ANAESTHETIC ASPECTS OF RENAL TRANSPLANTATION

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Introduction
Since the widespread acceptance of renal transplantation there have been many advances in management. From the point of view of the anaesthetist the most important is the great improvement in the pre-operative state of the patients. Whereas ten years ago they were frequently so ill that it was a considerable anaesthetic achievement to steer them successfully through the operative procedure, their condition is now generally so much better that they seldom give cause for real concern while in theatre. Against this background it is possible to pay greater attention to the interactions between the kidney and anaesthetic drugs, and an attempt can be made to devise an anaesthetic technique which will cause minimal disturbance to the transplanted kidney without being of any disadvantage to the recipient. In order to select such a technique one must first consider the potential problems presented by the state of the transplant patient.

While these problems overlap to some extent they can be discussed under the following headings; (1) anaemia; (2) hypertension; (3) electrolyte and acid–base imbalance; (4) bleeding tendency; (5) susceptibility to infection; (6) veins, shunts, and fistulae; (7) central venous pressure; (8) non-anaesthetic drugs; and (9) interaction of the kidney and anaesthetic agents.

Anaemia
Patients in renal failure become anaemic for many reasons. Failure to secrete erythropoietin results in a low rate of red cell production. Fluid retention results in a high circulating plasma volume and hence dilution of red cells. The patients are left anaemic intentionally because low viscosity and high blood flow reduce the likelihood of shunt failure, and because each transfusion involves the risk of causing thrombosis of a vein which may be needed for the establishment of a shunt or a fistula. The formation of antibodies which may subsequently prove to be antibodies to the transplanted kidney is also a possibility. Blood transfusion, by increasing haemoglobin levels, leads to further depression

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of erythropoietin production, and the increase in red cell destruction which follows transfusion leads to an overloading of the iron stores of the body, with the possible development of haemosiderosis. This increase in haemolysis is further aggravated by repeated dialysis. The patients are therefore transfused as seldom as possible, and since it is not known when a kidney will become available, recipients of cadaveric kidneys will often reach the operating theatre in an anaemic state.

**Arterial hypertension**

The prolonged hypertension in these patients may have led to atherosclerosis and heart disease. With the high blood volume due to fluid retention they may therefore be verging on congestive cardiac failure and pulmonary oedema. This is one of the aspects of the preparation of patients for surgery in which improvement has been most marked. The increased blood volume can be rectified by dialysis and the high arterial pressure modified by antihypertensive drugs. This combination is usually successful in controlling the tendency to develop cardiac failure. Antihypertensive drugs may interact with anaesthetic agents, notably tubocurarine and halothane, but this does not tend to be a major problem. A further complication which may arise in patients who are receiving methyldopa is the development of autoantibodies which interfere with the normal cross-matching procedure.

**Electrolyte and acid–base imbalance**

Because of the haemodialysis programme there is now rarely a large metabolic acidosis or high serum potassium level at the time of operation. Nevertheless, electrocardiographic monitoring is advisable as this allows early recognition of changes in the serum potassium concentration. Samuel and Powell1 gave the average serum electrolyte concentrations in 100 patients at the time of anaesthesia for renal transplantation. The mean serum bicarbonate level was 24 mEq/l. and that of potassium 4.4 mEq/l. (the mean levels in our hospital being 23.1 and 4.5 mEq/l. respectively). The serum sodium level tended to be a little low and that of urea to be rather high, typically being between 100 and 200 mg/100 ml (mean 121 mg/100 ml in our patients). When electrolyte imbalance or acidosis is present satisfactory reversal of the action of muscle relaxants may be difficult2.

**Bleeding tendency**

Patients with shunts may be receiving anticoagulant therapy, though this is now usually reserved for those whose shunts have shown a tendency to clot. Uraemia itself induces a bleeding tendency, while in some units patients undergoing renal transplantation are fully heparinized, although it is more common to rely on local heparinization at the site of the anastomosis. For these reasons one would expect a greater than average operative blood loss. Full heparinization appears to have little
effect on the degree of blood loss, raising the average replacement requirement from 2.2 to 2.4 units of blood in the series reported by Samuel and Powell. (The mean blood replacement in our patients is 3.1 units.) Aldrete et al. estimated that the mean blood loss due to transplantation alone was only 175 ml. Nevertheless, bleeding may be profuse, and this consideration, coupled with the anaemia, makes prompt and adequate blood replacement essential.

