ZUSAMMENFASSUNG

3 normale Versuchspersonen und 8 Tetraplegiker mit kompletten Querschnittsläsionen zwischen C6 und T3 wurden untersucht.

5 Patienten hatten komplette Lähmungen oberhalb C8. Durchblutung in der Hand und dem Unterarm wurde gemessen mit wassergefüllten Plethysmographen bei einer konstanten Temperatur von entweder 30°-32°C. oder 34°-36°C.

Hauttemperatur und Herzrhythmus wurden ebenfalls kontrolliert. Der Effekt des Valsalva Manövers, passiver Hochlagerung der Beine und indirekter Erwärmung wurde untersucht.

Wir fanden, dass beim Tetraplegiker die Durchblutung nicht ansteigt, wenn man den Patienten indirekt erwärmt—mit einem Temperaturanstieg im Munde um 2°C.—oder als Konsequenz des Valsalva Manövers.

Im Gegensatz zu diesem negativen Resultat fanden wir einen Anstieg in der Durchblutung des Unterarms, wenn die Beine hochgelagert wurden. Sobald sie wieder horizontal gelagert wurden, kehrte die Durchblutung zum Ausgangspunkt zurück. Dies war in einigen Fällen von Bradycardie begleitet. Wir deuteten dies als einen spinalen Reflex.

Die Bedeutung dieser Resultate für die Kenntnis der zentralen und peripheren Steuerung der Gefässe und der beteiligten Leitungsbahnen wird erörtert.

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RADIO-ISOTOPE NEPHROGRAPHIC STUDIES IN PARAPLEGICS

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'It should always be remembered that the bladder is a social convenience, but the kidneys are essential for life.'

In this statement of Davis the situation of the paraplegic is also defined. Pyelonephritis, uraemia and urosepsis are a threat to the life of every patient, and his prognosis is decided by the renal function. For that reason, regular kidney function tests are as necessary as the careful supervision of the bladder.

This requirement unfortunately is often neglected and is difficult to fulfil. The functions and structure of the kidney are so complex that it is difficult to distinguish which part is involved. For this reason, there is no single method by which adequate function of the whole organ can be measured. We depend upon a number of tests, of which the sedimentation rate, the determination of the non-protein nitrogen, the phenolphthalein-test, the kidney clearance, the I.V.P., and kidney biopsy are the most important. Each one of these tests gives only limited information. Some of them are time-consuming and a great inconvenience for the patient. Some are also very difficult to apply when we are dealing with paraplegics.

For this reason we tried to find new ways of assessing kidney function in these patients. One answer in this search was given by the application of radio-isotopes. With the help of the Geiger-counter it is possible to measure and follow minute amounts of such radioactive labelled substances in the body. For diagnostic purposes we use substances which are accumulated relatively quickly in the kidney and are eliminated through the urinary tract. Especially useful are the gamma-yielding isotopes which leave the body in almost undiminished strength and without deviation. Their action in the body can be measured by determining the intensity of the rays at certain given intervals of time in a circumscribed area of the organ; that is, by isotope-clearance and isotope-nephrography.

The method of isotope-nephrography or renography which is reported here was introduced as a diagnostic procedure during the past 12 years and is based upon the research work of Oeser and Billion (1952), especially that of Kimbel (1962), and of Taplin *et al.* (1956). Extensive clinical experience with this method was gained by zum Winkel and associates (1964) in the University Hospital for Radiotherapy, Heidelberg, during the past years on more than 3000 patients. Their findings were summarised in a monograph which was published recently (1964).

The radioactive o-iodohippurate (131-I-Hippuran) was found to be the most suitable substance for diagnostic purposes in the case of the kidneys and urinary passages. This substance possesses a very low affinity with the liver but a very great affinity with the kidney. Similar to phenophthalein it is excreted to a large extent by the proximal tubules.

