“Adequacy” of Haemodialysis
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The term 'adequate' haemodialysis has been used by many nephrologists over the past decade to mean many different things. For some, it is the maintenance of normal or near normal motor nerve conduction velocities (Eschbach et al., 1967). Others have indicated that rehabilitation with a return to full time employment is probably a satisfactory parameter by which to measure the adequacy of dialysis (Bower et al., 1971), while others have set forth the hypothesis (Babb et al., 1971) that the number of hours of dialysis per week for a given artificial kidney was the important factor. In the past three years we have evolved multiple criteria for defining the adequacy of haemodialysis. These criteria were determined principally by empiric means. These parameters encompass serum chemical determinations, physical signs, symptoms, and socio-psychological assessment as we believe no single parameter can be equated with adequacy of haemodialysis.

The following are the criteria that we use at the moment and which serve as guidelines for the staff physician and nurse in the routine assessment of the haemodialysis patient. In addition, the data of 22 patients (16 men and 6 women) on our dialysis programme was assessed by these parameters and are included. This patient group was dialysed for an average of 8 months (3 times per week, 6 hours per dialysis) at a blood flow of 200 ml/min and a dialysate flow of 500 ml/min using a single patient coil dialyser system (De Palma et al., 1969) and EX-01* or EX-03 coils.* The criteria are:

1. BUN The blood urea nitrogen, or BUN, measured on the first dialysis of the week, should be greater than 50 mg/100 ml pre-dialysis. BUNs less than 50 mg/100 ml are usually associated with poor dietary protein intake. It has been shown (Kopple et al., 1969) that a BUN to creatinine ratio in uraemic patients averages about 5.7:1 with a 40 g protein diet. The patients in our programme are generally prescribed a higher daily protein diet of 1 g

*Extracorporeal Medical Specialties Inc., King of Prussia, Pennsylvania, USA
protein per kilogram of body weight, and an average BUN to creatinine ratio of 7:1 is found in our patients.

The maximum BUNs, pre-dialysis, should be 100 mg/100ml or less. In the past three years we have seen several patients with pre-dialysis BUNs significantly greater than 100 mg/100 ml, who developed headache and hypertension post-dialysis consistent with the reverse urea shift phenomenon. These signs and symptoms were alleviated by decreasing the protein intake. In one patient, with pre-dialysis BUNs of 130-150 mg/100 ml, a marked bleeding diathesis with decreased platelet adhesiveness was seen. This was corrected by decreasing the protein intake and maintaining the pre-dialysis BUN at approximately 100 mg/100 ml. In our present patient group the average BUN was $80 \pm 44$ mg/100 ml (mean $\pm$ SD).

2. Serum creatinine The serum creatinine, pre-dialysis, the first dialysis of the week, should be 14 mg/100 ml or less for patients weighing 70 kilograms or less. For patients who weigh more than 70 kilograms, creatinines of up to 22 mg/100 ml are acceptable for weights up to 100 kilograms if the increased weight is due to an increased amount of musculature and the other measured parameters are within limits. In a stable patient, the serum creatinine reflects the number of hours of dialysis per week and the efficiency of the artificial kidney at given blood and dialysate flow rates. The average serum creatinine in the patient group studied was $13.0 \pm 8$ mg/100ml.

3. Serum potassium The serum potassium pre-dialysis is maintained, in most of our patients, at 5.5 mM/l or less. We use various concentrations of potassium in the dialysate and adjust bath potassium from 4.0 mM/l to 0 mM/l in accordance with the patient’s dietary habits and cardiac function. Most patients, including those who have significant atherosclerotic heart disease, are reasonably well if their post-dialysis potassium levels are 2.5 mM/l or greater. Patients who are digitalised may develop arrhythmias at this post-dialysis potassium level and their dialysate potassium and diet should be adjusted upward to increase their post-dialysis serum potassium to 3.0 to 4.0 mM/l. The pre-dialysis serum potassium in the 22 patients studied was $5.1 \pm 1.6$ mM/l.

4. Serum albumin By the third month of regular haemodialysis, the serum albumin is usually 3.5 g/100 ml or greater if the patient has faithfully followed the diet. We also use the serum transferrin level as a second indicator of adequacy of protein intake and protein nutrition and a level of 250 mg/100 ml is usually achieved by the third month of regular haemodialysis. Patients who are markedly malnourished when they are accepted onto the dialysis programme have their diet supplemented with a synthetic dairy product (Mocha-Mix TM), whipping cream, and egg 'shake' in order to increase their caloric intake and increase their lean body tissue. The serum albumin of
the patients studied was $4.5 \pm 1.4$ g/100 ml.