**Susceptibility to Infection**

Uraemia is known to increase susceptibility to infection. In addition, after transplantation the patient will receive a bombardment of corticosteroids and other immunosuppressive drugs. Many indeed are receiving a second transplant (approximately 30% of our patients at present) and may already have been receiving such drugs. A sterile technique for all procedures that may introduce infection, including insertion of intravenous cannulae and intubation of the trachea, is therefore advisable. The wearing of gloves has the additional advantage that it provides some protection for the anaesthetist against the virus of serum hepatitis, which is unfortunately all too commonly present in these patients.

Because of their susceptibility to infection the patients are likely to be given antibiotics, which may lead to anaesthetic complications. Katz et al. quote the case of a patient who received 30 mg of tubocurarine during the course of an operation. Postoperative recovery was normal for 36 hours. He was then given systemic colistin, which itself has neuromuscular blocking properties. This led to recurarization, and artificial ventilation was required for 12 hours.

**Veins, shunts, and fistulae**

In patients with renal failure requiring haemodialysis veins are required for the establishment of fistulae and shunts. They therefore assume a far greater importance than in other surgical patients. Because the failure rate for transplanted kidneys is still high (the world-wide two-year survival rate for transplanted cadaveric kidneys is only 41%) it is unwise to use a forearm vein for other purposes which might later be useful for a shunt. Indeed, most patients who have received a cadaveric kidney need to be haemodialysed once or twice after the operation even if the graft is a success. Any shunts already present must be scrupulously cared for as they are the patient’s lifeline in the event of graft failure. The sphygmomanometer cuff should therefore be placed on the opposite arm to the existing shunt or fistula.

**Central venous pressure**

It was found by Strunin that the arterial pressure tended to rise when the clamps were released after anastomosis of the renal artery. This is thought to be due to the release of renin. Examination of the
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anaesthetic records in our hospital confirms that this episode of hypertension on release of the clamps can occur. In one case the arterial pressure increased from 130/60 to 180/80 mm Hg, while the venous pressure fell from 5 to 2 cm H$_2$O. Another example is shown in Figure 1.

At this stage of the procedure it is an advantage to have a central venous pressure measurement, because the tendency for the arterial pressure to rise can mask the fall which blood loss would otherwise provoke. In our cases the mean fall in central venous pressure was 2 cm

\[ \text{mm Hg} \]
\[ \text{cm H}_2\text{O} \]
\[ \text{time} \]
\[ \text{clamps off} \]

Fig. 1. Increase in arterial blood pressure and fall in central venous pressure (CVP) following release of clamp.

H$_2$O. Thus while the arterial pressure is rising, the central venous pressure falls. Since the patient has no renal function, the central venous pressure measurement is also a safeguard against overloading of the circulation.

Non-anaesthetic drugs

The drugs in this category are mainly agents designed to produce urine flow and immunosuppressives, but may include antibiotics and heparin. The use of mannitol has been criticized because, if the kidney fails to excrete it, fluid may be drawn from the extracellular compartment into the vascular compartment, contributing to circulatory overload. Mannitol is an osmotic diuretic, and it may be questioned whether the tubular cells of a kidney which has been exposed to anoxia should be exposed to the further insult of high osmotic stress. Frusemide is not open to these criticisms. Nevertheless, a more physiological approach
is to use isotonic solutions—for example, Hartmann's solution—to increase urine flow. A recipient's serum commonly contains a high urea concentration and a low sodium concentration. A kidney with little functional impairment when transplanted into this environment will produce urine. The maintenance of extracellular fluid volume is therefore all that is required to ensure that the renal tubules are adequately flushed.