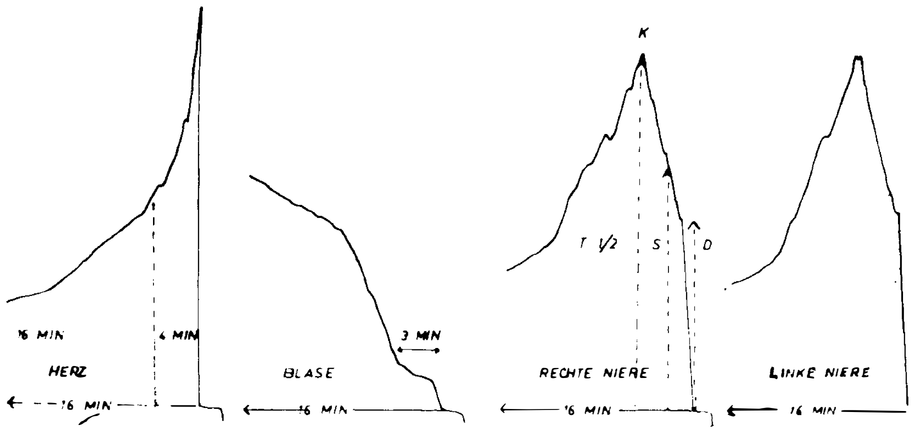
Procedure. The patient lying on the examining table receives an intravenous dose of the radioactive substance varying between 0·3 to a maximum amount of 1·0 ml. (*i.e.* 0·3 micro C 131-I-Hippuran pro kg. bodyweight). Half an hour before he is given 500 ml. of fluid to drink. The immediate accumulation of the substance and its discharge is followed with a ratemeter in the following 30 minutes after the injection and is recorded in the form of a graph.

With the help of a large number of animal experiments, the graphs resulting from such studies could be interpreted.

It was found that only a few seconds after injectı of hippuran there is an initial rise in the curve (D in fig. 1), which is, above all, dependent upon the primary accumulation of the radioactive substance in the renal vessels. Part of this rise in the curve is explained by smaller amounts of the radioactive substance circulating through the pararenal structures as well as being excreted already through the urinary passages. To evaluate this primary vascular phase in the kidney, an exact registration of the first circulation of the substance and of its subsequent recirculation is necessary. The results of one-sided ligature of the renal artery in animals support the thesis that this primary rise of the curve is related to the vascularisation of the kidney.

Following this primary phase, the secretory phase begins (S in fig. 1). The parenchym of the kidney has accumulated the radioactive substance and now begins to eliminate it via the proximal tubules. Disturbances in this part of kidney function are recognised in a disproportion between the primary and the secondary rise. Normally it should equal 1·25 or more in the first two minutes. The experimentally produced mercury-nephrosis, as an example of tubular damage, shows great changes in this part of the curve.

In the third phase, also measured over the kidney, we obtain an estimate of the excretory function. The loss of the hippuran from the pelvis of the kidney brings about a sharp decrease of recorded impulses, with a consequent drop of the curve. In excretory disturbances, we find a delayed drop, plateau-formation or even another rise as a result of retention of the radioactive substance. The experimental counterpart of this is the one-sided ligature of the ureter.



Heart Bladder Rt. Kidney Lt. Kidney

FIG. 1

Normal renogram.
D Initial phase.
S Second (secretory) phase.
T Third phase.

The renogram, whose evaluation was discussed here only very briefly and in a very simple way, gives us an estimate of the kidney circulation, of the tubular secretion and finally of the emptying of each kidney. The degree of the rise and fall of the curve over a given period of time gives us a semi-quantitative end-result. A precise quantitative evaluation is not possible, as there is considerable overlapping in the different phases. The simultaneous controls over heart and bladder give us additional information regarding the amount of loss of radioactive substance from the blood—i.e. how effectively the test substance is being secreted and excreted through the urinary passages.

Results. On the basis of these experiments we investigated a group of 24 paraplegics (5 women and 19 men) (Table I) by renography. Of these, 21 had complete lesions of the spinal cord, the remaining 3 incomplete spinal lesions. Seven of these had a high lesion (C5-D4), 8 an intermediate lesion (D5-D10) and 9 a low lesion (D11 and below). Ten of these cases were admitted to our clinic immediately following injury. In the case of the remaining 14, a period of months and several years ensued between the onset of the paraplegia and their admission here. By that time, most of them had the usual joint, skin and urinary complications. The result of the I.V.P. in these patients was normal in 10 cases while 8 showed moderate changes and 6 severe changes of the kidneys. In three of these cases, urinary calculi were found. Renography on the other hand showed 13 cases to be normal and 11 cases to have varying degrees of pathological changes.