5. **Calcium and phosphorus** To avoid the complications of metastatic calcification a serum phosphorus of 7 mg/100 ml or less pre-dialysis is maintained usually with the aid of antacids. We have now seen 5 patients with a pre-dialysis serum phosphorus below 2.5 mg/100 ml who presented with nausea, vomiting, abdominal pain, and occasionally with decreased mental alertness. They all responded to elevation of their phosphorus and were in retrospect diagnosed as having phosphate depletion. A post-dialysis serum phosphorus of 2.5 mg/100 ml or greater is felt to be necessary to avoid post-dialysis symptoms of phosphate depletion. A calcium-phosphorus product of 70 has been our accepted norm. Elevation of the calcium-phosphorus product is usually due to a high serum phosphorus which is most often due to dietary indiscretion. Hypercalcaemia has been seen only rarely pre-dialysis, but may occur post-dialysis with the use of bath calciums above 6 mg/100 ml. Patients who are hypocalcaemic usually elevate their serum calcium to within the normal range with the initiation of regular dialysis. The mean calcium-phosphorus product in the 22 patients studied was $74 \pm 58$.

6. **Tissue weight gain** Tissue weight gain of 0.5 - 1 kg per month was also felt to be a parameter of adequate dialysis. Most of our patients are malnourished and underweight prior to regular dialysis treatment. They are placed on a 100 g protein 5000 Calorie 6 meal diet and begun on weekly intramuscular androgens (testosterone enanthate 200 - 1000 mg/week in men and Deca-Durabolin* 50 - 200 mg/week in women). With this regimen, several patients have gained as much as a pound a week. The determination as to whether this is tissue or excess extracellular fluid weight is made by attempting to ultrafilter the patient to a lower weight. In the absence of constrictive pericarditis, pericardial tamponade or severe cardiac insufficiency, the patient will become hypotensive at this lower weight. Less vigorous ultrafiltration must be used as the patient gains tissue weight towards his normal or ideal body weight. Weight loss in the interdialytic period is usually associated with poor caloric intake, secondary to gastrointestinal upset or depression. After the patient's blood pressure has been stabilised significant weight loss (2-4 kg or greater) is felt to be strong evidence of 'inadequate' dialysis.

The average weight gain, for the first 3 months of regular haemodialysis in the 22 patients studied was 1 kg per month. No patient lost weight during this period and since many patients had significant reductions in their blood pressure, it is felt that they gained lean tissue weight at a rate commensurate with loss of excess extracellular fluid.

7. **Blood pressure** A standing pre-dialysis diastolic blood pressure of

*TM Organon Incorporated, New Jersey, USA
100 mm of mercury or less has been the acceptable upper limit. The level of diastolic pressure is felt to be more significant than the systolic pressure. The systolic blood pressure varies from 120-200 mm of mercury in our patients. The higher readings may reflect some aortic inelasticity and an increased cardiac output due to anaemia.

The post-dialysis blood pressure limits are individualised but the patient must be without significant orthostatic symptoms on discharge from the haemodialysis unit. Some patients can be sent home with a blood pressure of 90/60 and be asymptomatic, while others, especially those who have been hypertensive for years, cannot tolerate diastolic pressures below 90 mm of mercury post-dialysis. In several patients persistent hypertension after 3 months of dialysis has caused us to search for an endocrine or reno-vascular cause of hypertension. In 4 patients peripheral plasma renins (fasting upright) of up to 750 ng/100 ml or less have been found (normal to 500). In each patient, blood pressure has been controlled with dietary sodium restriction, increased frequency of dialysis, ultrafiltration, and occasionally antihypertensives. No bilateral nephrectomies have been performed in our present patient population. In the 22 patients studied, their average age was 46 ± 24 years. The average standing systolic blood pressure (pre-dialysis) was 145 ± 30 mm Hg and the average diastolic was 90 ± 18 mm Hg.