**Interaction of the kidney and anaesthetic agents**

If the effects of anaesthetic agents on the kidney and the effects of the lack of renal function on the length of action of anaesthetic agents are considered together with the factors dealt with above, it should be possible to deduce the requirements for an anaesthetic technique that will have the least chance of adversely affecting the transplanted kidney. In particular, a stable renal blood flow, absence of antidiuretic effect, and absence of sympathetic overactivity must be regarded as being of considerable advantage to the transplanted kidney. In order to facilitate discussion anaesthetic agents will be divided into inhalational agents, analgesics, muscle relaxants, and induction agents.

**Inhalational anaesthetic agents.** Wyant\(^8\) favours regional block, accompanied by sedation with either diazepam or fentanyl and droperidol, rather than inhalational methods for renal transplantation. However, the operative procedure involves major arterial surgery and can be extremely bloody, so that the interference with sympathetic reflexes caused by an epidural or spinal block may be a disadvantage. In addition, the patients realize that the operation will have a great effect on their lives and consequently tend to be apprehensive. The amount of sedation required to calm the nervous patient adequately over the length of time involved is therefore likely to approximate to general anaesthesia. Indeed, Aldrete et al.\(^3\) found that in 21 out of 22 patients undergoing renal transplantation under epidural analgesia a general anaesthetic was required in addition.

Induction of anaesthesia, irrespective of the agents used, results in a reduction of urine flow and an increase in the circulating levels of antidiuretic hormone (ADH)\(^9, 10\). Nitrous oxide has not been shown to have any renal effects apart from this universal action, and is therefore satisfactory.

Halothane has little effect on the kidney provided that the arterial pressure is maintained. The reduction of urine output under halothane anaesthesia has been claimed to be dependent only on the fall in arterial pressure and the resulting drop in glomerular filtration rate (G.F.R.)\(^11\). It was shown by Kaye\(^12\) that the diuretic effect of a dextrose infusion was more depressed by nitrous oxide, oxygen, and halothane than by nitrous oxide, oxygen, fentanyl, and droperidol. Halothane might
be better avoided in patients who are being given large doses of hypotensive drugs but, together with nitrous oxide, it is probably the most suitable inhalational anaesthetic agent. (A word of caution should perhaps be inserted, as Aldrete et al.\textsuperscript{3}, who used halothane for 55\% of their patients, found that six out of the seven cases of severe arrhythmias which they encountered occurred during its use.)

Ether and cyclopropane, besides having the disadvantage that the diathermy should not be used in their presence, both cause renal arterial constriction, and ether also results in a large increase in ADH levels\textsuperscript{13}.

Methoxyflurane has been indicted as a nephrotoxic substance, and the evidence for this is now substantial. In 1966 Crandell et al.\textsuperscript{14} found a 17\% incidence of polyuric renal impairment in patients who had received this agent. Their urine was of fixed low specific gravity and the diuresis failed to respond either to a water load or to an injection of pitressin; this suggests that it is not due to suppression of the release of ADH but is a true nephrotoxic effect of the methoxyflurane. In support of this suggestion, Mazze et al.\textsuperscript{15} found high blood levels of inorganic fluoride and oxalate in patients with renal impairment following methoxyflurane anaesthesia. This nephrotoxic effect is more common in patients receiving tetracycline therapy\textsuperscript{16}. McIntyre and Russell\textsuperscript{17} have shown that methoxyflurane depresses adenosine triphosphatase systems in the dog. These workers have also shown a reduction in inulin and para-aminohippurate clearances, although any anaesthetic agent that reduces G.F.R. can be expected to do this. Of the 23 patients given methoxyflurane by Aldrete et al.\textsuperscript{3}, all developed satisfactory renal function. The evidence at present available, however, strongly suggests a true nephrotoxic action of methoxyflurane. It is not, therefore, a good choice for use during renal transplantation.