Following more detailed analysis of the curves, we found three cases with marked changes in the primary phase, which gave a clue as to the circulation in the kidney. Nine patients showed considerable changes in the secretory phase,

TABLE I

Renographic Findings in relation to the Level of the Lesion

Level of lesion	No. of patients	Vascular phase		Secretory phase		Excretory phase	
		normal	pathologic	normal	pathologic	normal	pathologic
C_5-D_4	7	5	0	4	1	3	2
D_5-D_{10}	8	8	2	4	6	4	6
D_{11}-Cauda	9	8	1	7	2	7	2
Sa	24	24		24		24	

which gave us an estimate of tubular function. The so-called excretory phase was pathologically altered 10 times. The number of patients investigated is too small to draw statistical conclusions. However, the figures in Table I show clearly that the alterations in either of the three phases are not dependent upon the level of the lesion.

The duration of paraplegia, however, has a definite influence upon the development of disturbances of kidney function (Table II). When we investigated new paraplegics during the first six months of their stay in hospital, we nearly always found a normal renogram. The group that we are referring to here consists almost exclusively of patients admitted to our clinic immediately after the accident. This is an indication that immediate treatment in a special centre for spinal cord injuries

TABLE II

Renographic Findings in relation to the Duration of Paraplegia

Duration	Vascular phase		Secretory phase		Excretory phase	
	normal	pathologic	normal	pathologic	normal	pathologic
0-6 months	7	0	7	0	6	1
6-12 months	8	2	4	6	3	7
1-2 years	3	0	2	1	3	0
>2 years	3	1	2	2	1	3
No. of patients	21	3	15	9	13	11
	24		24		24	

is advantageous to the patients. In those paraplegics who came to us after a period of six months following injury, the results are definitely not as good, as shown in Table II.

Table III supports this assertion: It shows the findings in those patients who were admitted immediately to our department for treatment in contrast to those who were admitted for treatment after a long period of delay. The results in those belonging to the first group are definitely better.

Table III

Comparison of Renographic Findings between Patients admitted Immediately and those admitted after a Longer Interval of Time

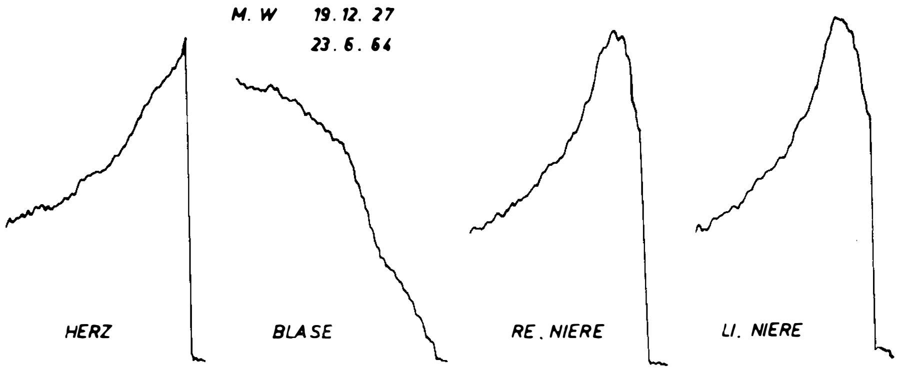
Admission to the unit	Renographic findings	
	normal	pathologic
Immediately . .	8	2
Delayed . . .	5	9

What we have been discussing will become clearer if we now analyse our graphs.

Figure 2 shows the renogram of a patient with a low lesion six months after injury. The progress of the curve is considered as normal. One recognises the immediate beginnings of vascularisation with a sharp, adequate, high, primary rise. The secondary phase follows with a somewhat slower rise to the apex. The distinguishing feature of the third phase is the quick and complete emptying of the urinary passages.

Variations of this physiological curve can be recognised in paraplegics in any one of the phases or in combinations; that is, it can involve one or several of the phases. Unilateral changes were found as well as bilateral.