8. Prevention of peripheral neuropathy Uraemic peripheral neuropathy has been assessed in our programme by periodic neurological history and examination. We have not performed periodic motor nerve conduction velocity studies because of some question as to how valuable and/or sensitive these studies are. It should be pointed out that motor nerve conduction velocities may have a significant daily variation in the same patient (Kominami et al, 1969) and a lowering of the serum magnesium levels may quickly improve the nerve conduction velocities (Stewart et al, 1969) so that a post-dialysis nerve conduction study might show an 'improvement' if compared to a pre-dialysis study.

One patient of the patient study group developed a foot drop after prolonged inactivity of that leg because of recurrent cannulations and intermittent infections. This condition cleared spontaneously. One patient has had the 'restless leg syndrome' prior to dialysis and this condition persists intermittently. In the remaining 20 patients, including 2 patients with lupus erythematosus, 1 patient with multiple myeloma, and 1 patient with scleroderma, there has been no progression or development of neuropathy.

9. Haematocrit and blood transfusions A pre-dialysis haematocrit of 18% or greater, without the use of routine blood transfusions, is possible for most of our patients. We use 50 ml of intravenous Imferon (2500 mg of elemental iron), infused during one haemodialysis, if there is evidence of
iron deficiency. Weekly injections of intramuscular testosterone enanthate or Deca-Durabolin are routinely used in all patients. Blood transfusions have been necessary in only 2 patients on an intermittent basis. One patient has multiple myeloma, and the second patient was not receiving his intramuscular testosterone at home on a regular basis. When weekly testosterone was administered, his haematocrit increased and blood transfusions were discontinued. The average haematocrit for the group is $26.5 \pm 14\%$ (range 17-50%).

10. Reasonable quality of life A reasonable quality of life for a haemodialysis patient is a difficult parameter to judge. Most patients are extremely grateful to the haemodialysis staff for repeatedly ‘saving’ their lives. At the same time they may be fearful of expressing anger, depression, or anxiety to the staff. These feelings make it difficult to assess the patient’s actual sense of well being.

The assessment of quality of life can be done by comparing the patient’s life state on dialysis to that which existed prior to the onset of terminal renal failure. This also is difficult as usually the patient is gradually pauperised in order to make him eligible for state welfare medical care. If the patient returns to work, at least in California, most of his earnings are used to pay for his medical expenses and do not improve his standard of living. Consequently, few of our patients return to work and an evaluation of the quality of life for our dialysis patients is not down graded if the patient has not returned to work. Our standard for a reasonable quality of life are:

1. a gradual increase in strength and endurance through exercise and diet
2. the patient’s ability to perform his usual work at least part-time
3. return of interest in food, family, and friends
4. an acknowledgment of the need for repetitive haemodialysis and an acceptance of this life state.

Adequacy of dialysis furthermore depends upon avoidance of post-dialysis fatigue. In our haemodialysis programme this is often caused by depletion of: extracellular fluid (from vigorous ultrafiltration); phosphorus depletion (from dietary restriction and use of phosphate binding antacids); and potassium depletion (from dietary restriction and use of potassium free dialysate).

Based on these broad, general categories, 12 (55%) of our patient group were rated 'good'. Seven (33%) were rated 'fair', 1 patient with recurrent angina and family problems was rated 'poor'. Two patients had died, 1 post-cadaver kidney transplantation, and the second from suicide. The ratings were based on the results of weekly patient conferences which were attended by the staff nurses, social workers, occupational therapists, physiotherapists, dietitians, and physicians.

Change in sexual potency was also considered as a possible parameter.
which might serve as a useful guide as to the adequacy of dialysis. We found it impossible, however, to separate fact from fantasy, or to separate out the psychological from the possible physical causes of change in sexual potency.

DISCUSSION

The foregoing comprises not only parameters by which the adequacy of dialysis may be evaluated, but also alludes to several guidelines of an adequate haemodialysis treatment programme. It is presently impossible in our programme to dissociate the problem of determining an adequate number of hours of dialysis per week for a given artificial kidney from dietary requirements, use of special medications, amount of exercise, and family support that a patient also receives. Adequacy of haemodialysis can probably not be simply measured by the number of square meter-hours of dialysis per week (Babb et al, 1971), as in that hypothesis no regard is made for the patient's size. Also, an increased frequency of dialysis may actually decrease the total number of hours per week that are needed as we had (De Palma et al, 1969) suggested some time ago.

SUMMARY

Multiple physical, chemical, dietary, and socio-psychological parameters are discussed as determinants of adequacy of haemodialysis. It is hoped that this information will stimulate the formalisation of standards for 'adequate haemodialysis'.

REFERENCES


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