**Analgesics.** Almost all analgesic, sedative, and anaesthetic drugs cause a fall in urine production and a rise in the circulating level of ADH\textsuperscript{9, 10}. The effects of the newer analgesics phenoperidine and fentanyl, both on renal function\textsuperscript{\textsuperscript{18}} and on the cardiovascular system\textsuperscript{19, 20}, have been assessed in man. Work on the renal effects of fentanyl has been carried out only when the drug has been used in conjuction with droperidol. In considering the analgesics, therefore, fentanyl with droperidol must unfortunately be compared with morphine or pethidine without droperidol. Scientifically, this is unsatisfactory, but since this is how the drugs are usually employed the unscientific nature of the comparison does not lessen its clinical validity. Morphine and pethidine produce a marked fall in G.F.R. and possibly an increase in the secretion of ADH\textsuperscript{9}. In contrast, fentanyl combined with droperidol has a very slight effect on urine production, having no significant effect on the haemodynamic parameters of renal function and producing only a moderate decrease in solute clearance and sodium and water excretion\textsuperscript{18}. The ability of the kidney to excrete a
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water load has also been shown to be less impaired under anaesthesia with fentanyl and droperidol than with halothane. The removal of phenoperidine from the body is effected almost equally by the kidneys and the liver, whereas the removal of fentanyl, pethidine, and morphine is mainly by the liver, only 10% being excreted by the kidneys. If renal excretion is inadequate, phenoperidine is the drug whose duration of action is most likely to become prolonged, and it should therefore be used with caution in patients with poor renal function. The evidence would thus suggest that fentanyl is the analgesic of choice.

**Muscle relaxants.** Suxamethonium is frequently used. Using assisted ventilation, Katz et al. found no difficulty with this drug. The dosage employed in their series was modest, being of the order of 200 mg in 3–5 hours. Wyant found that in some patients repeated haemodialysis led to reduced pseudocholinesterase concentration in the blood and that in consequence a prolonged action of suxamethonium could be expected. Other workers have confirmed this finding, although some claim that total body pseudocholinesterase is not reduced. Suxamethonium is known to raise the serum potassium level. Most of these patients either have a high serum potassium level or have had repeated haemodialysis, which in either case is an argument for not using suxamethonium. Indeed, Roth and Wüthrich state that uraemia with a raised serum potassium level is an absolute contraindication to the use of suxamethonium and that uraemia is a relative contraindication to its use even when the potassium level is normal.

Gallamine is totally excreted by the kidney in the dog. Patients in renal failure who were given gallamine in normal dosage showed signs of residual paralysis after reversal of the neuromuscular block by neostigmine. Gallamine is therefore a quite unsuitable relaxant for use in renal transplantation.

Tubocurarine is the relaxant that has been most frequently used for transplantation in our hospital (over 95% of patients). Normally 70–80% of this drug is excreted by the kidney; the balance is managed by the liver and mainly excreted in the bile. In view of the relatively large component of renal excretion, one might expect a prolongation of the action of tubocurarine in patients with renal failure. Its length of action does not seem to be prolonged in this condition however, and it has been shown that patients with a successful transplant who return for other types of surgery do not require more tubocurarine than they did when they had no renal function. Nevertheless, experience with tubocurarine has not been uniformly favourable. Katz et al. had difficulty in two out of four patients who were given the drug. Strunin and Aldrete et al. also reported some trouble, but Samuel and Powell used it without encountering any problems. The action of tubocurarine is
prolonged by acidosis. This is seldom of importance, as the acid–base state of the patients has usually been corrected by dialysis. If it has not, the metabolic acidosis can be corrected during the operation.

Pancuronium has been used without trouble in a few cases. The pattern of excretion of pancuronium is essentially similar to that of tubocurarine. Some is excreted in the urine\(^{28}\), some is taken up by the liver, and some of this appears in the bile. The percentages concerned are, however, uncertain. As with tubocurarine, pancuronium block is prolonged by acidosis\(^{20}\). The advantages of tubocurarine over pancuronium are that it has a flatter dose–response curve\(^2\), which will give a slightly greater margin for error if there is any potentiation of its action, and that its pattern of excretion is more fully elucidated. Pancuronium on the other hand has an advantage in cases in which one is worried about the interaction of hypotensive agents, as its action on the cardiovascular system is hypertensive\(^{20}\). It may also have an advantage over tubocurarine in its ability to maintain the G.F.R., though this is probably merely a further expression of its hypertensive action\(^{12}\).

The balance of evidence at present would seem to favour tubocurarine, though the situation may well change when more is known of the normal excretory pathway of pancuronium.

