8. L'examen n'est pas sous la dépendance de l'évacuation vésicale et ne requiert pas la présence d'un sonde.

9. Jusqu'à présent aucune contreindication n'a été trouvée.

Malgré que cet examen a été fait sur un nombre assez restreint de malades, l'auteur pense qu'il s'agit là d'une méthode très utile dans l'établissement d'un bilan rénal chez les paraplégiques.

ZUSAMMENFASSUNG

Die wesentlichen Vorteile der Isotop-Nephrographie sind die folgenden:

1. Das Risiko des Bestrahlungsschadens ist minimal, nur etwa 1% eines intravenösen Pyelogramms.

2. Die Untersuchungsmethode kann oft wiederholt werden und ermöglicht daher regelmässige Nachuntersuchungen.

3. Das Isotopennephrogramm erlaubt uns, die Funktion jeder einzelnen Niere zu ermitteln.

4. Darüber hinaus kann die Störung einzelner Phasen der Nierenfunktion getrennt beurteilt werden und nicht nur die totale Nierenfunktion.

5. Die Methode gibt ein klares Bild der tubulären Funktion, die so besonders wichtig für die Beurteilung der Nierenfunktion beim Paraplegiker ist.

6. Die Technik ist weder anstrengend noch gefährlich für den Patienten. Weniger als 1 mg der Testsubstanz ist notwendig.

7. Auch bei Patienten mit schwerer Nierenschädigung kann die Methode ohne Gefährdung des Patienten angewandt werden.

8. Die Methode stützt sich nicht auf die Entleerung der Blase und Katheterisierung ist nicht notwendig.

9. Es spricht für die Methode, dass bis jetzt sich keine Kontraindikationen ergeben haben.

Obwohl unsere Untersuchungen sich nur auf eine relativ kleine Patientenzahl stützen, halten wir die Methode für eine erhebliche Unterstützung in der Beurteilung der Nierenfunktion.

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THE USE OF HAEMODIALYSIS IN RENAL FAILURE COMPLICATING PARAPLEGIA—A REPORT OF FIVE CASES

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BETWEEN July 1962 and April 1964, five patients were admitted to the Renal Unit, Princess Mary's R.A.F. Hospital, Halton, from the National Spinal Injuries Centre, Stoke Mandeville Hospital. These patients had paraplegia and uraemia, three due to acute renal failure and two acute on chronic renal failure. The case reports are presented, and the causes, management and prognosis of the renal failure are discussed.

Haemodialyses were carried out using a Kolff disposable twin-coil unit in an electronically monitored artificial kidney (with one exception described in the case report).

CASE REPORTS

Case 1. A 53-year-old male (A. O.) was admitted to hospital on 8 July 1962 following a road traffic accident. On admission he was found to have concussion, a fractured spine, a left pneumothorax, fractured (L) ribs and multiple lacerations. Because of a paraplegia at T10 level he was transferred to the National Spinal Injuries Centre, Stoke Mandeville Hospital, on 9 July. Oliguria had developed as a result of the accident and increasing uraemia ensued. On 15 July he was transferred to the Renal Unit, Princess Mary's R.A.F. Hospital, Halton, and on admission was noted to be drowsy, hyperpnoeic and overhydrated with a plasma urea of 705 mg. per cent. and plasma potassium of 7.2 mEq./litre. Haemodialysis was commenced later the same day and continued into the early hours of the morning for a total of six hours. This procedure lowered the plasma urea to 355 mg. per cent. and plasma K to 5.0 mEq./litre, but was complicated by persistent hypotension, convulsions and difficulty in respiration. Two hours after dialysis a tracheostomy was performed and this allowed improved ventilation. Later in the day further deterioration in the patient's condition occurred with the onset of copious 'coffee ground' vomiting.

On the following day (17 July) the plasma urea had risen to 560 mg. per cent. and plasma K to 7.3 mEq./litre, so a second dialysis was carried out. After 2 hours and 50 minutes he had a convulsion followed by rapid deterioration and death.