Vascular disturbances were rarely seen. We found only three of our patients



Heart Bladder Rt. Kidney Lt. Kidney

FIG. 2

Normal renogram of paraplegic with low lesion 6 months after injury.

with such changes. In the case of the patient to whom Figure 3 belongs, it was interesting that in addition to the complete tetraplegia below C5, there existed generalised sclerotic changes in all vessels, which had previously led to myocardial infarction. Possibly this is the underlying reason for the vascular disturbances in the kidney.

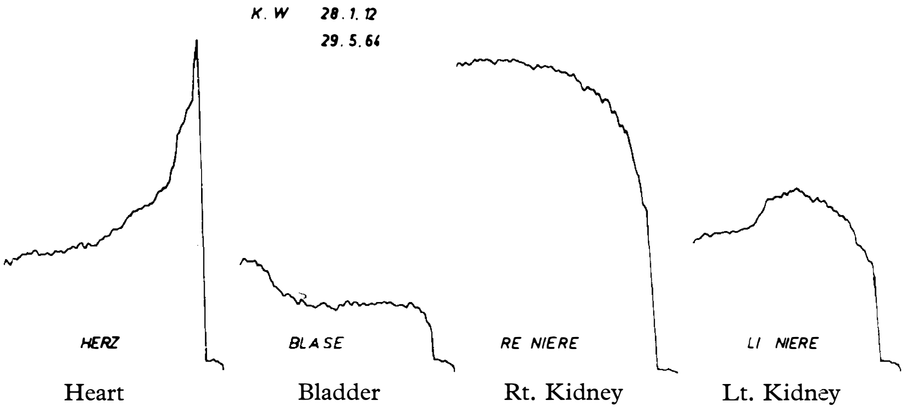


FIG. 3

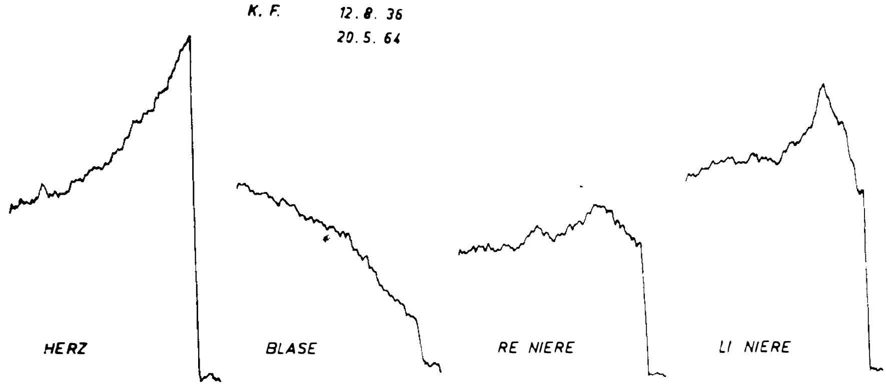
Renogram of tetraplegic below C5 with vascular disturbances of kidneys. Severe changes in the 2nd and 3rd phases of the renogram.

Severe changes were much more common in the second and third phases, reflecting the secretory and excretory functions of the kidney. As mentioned above the hippuran is almost exclusively secreted in the proximal tubules and thus the renogram gives us important information about this part of the kidney substances. This finding is particularly important because there is almost always tubular damage due to previous pyelonephritis and only rarely changes in the glomeruli. In these cases we miss the second rise in the curve, which is due to the accumulation of the substance in the tubuli. These changes were noted in nine patients and this has led us to believe that at least one-third of our cases have a varying degree of damage to the tubulo-secretory mechanism. The patient, whose renogram is shown in Figure 4, also had definite increase of the non-protein-nitrogen, occasionally presence of haematuria and intermittently a pseudo-uraemic episode with seizures. Blood pressure was always within normal limits.

Disturbances in the excretory phase were seen in 11 of 24 renographic tracings. Failure of the curve to drop below the apex can be explained by the delayed loss of the indicator from the kidney area. In the case of a young patient with a complete T6 lesion (fig. 5), the I.V.P. showed a large calculus in the pelvis of the kidney, which obviously led to obstruction.

When interpreting these findings we must be very cautious, since not only obstruction of the hippuran in the calices and pelvis but also pathologic accumulation in the renal cortex influences this part of the curve. In some cases there may also be an increased intra-renal reabsorption.