**Induction agents.** Arguments for and against different methods of induction of anaesthesia are not altered appreciably by the absence of renal function. The termination of action of most intravenous induction agents is by redistribution of the drug, although propanidid is an exception. It is only with incremental doses, therefore, that the metabolic and excretory pathways take on any clinical significance. For cadaver transplants the patient is frequently informed at the last minute, so that there will have been no period of starvation. A ‘crash’ induction may then be thought advisable. In this case the intravenous agent should be as rapidly acting as possible. Thiopentone, methohexitone, and propanidid are therefore preferable to diazepam or droperidol. The chosen drug should be followed by suxamethonium for rapid intubation (though if the serum potassium level is high a strong case can be made out for avoiding this agent by using an inhalational induction and intubating under halothane). Propanidid has the potential disadvantage that it prolongs the action of suxamethonium, which may already be prolonged because of low pseudocholinesterase levels following haemodialysis. Thiopentone and methohexitone are therefore theoretically preferable.

If the procedure is not an emergency, the speed of onset of the induction agent is of less importance. The likelihood of vomiting in a uraemic patient, however, is high. This may be due in part to the gastritis which accompanies the condition, but the main factor is thought
to be the electrolyte imbalance and the high blood levels of nitrogenous waste acting on the chemoceptive trigger zone. The butyrophenones such as droperidol depress the chemoceptive trigger zone and suppress vomiting initiated from this source, though they will have no effect on vomiting caused by gastritis. The droperidol/fentanyl combination has also been shown to have some advantages in maintaining stability of the renal vascular state and of the cardiovascular system in general. This combination, therefore, offers a good method of intravenous induction for an elective procedure.

**Anaesthetic technique**

It is now possible to assemble the anaesthetic technique which, in the light of present evidence, should be the most satisfactory. Many others are, however, used without any practical disadvantage. This technique is summarized in Table I. Two intravenous infusions are necessary to allow early or rapid blood replacement, the administration of drugs, and measurement of central venous pressure. In addition,

<table>
<thead>
<tr>
<th>Anaesthetic Technique for Renal Transplantation</th>
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<tbody>
<tr>
<td><strong>Emergency cases</strong></td>
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<tr>
<td>Induction</td>
</tr>
<tr>
<td>Thiopentone</td>
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<tr>
<td>To intubate</td>
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<tr>
<td>Cricoid pressure</td>
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<tr>
<td>Maintenance of anaesthesia</td>
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<tr>
<td>Maintenance of relaxation</td>
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<tr>
<td>Maintenance of analgesia</td>
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<tr>
<td>Termination of relaxation</td>
</tr>
</tbody>
</table>

because serum potassium levels may change and most of the patients are receiving antihypertensive drugs, the electrocardiogram should be monitored. Because of the anaemia, oxygen administration by mask should be carried on well into the postoperative period.

**Some results of neuroleptanaesthesia in renal transplantation**

Since this technique has been largely planned on the basis of work in other fields, it is of interest to consider the results of its use in anaesthesia for renal transplantation. During the past year 10 patients have undergone elective renal transplantation, receiving a kidney from a relative. Both the donor and the recipient were premedicated with droperidol 2.5–5 mg, papaveretum 10–15 mg, and hyoscine 0.2–0.3 mg given intramuscularly 1½ hours before operation. Typical anaesthetic charts for a recipient and donor on one occasion are shown in Figures 2 and 3. Usually the anaesthetic drugs chosen were identical for both donor and recipient in order to ensure that the donated kidney was exposed to the same drugs throughout.
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C.P. 14years Renal Transplant

<table>
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<tr>
<th>14</th>
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-1-2 Atropine 1-2mg
-2-5 Neostigmine 2-5mg

Fig. 2. Anaesthetic record chart of recipient C.P. The top row of figures indicates time in hours. dtc = D-tubocurarine. I.P.P.V. = intermittent positive pressure ventilation. B.P. = arterial blood pressure (mm Hg). C.V.P. = central venous pressure (cm H2O).