At post-mortem examination he was found to have a fractured skull, a moderate subdural haematoma, and fractures of 10th and 11th thoracic vertebrae and of eight spinous processes. The sharp ends of two fractured left ribs projected into the pleural cavity which was filled with blood and the underlying lung was solid due to haemorrhage. It is believed that death followed perforation of the lung during a uraemic convulsion.

Case 2. A 34-year-old male (G. S.) was admitted to hospital on 29 July 1962 following an accident in which a tractor toppled over him. He sustained a fracture of the 11th thoracic vertebra and fractures of the right 12th rib, the transverse processes of the 2nd, 3rd and 4th lumbar vertebrae and the right ulnar styloid process. He had burns of the fingers and right palm. He was transferred to the National Spinal Injuries Centre the following day, during which he developed a left hemiplegia. Parietal burr holes showed bruising of the brain but no collection of blood.

Oliguria had been present since the accident and on 2 August he was admitted to the Renal Unit with a plasma urea of 550 mg. per cent. and a plasma potassium 6.0 mEq./litre. At the beginning of dialysis later the same day the plasma urea was 610 mg. per cent. and plasma potassium 5.8 mEq./litre. Six hours dialysis continuing into the early hours of the morning lowered the plasma urea to 255 mg. per cent. and the plasma potassium to 4.3 mEq./litre. The plasma urea and potassium and the urine volume is illustrated in Figure 1. Three dialyses with one and two day intervals respectively were required to control the biochemical disturbances. Diuresis began on the 11th day and thereafter the blood urea rose more slowly, levelled out then fell spontaneously. He returned to Stoke Mandeville in the diuretic phase on the 20th day of his illness with a plasma urea of 200 per cent.

The paraplegia remained but after a course of rehabilitation he became independent and was discharged home on 2 June 1963. By November 1963 he was generally well, and noted to have a normal urea clearance and a creatinine clearance of 102 ml./min. Persistent urinary infection was a residual problem.

PARAPLEGIA

G.S. AGE 34 YEARS

FIG. 1

Chart showing plasma ureas, plasma potassiums and urine volumes of patient G. S. during period of acute renal failure.

Case 3. A 36-year-old male (W. P.) was admitted to hospital on 4 September 1963 following an accident in a mine; a rock fell on to his back. He was severely shocked, had multiple fractures of the ribs and pelvis and a fracture dislocation of the third lumbar vertebra. Because of a T10 paraplegia he was transferred to Stoke Mandeville the next day. He was discovered to have acute renal failure with a rapidly rising blood urea and was admitted to the Renal Unit on 7 September with a plasma urea of 300 mg. per cent. and potassium of 7.2 mEq./litre. Figure 2 illustrates the progress of the plasma urea and potassium and of the urine output. In spite of five dialyses in 11 days he developed uraemic changes in his gastro-intestinal tract first manifested by the onset of haematemesis on 19 September. A subsequent dialysis on the Kolff twin-coil artificial kidney was carried out using regional heparinisation, but in spite of maintaining the patient's clotting time at normal levels and improving the biochemical changes of uraemia the gastro-intestinal bleeding continued. An attempt was made to maintain the biochemical improvement by continuous haemodialysis using a 'Minicoil' (Lawson *et al.*, 1962) and to keep pace with the blood loss by transfusion until it became obvious that the condition was irremediable. The patient died 24 September. Post-mortem examination showed fracture dislocation of the body of the third lumbar vertebra, fractures of the pelvis and of the 8th to 11th ribs and lateral processes of the 2nd and 3rd lumbar vertebrae, extensive haemorrhage into the paraspinous and psoas muscles, diffuse gastro-enteritis, pre-pyloric peptic ulcer, bilateral renal tubular necrosis with focal renal cortical necrosis, and necrosis of the lower lumbar cord.

FIG. 2

Chart showing plasma ureas, plasma potassiums and urine volumes of patient W. P. during period of acute renal failure.

