ACUTE RENAL FAILURE AFTER SURGERY
USING CARDIOPULMONARY BYPASS

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This paper is the brief report of a number of patients who developed acute renal failure after open heart operations in which cardiopulmonary bypass was used. It seemed of interest to discuss these patients here, since, after being maintained on one artificial internal organ, they developed pathology treated with another artificial internal organ.

PATIENTS AND OPERATIONS

All patients were under the care of Sir Russell Brock and Mr. Donald Ross at Guy's Hospital. Four of the cases were dialysed by Wing-Commander Jackson and his team at Halton, and were mentioned in the paper by Molloy. Table I shows the diagnosis and operations in the fifteen patients under consideration. These occurred during a two and a half year period during which 410 open heart operations were performed. All but two of the patients who developed renal failure had prolonged and complex operations, two thirds having either total corrections of Fallot's tetralogy or aortic valve substitutions and reconstructions. The ages and sex of patients are given in Figure 2. All perfusions were carried out under halothane anaesthesia using the machine designed by Ross and described by Molloy and Linfield.

COURSE OF THE RENAL FAILURE

The mortality in this group was very high; only 3 patients survived. The rate of tissue catabolism was high with accumulation of blood urea averaging 60 mg.\%/day (Figure 1). The course of all cases is summarised in Figure 2. With three exceptions, the patients failed to pass more than 300 ml. urine/12 hours from the time of operation. Severe oliguria of this degree is present in about half the cases similar to those considered here so that only if anuria, or oliguria with low urinary urea or osmolarity is present can renal failure be diagnosed. Five patients required re-operation, 4 for cardiac tamponade- one patient had a new aortic homograft inserted 5 days after the first. Nine patients were dialysed a total of 15 times. All three survivors received this treatment.

FACTORS INVOLVED IN THE GENESIS OF THE RENAL FAILURE

Time of perfusion, How rates and arterial pH are given in Table II. There was evidence of previous renal disease in six cases (Table III). Of the factors listed in Table III as being present in the post-operative period, most patients showed more than one (average of 2.6). The commonest associated factor was heavy post-operative bleeding, defined as more than three litres which was not always associated with persistent hypotension.

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DISCUSSION

There is little data on renal function and renal failure during and after cardiopulmonary bypass. Renal plasma flow is reduced when low rates of perfusion are employed and is never normal unless higher flow rates than usual (3.5 l./sq.m./min.) are used. Formation of urine may depend as much upon the pressure at which the blood is supplied as the flow rate. The effects of replacing the normally pulsatile blood flow to the kidneys with continuous flow are unknown. Hypothermia, if used alone or in addition to bypass will also reduce both renal plasma flow and glomerular filtration. Patients, who pass urine during operation seem to have less oliguria post-operatively.

Doberneck, Reiser and Lillehei reported 30 cases of renal failure in a series of 1000 bypasses. Fallot's tetralogy was proportionately the commonest diagnosis, and the mortality was 87%. The authors concluded that the bypass itself did not contribute directly to the renal failure, but that hypotension and arrhythmias during and immediately after the procedure were the main causes. In contrast, Yeh, et al. concluded from their 17 cases that 'renal failure' was more likely with increasing length of perfusion, increasing haemolysis, lower blood pH and particularly poorer perfusion rates (below 2 litres/sq. m./min.). Their cases, however, were much less severe than those of Doberneck et al.; only one patient needed dialysis and only one died. The present series resembles the severely ill cases of Doberneck et al.

These authors note that 20 of their 30 cases had evidence of renal abnormalities before bypass; Yeh et al. do not comment on this aspect. In our series, 6 of 15 cases had pre-operative renal impairment. No control data are available for renal function in a population of patients such as those coming to bypass, and this may well be a significant factor; more information is needed. However, many operations have been performed successfully on patients with albuminuria and/or reduced creatinine clearances.

During the bypass itself, a number of factors might contribute to the onset of renal failure; these have been well discussed by Yeh et al. (Table II). It is impossible to compare the present series with an adequate control group because both the type of case and operation, and the techniques of perfusion, have changed during the period in which these cases arose. The appearance of renal failure has been very intermittent. All the patients had long perfusions but flow seems to have been adequate and arterial pH maintained.