The recipients’ ages ranged from 14 years to 40 years. Eight out of ten were treated hypertensives. Their haemoglobin levels ranged from 8.3 to 15.5 g/100 ml (mean 9.9 g/100 ml) and their haematocrit readings from 24 to 47%. Two patients (E.M. and J.Wi.) had preoperative cardiac involvement other than left ventricular hypertrophy. E.M. had second-degree heart block and J.Wi. had a pericardial effusion which required drainage before, during, and after the operation. Only E.M. had a serious intra-operative complication. This was a transient cardiac arrest 5 minutes after reversal of paralysis, from which there were no long-term ill effects.

H.P. 47years Renal Transplant Donor

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-1-2 Atropine 1-2mg
-2-5 Neostigmine 2-5mg

Fig. 3. Anaesthetic record chart of donor for C.P. Key as for Fig. 2.
### TABLE II
CLINICAL DATA FROM RENAL TRANSPLANT RECIPIENTS

<table>
<thead>
<tr>
<th><strong>Patient and weight</strong></th>
<th><strong>Age (years)</strong></th>
<th><strong>Preoperative Haemoglobin (g/100 ml)</strong></th>
<th><strong>Preoperative Haematocrit (%)</strong></th>
<th><strong>Minimum Blood Pressure (mm Hg)</strong></th>
<th><strong>Duration of Operation (hours)</strong></th>
<th><strong>Blood Loss (ml)</strong></th>
<th><strong>Ischaemic Time (min)</strong></th>
<th><strong>Total Dosage</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>C.P. 38.5 kg</td>
<td>14</td>
<td>12.2</td>
<td>35</td>
<td>120/80</td>
<td>100/60</td>
<td>5½</td>
<td>750</td>
<td>55</td>
</tr>
<tr>
<td>R.W. 57.8 kg</td>
<td>33</td>
<td>8.9</td>
<td>28</td>
<td>105/60</td>
<td>No fall</td>
<td>5½</td>
<td>1,000</td>
<td>55</td>
</tr>
<tr>
<td>E.M. 51 kg</td>
<td>21</td>
<td>7.2</td>
<td>24</td>
<td>140/70*</td>
<td>No fall</td>
<td>5</td>
<td>3,400</td>
<td>65</td>
</tr>
<tr>
<td>J.A. 62.9 kg</td>
<td>33</td>
<td>9.3</td>
<td>30</td>
<td>200/85*</td>
<td>170/70</td>
<td>4</td>
<td>1,800</td>
<td>55</td>
</tr>
<tr>
<td>A.M. 65 kg</td>
<td>33</td>
<td>15.5</td>
<td>47</td>
<td>140/80*</td>
<td>120/70</td>
<td>3½</td>
<td>1,160</td>
<td>49</td>
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<tr>
<td>S.G. 61.7 kg</td>
<td>25</td>
<td>10.6</td>
<td>34</td>
<td>140/80*</td>
<td>No fall</td>
<td>4½</td>
<td>2,000</td>
<td>52</td>
</tr>
<tr>
<td>B.P. 55 kg</td>
<td>34</td>
<td>8.8</td>
<td>—</td>
<td>150/100*</td>
<td>130/100</td>
<td>5</td>
<td>900</td>
<td>70</td>
</tr>
<tr>
<td>J.Wi. 50 kg</td>
<td>40</td>
<td>8.3</td>
<td>—</td>
<td>200/100*</td>
<td>150/90</td>
<td>5½</td>
<td>2,800</td>
<td>75</td>
</tr>
<tr>
<td>J.Wa. 68 kg</td>
<td>35</td>
<td>9.1</td>
<td>26</td>
<td>140/85</td>
<td>120/80</td>
<td>4½</td>
<td>1,500</td>
<td>78</td>
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<tr>
<td>S.W. 55 kg</td>
<td>22</td>
<td>9.0</td>
<td>29</td>
<td>160/100*</td>
<td>No fall</td>
<td>5½</td>
<td>750</td>
<td>62</td>
</tr>
</tbody>
</table>

*Treated with antihypertensive drugs
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Induction. Before induction all recipients were sedated. During induction of anaesthesia an assessment was made of the following possible effects:

1. A fall in arterial blood pressure. This was noted in six patients, but was always transitory and usually small (see Table II).