Case 4. A 32-year-old male (J. D.) sustained a fracture of T5/6 vertebrae in a motor-cycle accident in 1952 and developed a complete transverse spinal cord syndrome below T4/5. Subsequent complications included the development of bilateral hydro-nephrosis, intermittent urinary tract infections, and chronic renal insufficiency. In April 1963 the left kidney was non-functioning due to stone formation and a nephrostomy was carried out on 3 May 1963. Pre-operatively the blood urea was 77 mg. per cent. and the urea clearance 47 per cent. Post-operatively the blood urea rose to 130 mg. per cent. and remained there for about 10 days during which time the urine volume was 2.5 to 3.0 litres per day. On 15 May a 'Renacidin' drip was given via the nephrostomy tube to the left renal pelvis. Haematuria occurred next day after difficulties with the bladder catheter; but on the following day in addition to the bleeding per urethram blood loss occurred via the nephrostomy. Deterioration in the patient's general condition, fall in the urine volume and increasing uraemia ensued. By 21 May the urine volume had improved to 2.0 litres in 24 hours but the blood urea had risen to 336 mg. per cent.; vomiting 'coffee grounds' had commenced and the patient had become hypotensive. He was admitted to the Renal Unit on 22 May with a blood pressure of 105/60, haemoglobin 61 per cent. (Haldane), plasma urea 390 mg. per cent. and potassium 5.5 mEq./litre. He was dialysed the next day and the changes in plasma urea and potassium and in urine volume are shown in Figure 3. His condition remained poor and he required very large doses of metaraminol to maintain his blood pressure. Bleeding from the stomach, showed by

FIG. 3

Chart showing plasma ureas, plasma potassiums and urine volumes of patient J. D. during period of acute renal failure in chronic renal deficiency.

'coffee ground' vomit or aspirate, occurred repeatedly. The urine was heavily infected. Urine output was inadequate and a second dialysis was carried out on 30 May. He gradually improved and by 3 June the metaraminol infusion was discontinued, gastric aspiration ceased and the nephrostomy tube was removed.

Haematemesis and melaena recurred two days later. The blood pressure fell once again, the urine volume diminished and the uraemia increased. Treatment included blood transfusion and intravenous metaraminol. The haemorrhage gradually decreased. His two dialyses had produced profound hypotension which required intravenous fluids and up to 2000 mg./day of metaraminol to maintain a systolic pressure of 100 mm. Hg. and so it was felt that a further dialysis would be an extremely hazardous undertaking in this particular patient and that conservative management should be continued. The plasma urea rose to 520 mg. per cent. by 8 June, but the urine volume also increased and from this peak level the urea gradually fell. Convalescence was slow and rehabilitation prolonged but he was discharged from hospital on 15 July and returned to work in October 1963. In April 1964 he felt well, haemoglobin 72 per cent. (Haldane), plasma urea 115 mg. per cent., blood pressure 210/120. He is on a regime of hypotensive therapy with methyl dopa, intermittent antibiotics to combat urinary infection, oral iron and sodium bicarbonate supplements.

Case 5. A 43-year-old male (P. B. P. C.) was blown up by a landmine in Italy in 1944 and sustained a paraplegia. In 1962 he developed a urinary tract infection and in 1963 he had haematuria and renal colic. Right and left renal calculi were demonstrated. He was admitted to Stoke Mandeville Hospital for removal of the right renal calculus,

and this was undertaken on 7 April 1964, at which time the blood urea was 86 mg. per cent. Operation was difficult because of adhesions, an aberrant artery to the upper pole, an intra-renal pelvis, the staghorn nature of the calculus and the atrophic renal cortex. Oliguria occurred after the operation and the plasma urea gradually rose. On 10 April he had haematemesis and melaena which continued and required frequent blood transfusions to maintain life. His general condition was critical but the staff of the Renal Unit were not able to leave Halton to dialyse the patient at Stoke Mandeville. He was finally transferred to the Renal Unit on 14 April with a blood urea of 730 mg. per cent. Haemodialysis commenced later the same day and continued for six hours until the early hours of the next morning. Biochemical improvement had been effected (post-dialysis blood urea was 290 mg. per cent.) but the patient's overall general condition deteriorated during and following dialysis and he died later that morning (15 April).

Post-mortem examination showed little viable renal tissue on the right, the kidney being difficult to locate in a mass of fibrous tissue and blood clot. The left kidney weighed only 90 g. with very little recognisable renal tissue remaining. Two large staghorn calculi were present. The stomach showed evidence of bleeding over the whole mucosal surface.