In the post-operative period, a number of significant factors were present (Table III). Most patients were oliguric from operation but this is to be expected in 50% of cases recovering normally from bypass. Persistent anoxia only contributed in 3 cases and persisted in spite of intermittent positive pressure respiration. Two of these cases showed acute cortical necrosis at post mortem rather than the expected tubular necrosis. Obviously such anoxic cases are unlikely to recover. Haemolysis was present in 4, and severe in 2. Heavy post-operative bleeding was present in 11, with cardiac tamponade in 4. Persistent hypotension was not recorded in all cases, but it is known that in oligaeic states the renal blood flow may cease altogether at systolic blood pressures as high as 100 mm Hg, presumably as the result of pressor amine release. These agents were also given therapeutically in 8 out of 11 cases.
It is likely that a number of causes during the operation, haemolysis, acidosis, low perfusion rates and hypothermia will pre-dispose to the renal impairment described by Yeh et al., and frequently seen in cases similar to those described here with long perfusions. Post-operatively, hypotension, bleeding tamponade, arrhythmias, and re-operation with another anaesthetic will add all their effects. In the present series these post-operative factors, in particular bleeding, have been the major determinants in the appearance of the renal failure.

A survival rate of only 13% of Doberneck's cases and 20% in the present series leaves a great deal to do. The cases here were mostly 'hyercatabolic' but the rates of urea accumulation were no higher than those found in renal failure after other major surgical operations (17) (Figure 1). Frequent or continuous dialysis was not employed, except in one jaundiced patient who did not survive (Figure 2). This patient had haemolysis from an unrecognised anti-P factor, with cardiac arrest and hypotension during and following re-operation for cardiac tamponade. However, in view of the favourable results with continuous or early dialysis in severe renal failures from other causes (17-19), this type of management would seem to be the best to pursue in this group with its high mortality. To finish on a more cheerful note, there have been no cases of renal failure now for more than six months, during which more than 80 bypass operations have been carried out. It is difficult to be certain of the reason for this improvement; the routine use of mannitol diuresis (20) post-operatively, and better control of bleeding have probably contributed most.

REFERENCES

TABLE I

<table>
<thead>
<tr>
<th>Total correction of Fallot*</th>
<th>No. of cases</th>
<th>Survivors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aortic Stenosis/incompetence</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>(homograft, 2; reconstruction, 2)</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Mitral incompetence; reconstruction</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>ASD (one with PVS and valvotomy)</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Closure of VSD</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>**</td>
<td>15</td>
<td>3</td>
</tr>
</tbody>
</table>

*2 patients had previous Blalock operations, one a closed infundibular resection. (ASD = atrial septal defect; PVS = pulmonary valve stenosis; VSD = ventricular septal defect.)

TABLE II

| Perfusion rate | 2.06-2.64 (mean 2.28) l./sq. m. Imino |
| Duration of bypass | 66-175 (mean 110) mins. |
| Hypothermia | 5 cases (lowest temp. 22, 26, 27, 28, 28°C) for 10-70 mins. |
| Final Arterial pH | 7.34-7.42 (only five cases available) |

TABLE III

| Previous renal impairment* | 6 cases |
| Persistent postoperative hypoxia + | 3 “ |
| Free circulating haemoglobin | 4 “ |
| Cardiac tamponade | 4 “ |
| Persistent postoperative hypotension* | 5 “ |
| Heavy postoperative bleeding** | 11 “ |
| Jaundice | 3 “ |
| Air embolism | 1 “ |

* blood urea raised in one, creatinine clearance down in four, albuminuria in one.
+ arterial oxygen saturation below 80%
* three with persistent cardiac arrhythmias.
**in excess of three litres (10 cases thoracic; one femoral; three cases, abnormal coagulation).
Figure 1. Rate of tissue breakdown roughly assessed by rate of rise of blood urea. These patients are not more hypercatabolic than other post-surgical renal failures.

Figure 2. The clinical course of the renal failure. Most deaths occurred in cardiovascular collapse with arrhythmias. Two patients died in anuria two days after operation.
THE CHAIRMAN, W. J. KOLFF, Cleveland: Would you perhaps tell the audience what is the type of oxygenator used by Mr. Ross?

J. S. CAMERON (London): Yes, he designed this machine. It is a double disc oxygenator.

THE CHAIRMAN: Is there a direct relationship between the kind of oxygenator which is used - -?

J. S. CAMERON (London): I am sorry, I should have mentioned this. This is a disc oxygenator. There was air embolism in one patient, but this was not due to the heart-lung machine; it was due to a technical error at the operation.