2. Bradycardia. This was seen in three patients only and responded to the administration of atropine 0.3 mg in each instance.

3. Muscle rigidity. This was not apparent in any of the patients, although it has been described as a possible side-effect of this technique.

Intra-operative data. The total doses of intravenous anaesthetic agents given to each patient can be seen in Table II. The central venous pressure was measured from the sternal angle and an early transfusion of 250–750 ml of Hartmann's solution was given to raise the level to 2–6 cm H₂O. This was done in an attempt to counteract preoperative dehydration and also as a fluid load to help promote a diuresis when transplantation had been effected. Blood loss was assessed by weighing of swabs and measurement of suction loss. Replacement was achieved with a combination of blood and Hartmann's solution, depending on the original haemoglobin and haematocrit levels. The central venous pressure measurement was used as well as the estimated blood loss as a guide in the assessment of the volume to be replaced.

All patients, including E.M., returned to consciousness and good ventilatory function immediately after the operation. Analgesia was prolonged into the postoperative period, no further analgesic being required for between 40 minutes and 18 hours (mean 4.6 hours). The quantities of urine passed during the first night until 8 a.m. the next morning are shown in Table III, with the length of time over which they were produced. The volume of urine produced was satisfactory in all cases except one.

TABLE III

<table>
<thead>
<tr>
<th>Patient</th>
<th>Time (hours)</th>
<th>Urine output (ml)</th>
<th>Sodium (mEq/l.)</th>
<th>Potassium (mEq/l.)</th>
<th>Chloride (mEq/l.)</th>
<th>Urea (mg/100 ml)</th>
<th>Glomerular filtration rate (ml/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C.P.</td>
<td>14</td>
<td>240</td>
<td>46</td>
<td>30</td>
<td>35</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>R.W.</td>
<td>13</td>
<td>1,700</td>
<td>78</td>
<td>39</td>
<td>92</td>
<td>395</td>
<td>—</td>
</tr>
<tr>
<td>E.M.</td>
<td>13</td>
<td>5,680</td>
<td>100</td>
<td>22</td>
<td>—</td>
<td>570</td>
<td>—</td>
</tr>
<tr>
<td>J.A.</td>
<td>14</td>
<td>2,960</td>
<td>88</td>
<td>22</td>
<td>90</td>
<td>240</td>
<td>6</td>
</tr>
<tr>
<td>A.M.</td>
<td>14</td>
<td>1,635</td>
<td>103</td>
<td>20</td>
<td>102</td>
<td>300</td>
<td>—</td>
</tr>
<tr>
<td>S.G.</td>
<td>13½</td>
<td>480</td>
<td>87</td>
<td>21</td>
<td>97</td>
<td>190</td>
<td>—</td>
</tr>
<tr>
<td>B.P.</td>
<td>12½</td>
<td>1,730</td>
<td>63</td>
<td>42</td>
<td>70</td>
<td>465</td>
<td>71</td>
</tr>
<tr>
<td>J.Wi.</td>
<td>11</td>
<td>3,820</td>
<td>94</td>
<td>25</td>
<td>—</td>
<td>590</td>
<td>64</td>
</tr>
<tr>
<td>J.Wa.</td>
<td>13½</td>
<td>400</td>
<td>90</td>
<td>27</td>
<td>82</td>
<td>390</td>
<td>—</td>
</tr>
<tr>
<td>S.W.</td>
<td>12½</td>
<td>2,230</td>
<td>78</td>
<td>30</td>
<td>77</td>
<td>340</td>
<td>15</td>
</tr>
</tbody>
</table>

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In a field where such factors as tissue typing, ischaemic time, and surgical technique have so much influence on results, slight variations in anaesthetic technique cannot be expected to produce dramatic changes in outcome. Neuroleptanaesthesia has, however, proved itself in practice to be at least as good as other anaesthetic methods used during renal transplantation. This technique has been recommended in renal mal-function generally\(^3\), and the evidence presented suggests that it should provide the transplanted kidney with the best environment currently available.

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REFERENCES