DISCUSSION

Urinary tract complications of paraplegia occur frequently; and conditions such as retention of urine, infections, hydronephrosis, stone formation and amyloid disease may be recognised during the course of the patients' disease. Death from chronic renal failure is by no means uncommon but acute renal failure may also occur. It may complicate accidental or surgical trauma, infection, investigations such as intravenous pyelography or instrumentation of the urinary tract to mention but a few causes.

Patients who develop acute renal failure following the accidental trauma which produced the paraplegia usually have multiple injuries and are hypercatabolic, the blood urea often rising by 100 mg. per cent. or more per day. Cases 1, 2 and 3 are examples of such hypercatabolic uraemic patients:

Case 1 shows many of the features of severe uraemia which two dialyses in 36 hours could not reverse.

Case 2 had a blood urea of 610 mg. per cent. on the 5th day of acute renal failure. Three dialyses in four days and a diuresis commencing on the 11th day of his illness allowed him to recover.

Case 3 was not controlled by six dialyses in 14 days. He developed intractable gastro-intestinal bleeding and uraemia must have been an important factor in the haemorrhagic state.

Patients in this group of acute renal failure have a very poor prognosis unless they are dialysed early in the course of the disease before the onset of irreversible complications, and then dialysed frequently to minimise the features of uraemia. The 54-hour continuous dialysis using a 'Minicoil' in Case 3 was technically difficult and did not affect the outcome. However, the demonstration of effective lowering of the plasma urea by this method encouraged us to modify the apparatus to increase its efficiency and safety for continuous use (Blackmore & Mitchell, 1964). It is hoped to treat a series of hypercatabolic patients by this method and to compare the results with those of Teschan *et al.* (1960), who used intermittent daily dialysis, and of Murray *et al.* (1961), who employed continuous dialysis with a Kiil dialyser. Both these groups report significantly lower mortality rates than in any series in which relatively infrequent intermittent dialyses were carried out.

Patients with chronic renal failure may have episodes of acute renal insufficiency. Treatment of aggravating factors and management of the acute phase—using haemodialysis if necessary—may permit recovery to a state in which the residual renal function is sufficient to support life for many months or years. Case 4 had such an episode following the use of Renacidin; the acute renal failure in chronic renal deficiency Case 5 followed surgery. Had the latter recovered from the acute attack it is doubtful if he could have survived for more than a few weeks with kidneys as described on post-mortem examination—but this had not been established when he presented for treatment.

As renal function becomes progressively impaired a variety of measures may be useful in preserving health and prolonging life. Advice about fluid intake, dietary measures such as protein restriction, and sodium and bicarbonate or lactate supplements may be required. However, when the urine volume falls and increasing uraemia develops in the absence of acute precipitating factors dialysis produces only temporary improvement. It may be required to allow time for a firm diagnosis to be made but thereafter it tends to be employed only in units specially staffed and equipped for a programme of intermittent dialysis on a small group of selected patients (Hegstrom *et al.*, 1962).

Intermittent haemodialysis and renal transplantation for the treatment of chronic renal failures are still experimental procedures, but as our knowledge increases treatment will become more effective and therefore the future holds promise of ability to treat the chronic renal failure which is so often the terminal event in the lives of paraplegic patients.

SUMMARY

Case histories of five patients with paraplegia and renal failure are presented and are reviewed. Renal failure in paraplegia is discussed and the place of haemodialysis in its management is assessed. Possibilities for treatment in the future are mentioned.

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I wish to thank the Director-General of Royal Air Force Medical Services for permission to publish.

RÉSUMÉ

Cinq cas de paraplegie avec insuffisance renale sont présentés et passés en revue. L'insuffisance renale dans la paraplégie est discutée ainsi que son traitement par l'hémodialyse. Les possibilités futures de traitement sont discutées.

ZUSAMMENFASSUNG

Krankenberichte von 5 Patienten mit Paraplegie und Niereninsuffizienz werden beschrieben und erörtert. Niereninsuffizienz in Paraplegie wird diskutiert und die Anwendung der Haemodialyse analysiert. Möglichkeiten für zukünftige Behandlung werden erörtert.