THE CHAIRMAN: Thank you very much. Are there other questions or comments?

E. J. DORHOUT MEES (Utrecht): We have had the opportunity of following five patients operated on by a team at the St. Antonais Ziekenhuis for acute renal failure, and we got the impression that the course was different from ordinary acute renal failure. All died eventually, but one of them was kept alive for rather a long time and his renal failure eventually recovered, but the recovery was very slow and there was not a typical polyuric phase. Throughout the whole course of all these patients there was a relatively high creatinine and low sodium concentration in the urine. Post mortem the patient who survived anuria died from infective complications - they all had tubular swelling, no necrosis and very few abnormalities. I should like to ask Dr. Cameron, or anybody else, if he has had similar experience.

J. S. CAMERON (London): With regard to the first point, of the three cases who survived, one, you may have noticed, was never oliguric at all by the definition we imposed. He passed up to 800 cc. or 900 cc. dilute urine each day and his blood urea climbed. The other two did have a fairly typical diuretic phase with large volumes of urine being passed, and some of the other patients were completely anuric so that we had no urine to analyze.

The data on sodium concentration that we have is not remarkable in terms of ordinary acute renal failure and, as far as I can remember, the urinary ureas - we did not do urinary creatinines - were of the order of 200 mg. to 400 mg. per cent, in other words very low.

On the last point, we do not have post mortem pathology on all of these cases although we have biopsy information on one. We know of one acute cortical necrosis and one probable acute cortical necrosis on which unfortunately no histology was done. Other than that, we have one biopsy which showed a fairly typical picture of acute tubular necrosis. We have not a great deal of information on the pathology, and I should be interested to hear if anyone has experience on this.

THE CHAIRMAN: My guess is that when Dr. Dorhout Mees sees that these patients recover less well than other patients in acute renal failure, perhaps the repair to the heart has not been as good.

E. J. DORHOUT MEES (Utrecht): That was our impression, indeed.
THE CHAIRMAN: My feeling about this has been fortified by the fact that since at the Cleveland Clinic they have virtually stopped fooling around with hearts, and have virtually stopped trying to repair leaking mitral valves and trying to cut and repair aortic valves and have simply replaced them by ball valves, the occurrence of renal failure has disappeared. If it still occurs it is a complication of cardiac failure after the operation.

E. J. DORHOUT MEES (Utrecht): It was usually after a second operation had taken place.

A.M. JOEKES (London): I have seen a fairly large number of patients with acute renal failure following open heart surgery. I certainly would not agree with Dr. Dorhout Mees’ suggestion that these follow a different course either functionally or prognostically unless, as Dr. Kolff has suggested, the myocardium is primarily at fault.

There is one question that I should like to ask Dr. Cameron. Has the priming mixture of the heart-lung machine been altered since April of this year? Does he know whether it previously used whole blood, or whole blood and glucose, or Rheomacrodex? Does he know what the position is now?

J. S. CAMERON (London): I should say that some of the patients whom Dr. Joekes has seen were included in this presentation. The priming mixture has not been altered since April of this year. One of the troubles about doing such a study and trying to get useful information from it has been the difficulty of getting adequate control information, and the fact that techniques over the two-and-a-half year period during which these cases have arisen have changed very considerably, though not, so far as I am aware, during the last six months. During 1962 and 1963 a fair number of changes took place in the composition of the primer for the pump. That is one reason for my not discussing this in relation to these cases, because we really do not know what went on at a particular point. I am sure this may be important, particularly the haematocrit of what goes through the pump.

THE CHAIRMAN: For those in the audience who are more familiar with artificial kidneys than with heart-lung machines, there is a tendency now to prime heart-lung machines with 5 per cent dextrose or glucose in water, or with dextran and mannitol instead of blood. There is a feeling that this, combined with adequate hydration of the patient before, goes a long way toward avoiding the complications that we are discussing.

E. KUTILAKE (London): We use Rheomacrodex in priming the Melrose heart-lung machine. The incidence of renal failure in total bypass is not high. Last year, 3 cases were referred to the Urological Service with acute tubular necrosis. We found that peritoneal dialysis was better in these cases.

We agree with Dr. Joekes that the course of renal failure after cardiac surgery is no different from that of any other acute tubular necrosis.

*Note added in proof: Rheomacrodex has been included in the priming mixture since August, 1963. The usual mixture is 4 blood: 3 dextrose