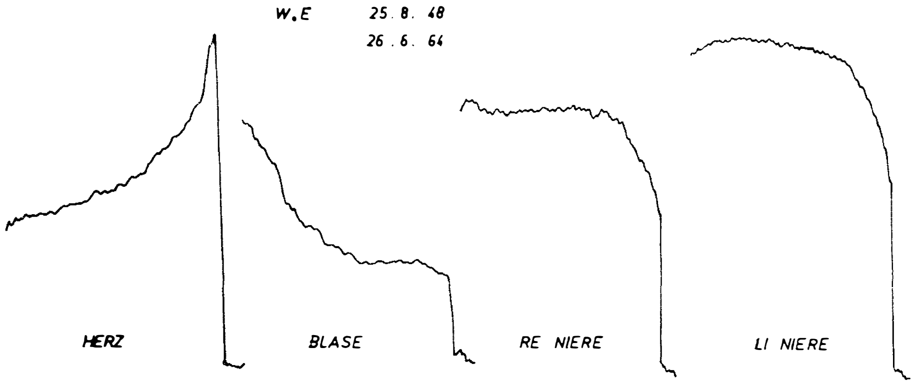
We can only mention the most important diagnostic possibilities of the renogram here. Careful micro-analysis gives us a great deal of additional information, which we are unable to discuss in detail here.



Heart Bladder Rt. Kidney Lt. Kidney

FIG. 4

Chronic paraplegia with tubular damage as a result of pyelonephritis. Marked changes in the 2nd and 3rd phases.



Heart Bladder Rt. Kidney

FIG. 5

Complete paraplegia below T6 with renal calculosis. Failure of graph to drop below apex.

The comparison of our renographic findings with the I.V.P. shows the value of this method of investigation (Table IV). Parallel diagnostic tests showed comparable findings in nine cases. Important additional information was gained on six occasions. In a further six cases it was only after the isotope-nephrogram that we could make a definite diagnosis. In three other cases it was the I.V.P. that confirmed the diagnosis. In a number of cases only a combination of these two tests gave us adequate information. In our series there was no contradiction between the findings by I.V.P. and renogram.

TABLE IV

Relation of Renographic Findings to the I.V.P.

No. of patients	Correspondent findings in I.V.P. and renogram	Important additional findings by renogram	Improved findings by I.V.P.	Improved findings by renogram
24	9	6	3	6

Conclusions. The most important advantages of using isotope-nephrography are the following:

1. Radiation hazard is kept at a minimum, it is but 1 per cent. of the dose of an I.V.P.
2. This test can be applied more frequently and hence permits regular follow-up examination.
3. The isotope-nephrogram gives us an estimate of the function of each individual kidney.
4. Moreover, disturbance of individual phases of kidney function can be distinguished and not only that of the kidney as a whole.
5. This method gives a clear picture of tubular function, which is so very important in assessing kidney function in a paraplegic.
6. The procedure is not strenuous for the patient and is without risk. It needs less than 1 mg. of the test substances.
7. This method can also be employed without any risk to patients with considerable kidney damage.
8. This test is not dependent upon the emptying of the bladder and does not require catheterisation.
9. In favour of this method is the fact that, so far, no contra-indications have been found.

In spite of the fact that our study involves a relatively small number of patients we believe it to be a very useful aid in assessing kidney function in paraplegics.

RÉSUMÉ

Les advantages de la néphrographie par isotopes sont les suivants:

1. Les risques de radiations sont minimes, un peu moins d'un pour cent de la dose pour une urographie intraveineuse.
2. Ce test peut être employé plus fréquemment et de ce fait permet d'éffectuer des contrôles reguliers.
3. Les néphrogrammes par isotopes peuvent permettre une estimation de la fonction individuelle de chaque rein.
4. De plus, les differentes phases de la fonction rénale peuvent être distinguées non seulement la fonction globale.
5. Cette méthode rend clairement compte de la fonction tubulaire, ce qui est très important chez un paraplégique.
6. L'examen ne représente pas d'inconvenients pour le malade et ne comporte pas de risques. Moins de 1 milligramme de la substance est injectée.
7. Cette méthode peut aussi être employée sans risques quand le rein est très endommagé.

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

9. J'usqu'à présent aucune contraindication 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 das 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 stüzt sich nicht auf die Entlehrung 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.