consumption before conversion was 280 ml./min. (range 217–383). Three hours after conversion the mean oxygen consumption of 283 ml./min. (range 227–400), was not significantly altered ( $p > 0.5$ ). Three days after conversion the mean oxygen consumption was 270 ml./min. (range 210–375). The mean fall in oxygen consumption at 3 days, compared with the value before conversion, was just significant ( $p = 0.05$ ).

### DISCUSSION

These results show a well-marked increase in cardiac output 3 days after conversion of atrial fibrillation to sinus rhythm. Most workers (Oram *et al.*, 1963; Kahn *et al.*, 1964; Morris *et al.*, 1965)

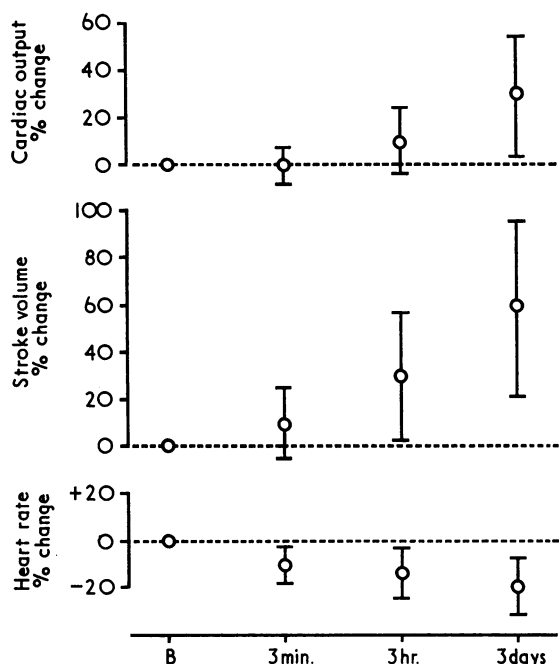


FIG.—The change in cardiac output, stroke volume, and heart rate expressed as a percentage of the value before conversion (B) in 15 patients. The open circles represent the mean change and the vertical lines the standard deviation.

have shown an increase in output in the majority of patients studied, but several have found no significant increase. Graettinger, Carleton, and Muenster (1964) studied 21 patients one to two hours after conversion and found no significant change in cardiac output in 20. Duchelle (1966) studied 11 patients one hour after conversion and found no change in output. Similarly, Rodman, Pastor, and Figueroa (1966) showed no change in cardiac output immediately after conversion. Rodman *et al.* repeated their observations three hours after conversion, and found a 12 per cent increase. Duchelle repeated his observations one day after conversion and demonstrated a 25 per cent increase in cardiac output.

Table I shows the results obtained by other investigators and the interval between conversion and measurement. In general, measurements made within a few hours of conversion have shown little change in cardiac output, and measurements made after a longer interval have shown an increase.

In the patients studied here the cardiac output immediately after conversion was unchanged. The mean increase in output of 10 per cent recorded three hours after conversion was not statistically significant. But the average increase in cardiac

output of 29 per cent found three days after conversion was highly significant. It appears that after conversion to sinus rhythm the cardiac output does not immediately alter, but increases over the next few days. This increase is associated with an increased stroke volume.

Immediately after conversion the cardiac output failed to increase. The effect of the anaesthetic agent and the possible myocardial depressant effect of the countershock itself make interpretation of data obtained three minutes after conversion difficult.

Three hours after conversion the cardiac output was not significantly altered. Residual cardiac depression from methohexitone sodium is unlikely. The actions of this drug are brief and are unlikely to affect observations made at 3 hours after injection (Dundee, 1963). Persistence of a depressant effect of DC countershock is possible. However, one patient in whom DC conversion was unsuccessful had cardiac outputs of 5.6, 6.1, 5.8, and 6.1 l./min. before, 3 minutes, 3 hours, and 3 days after DC conversion. This does not support a depressant effect from DC shock.

In comparing measurements of cardiac output made at different times in any patient, it is important that the patient's metabolic state should be constant (Morris *et al.*, 1965). In these experiments an increase in metabolic rate can be excluded as the cause of the increased cardiac output observed three days after conversion. At this time there was a slight fall in mean oxygen consumption, probably accounted for by diminished anxiety on the part of the patient. In spite of this fall, the resting cardiac output was increased in all but 2 instances.

Other possible explanations for the rise in cardiac output between 3 hours and 3 days after conversion were examined. The first was change in heart rate. Between 3 hours and 3 days after conversion the heart rate fell by six beats per minute and the cardiac output rose by 0.95 l./min. However, in the 10 patients in whom the heart rate changed by six beats per minute or less between the third hour and third day after conversion, the mean rise in output was similar to that recorded in the 5 patients in whom the change in heart rate was greater. Atrial and ventricular pacing studies in normal subjects (Ross, Linhart, and Braunwald, 1965) and in patients after DC conversion (Duchelle, 1966) have revealed no significant change in cardiac output over a comparable range of heart rate. It is unlikely that the increase in cardiac output can be accounted for by change in the heart rate.

Another possible explanation for the delayed rise was change in the time relation between atrial and ventricular contraction. Prolongation of the P-R

interval after DC conversion has been reported (Halmos, 1966). In the patients studied here the mean P-R interval at 3 hours was 0.18 sec. (range 0.13-0.22). Three days after conversion the P-R interval was still 0.18 sec. (range 0.13-0.21). Thus, a change in the time relation between atrial and ventricular contraction cannot account for the increase in output between 3 hours and 3 days.

The most likely explanation for the delayed rise in cardiac output is delay in return of effective mechanical contraction of the atria. Duchelle (1966) measured the height of the "a" waves in the right atrium immediately, and 24 hours after DC conversion. He found an increase at 24 hours. Ikram, Nixon, and Arcan (1968) recorded the left ventricular apex displacement curve and showed that return of detectable left atrial contraction might be delayed for several days after restoration of sinus rhythm, especially in patients with rheumatic heart disease.

It appears that after DC conversion, the immediate return of normal electrical activity in the atria, as indicated by the electrocardiogram, is often not associated with immediate mechanical improvement in atrial function. Measurements of cardiac output made within a few hours of restoration of sinus rhythm may fail to show any increase, and this could account for the differing conclusions reached by various authors as to the effect on cardiac output of atrial contraction.

#### SUMMARY

In 16 patients with atrial fibrillation, cardiac output and heart rate were measured before, and at 3 minutes, 3 hours, and 3 days after attempted DC conversion.

There were 11 male and 5 female patients. The mean age for patients of each sex was 53 years.

Nine patients had rheumatic, 3 ischaemic, and 3 thyrotoxic heart disease. One patient had idiopathic atrial fibrillation.

DC conversion was successful in 15 patients.

There was no significant change in cardiac output at 3 minutes and 3 hours after conversion. Three days later there was an average rise in cardiac output of 29 per cent.

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