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Discussion

GUTTMANN, L. (*England*) congratulated Squadron Leader Mitchell on his excellent paper and also included in his warm appreciation the whole Artificial Kidney Unit of the R.A.F. Halton, under the leadership of Air Commodore Jackson. All present were well aware of the extreme seriousness of the patients they had sent to Halton for dialysis. The figures they had seen spoke for themselves. With regard to the third case, whom they had treated after the kidney operation with Renacidin, they had been previously quite impressed by the very optimistic and enthusiastic papers published from the other side of the Atlantic; therefore, they had used this and the meeting heard today what had happened. Immediately following the unfortunate result they had made inquiries about the toxicity of Renacidin, and the firm wrote back immediately, warning them not to use it as they themselves had given it up. The Artificial Kidney Unit at Halton had saved the man's life and he was now back at work. He would like to endorse what Squadron Leader Mitchell had said about sending these cases as early as possible. In the first cases, they had waited too long, and he thought that when the blood urea reached 150 mg. per cent. in acute cases it was time to carry out dialysis. Finally, he would like to ask Squadron Leader Mitchell's opinion about the relationship between blood dialysis and abdominal dialysis. Was there any advantage in trying abdominal dialysis in the wards or did he recommend a blood dialysis in any case?

MITCHELL, G. (*England*) said that from the point of view of dialysing patients with acute hypercatabolic renal failure one found that peritoneal dialysis was not adequate to keep pace with the rate of rise of blood urea. Dr. Bone's figures in his M.D. thesis could be used to demonstrate this; if the blood urea were rising over 70 mg. per cent. per day then peritoneal dialysis might not be adequate to cope with the biochemical changes. Another point was that many of these patients had bleeding into paravertebral muscles and retroperitoneal haematomata, and that in itself would be a contra-indication to the use of peritoneal dialysis. They had carried out some 16 or 17 peritoneal dialysis in the Unit at Halton because it was considerably easier than haemodialysis as a technique and did not require anything like the same amount of medical supervision. It was very largely a nursing technique but they had been rather disappointed with the results they had had in these patients with rapidly rising blood ureas and the ones who were desperately ill. He thought from the point of view of treating patients with chronic renal failure, as a first line of treatment it might be of some value and then if it did not work one had haemodialysis to fall back on. But he would not recommend it as the first line of treatment for patients who developed acute renal failure following multiple injuries that produced the paraplegia.

Ross, J. C. (*England*) said he had enjoyed this paper. He had one or two comments he would like to make; firstly, surely this renal failure was a manifestation of multiple injuries and not of paraplegia in itself, and it fell into that large troublesome group which, as Shoesmith and others had shown, had a rather worse prognosis than the other groups of renal failure. Secondly, about peritoneal dialysis: in Liverpool they had grown very wary in using haemodialysis in patients liable to further bleeding and had used peritoneal dialysis, being on the whole impressed with the results. It was a slow process, but one could carry on for several days and one might very well save those patients who were desperately ill and one might obviate the added strain of haemodialysis. Thirdly, with regard to chronic renal failure in cases with paraplegia, they might well be suitable subjects for the repeated dialysis as used by Scribner and others in the States.

MITCHELL, G. (*England*) said that the only point he would like to make was that, provided the team was experienced, whatever method used tended to produce successful results. They had a background of seven years of haemodialysis whose limitations they knew, whereas having done 17 cases with peritoneal dialysis and not being very happy with the results, they tended to use haemodialysis. He agreed that the patients with paraplegia fell into the multiple injuries group, but the paraplegic patients they had had in the acute phase had been some of the most hypercatabolic patients they had seen. The third patient, W. P., had he not been dialysed by the Minicoil, would have shown a rise of some 250 to 300 mg. per cent. per day of urea during that 54 pre-terminal period.

SILVER, J. (*England*) said Squadron Leader Mitchell was referring to the particular hypercatabolic state of the acute paraplegics he had received in the Renal Unit. They had been particularly interested in the early metabolic response to transection of the cord at Stoke Mandeville and had studied over 100 patients not transferred to the Renal Unit. They came into the Spinal Unit within 24 or 36 hours of trauma, many with no other injuries at all but just a broken neck or fractured spine and no massive haematomata. Several striking points emerged: up to six days they had a very low urinary output of 600 to 800 ml. of urine per day and the blood urea might rise as high as 150 mg. of urea. Just looking at this one might worry in case they were developing an acute renal necrosis but there were several distinguishing factors which Ucus pointed out as long ago as about 1952. If one examined the urine of these patients with acute metabolic response to trauma, the specific gravity was very high, 1028 as opposed to a patient who was developing acute renal necrosis where the specific gravity was fixed at about 1010; this was confirmed in the three cases referred to the Renal Unit. Furthermore, there was no blood or protein in the urine of the acute metabolic cases, whereas the patients with acute tubular necrosis all had protein and blood in the urine. The most interesting observations of all was the sodium and urea content: the patients referred to Halton had a fixed urea and fixed sodium content, whereas in the first five or six days after transection of the cord the patients showing this acute metabolic response had an almost complete absence of sodium in the urine. This absence of sodium was not just due to the deprivation of sodium from the diet because transfusions of sodium and a fixed sodium diet had still failed to show the sodium in the urine. The differential diagnosis between incipient acute tubular necrosis and the acute metabolic response to trauma, which he would stress subsided after five or six days completely and the renal function, as shown by other tests, was completely normal.

HARRIS, P. (*Scotland*) said he appreciated that some of the patients with recurrent episodes of renal failure were suitable for dialysis. Eventually there would be chronic and more permanent changes in the kidneys and he wondered if they might just take this opportunity of asking Squadron Leader Mitchell about the possible place of renal transplantation in the more chronic renal failure. After all, when paraplegic patients died from paraplegia it was from renal failure, and although dialysis might help in the chronic case temporarily there might come a time sooner or later where this might be considered.

MITCHELL, G. (*England*) replied that his only comment in the paper was a hopeful glimpse into the future. The problem with either intermittent haemodialysis or renal transplantations was a question of facilities and economics, and he felt justified that both procedures were still experimental. One could not cope with patients with terminal chronic renal failure in the normal type of dialysis unit, where one took in the acute renal failure as well. It still had to be a special unit and these were opening up in this country: Professor de Wardener had started one with two keen dialysers at Fulham for example in the last six months and there was a Unit at the Royal Free Hospital, but their problem at Halton was really one of being able to treat patients with acute renal failure and if they filled the Unit, which they could easily do, with terminal chronics and dialysed them twice a week then their machines could be kept busy 24 hours a day, and those with acute recoverable renal failure—the acute tubular necroses, the pregnancy complications, for example, which have a 90 per cent. recovery rate—would be excluded from their Unit because they would be full of patients with chronic renal failure. One had to outline one's programme and one's justification for any particular Unit. He would quite like to take on a chronic renal failure programme as an aside, provided one could get the extra staff. They could not cope with them at Halton, and this applied to most Units taking acute renal failures. However, there were these special Units opening up and down the country.

From the point of view of renal transplantation, the overall figures were of the order of 10 per cent. survival rate for some 6 to 18 months. The best figures in this country were at Edinburgh and the patients would survive for many months; two of them had died in the last 12 months and this had been very disappointing to Dr. Orbison and Professor Woodruff because they thought they had had one or two of the problems sorted out. Unless the patient had an identical twin he certainly would not recommend patients' being transferred for renal transplantation. It was an extraordinary problem of ethics, of course, to ask a brother or sister who was otherwise fit and well to donate a kidney. What happened when they developed kidney disease in the remaining kidney? What happened if they had an accident? What about the girl who was about to marry and her sister was dying of chronic renal failure—should she donate her kidney and approach married life and pregnancy with only one kidney plus the risks that one runs by having this operation? No one had died yet from having a kidney removed for transplant, but when they did it was going to be quite a problem, and the cadaveric transplant problem was very far from being worked out, but obviously the answer was going to come. He had no doubt that over the next few years both intermittent dialysis for chronic renal failure and renal transplant problems would be sorted out, but at the moment it was just a glimpse into the future.