Haemodialysis of Premature and Newborn Babies

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Haemodialysis in children was first described by Mateer et al in 1955 and since then many reports of acute and chronic haemodialysis of the paediatric patients have been published. These reports have emphasized that haemodialysis in small children may be fraught with many difficulties and complications including shunt problems, hyper- and hypotension, and convulsions.

In order to avoid these complications we have developed and described special techniques for paediatric haemodialysis. Through the use of special but simple techniques of haemodialysis for small children we have not encountered major problems and have reduced the incidence of minor complications to one-third (Kjellstrand et al, 1971a).

At the University of Minnesota 89 children below 15 years of age have been dialysed between 1968 and May 1973. This report concerns our experience with the most difficult group of patients, nine newborn (including two premature) infants haemodialysed within the first four months of life. All except one of these infants weighed 4 Kg or less; all died.

Previous reports have described haemodialysis in a total of only seven patients in this age and weight range and a review of this literature is presented in Table I.

PATIENT MATERIAL

The data of the nine patients are summarised in Table II. Seven of these patients required dialysis for acute problems. All these patients except one (IF) had acute renal failure or acute exacerbation of chronic renal failure. Patient IF received one haemodialysis in an attempt to improve a comatose state of unknown cause.

Three patients were haemodialysed for chronic end-stage renal failure in order to keep them alive for renal transplantation. The first transplant was performed after two months of haemodialysis. The patient had normal
<table>
<thead>
<tr>
<th>Reference</th>
<th>Age</th>
<th>Weight Kg</th>
<th>Diagnosis</th>
<th>Dialyser</th>
<th>No. Dyalyses</th>
<th>Blood Access</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Makela et al (1972)</td>
<td>2 months</td>
<td>4.0</td>
<td>Congenital nephrosis</td>
<td>Alwall-Gambro 3-layer</td>
<td>6</td>
<td>Jugular and saphenous veins</td>
<td>Septicaemia-died</td>
</tr>
<tr>
<td>Ahola et al (1972)</td>
<td>4.5 months</td>
<td>3.2</td>
<td>Congenital nephrosis</td>
<td>Alwall-Gambro 3-layer</td>
<td>114</td>
<td>Jugular and saphenous veins</td>
<td>Transplanted died</td>
</tr>
<tr>
<td>Sieberth et al (1971)</td>
<td>7 weeks</td>
<td>?</td>
<td>Barbiturate intoxication</td>
<td>1/2 Kill dialyser</td>
<td>1</td>
<td>Femoral artery and vein</td>
<td>Survived</td>
</tr>
<tr>
<td>Lee and Sharpstone (1966)</td>
<td>11 weeks</td>
<td>5.5</td>
<td>Bladder neck obstruction</td>
<td>1/2 Twin Coil</td>
<td>1</td>
<td>Bilateral, saphenous veins</td>
<td>Survived</td>
</tr>
<tr>
<td>Anderson et al (1965)</td>
<td>10 weeks</td>
<td>3.4</td>
<td>Dysplastic kidneys</td>
<td>1/2 Twin Coil</td>
<td>1</td>
<td>Bilateral, saphenous veins</td>
<td>Died 4 months later of renal failure</td>
</tr>
<tr>
<td>Brokeley et al (1961)</td>
<td>4 weeks</td>
<td>?</td>
<td>Cortical necrosis</td>
<td>1/2 Twin Coil</td>
<td>2</td>
<td>Bilateral, saphenous veins</td>
<td>Died</td>
</tr>
<tr>
<td>Walker et al (1963)</td>
<td>6 weeks</td>
<td>3.4</td>
<td>Infantile nephrotic syndrome</td>
<td>1/2 Twin Coil</td>
<td>2</td>
<td>Femoral artery and vein</td>
<td>Died</td>
</tr>
</tbody>
</table>

renal function for 12 days followed by an acute rejection episode with renal venous thrombosis. A second transplant kidney had acute tubular necrosis and the patient required another two dialyses before renal function returned.

**METHODS**

**Blood access for acute infant haemodialysis:**

In four newborn patients (BJ, GF, GS and KE), the umbilical vessels were used for standard umbilical cannulas. In two others the umbilical artery and a peripheral vein were used.

In two cases (IF and CL) vein-to-vein dialysis with routine cut-down procedures and polyvinyl catheters (PE 240) were used. ML had been on chronic haemodialysis and for the acute post-transplant dialysis, the arterial side of his arm shunt was used for outflow and the jugular vein for return.

**Blood access for chronic infant haemodialysis:**

We have developed special paediatric shunt materials (Kjellstrand et al 1971b), with silicone rubber segments of the same shape as those for adult shunts, but with an outer diameter (OD) of 4.3 mm and an inner diameter (ID) of 1.8 mm. Teflon vessel tips were used. Vascular access has been via the superficial or profunda femoral artery and the saphenous vein in the groin or the brachial artery and cephalic or basilic vein in the distal third of the upper arm. The operative techniques and results have been detailed elsewhere (Kjellstrand et al, 1971b; Buselmeier et al, 1971a).

**Blood lines:**

Ordinary dialysis blood lines have volumes of 100 - 200 ml; these are equal
Table II. Summary of data on patients, dialysers, and shunts

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age</th>
<th>Weight (Kg)</th>
<th>Primary Diagnosis</th>
<th>Dialysier</th>
<th>No. dialyses</th>
<th>Blood access</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>BJ</td>
<td>Premature (32 weeks)</td>
<td>1.6</td>
<td>Hyaline membrane disease, ARF, hyperkalaemia, acidosis, and multiple cardiac arrest</td>
<td>MD-2</td>
<td>1</td>
<td>Umbilical artery</td>
<td>Died at the end of dialysis. Massive intra-cranial haemorrhage of many days duration at autopsy.</td>
</tr>
<tr>
<td>GF</td>
<td>1 week</td>
<td>3.5</td>
<td>Ruptured spleen, fluid overload, hyperkalaemia, ARF</td>
<td>MD-1</td>
<td>1</td>
<td>Umbilical artery</td>
<td>Splenectomy. Died two days after dialysis of septicaemia</td>
</tr>
<tr>
<td>GS</td>
<td>Premature (36 weeks)</td>
<td>1.7</td>
<td>Perforated ileum, septicaemia, fluid overload, ARF</td>
<td>MD-1</td>
<td>2</td>
<td>Umbilical artery</td>
<td>Partial resection of ileum and gastrectomy. Died during 2nd dialysis</td>
</tr>
<tr>
<td>KE</td>
<td>2 weeks</td>
<td>3.0</td>
<td>Multiple congenital cardiac defects, septicaemia, ARF</td>
<td>MD-3</td>
<td>3</td>
<td>Umbilical artery</td>
<td>Renal function improved. Died 18 days after last dialysis of septicaemia</td>
</tr>
<tr>
<td>IF</td>
<td>14 weeks</td>
<td>5.2</td>
<td>Dialysis for progressive coma of unknown origin</td>
<td>MD-3</td>
<td>1</td>
<td>Jugular vein</td>
<td>Died 2 days after dialysis of cardiac arrhythmia</td>
</tr>
<tr>
<td>CL</td>
<td>9 weeks</td>
<td>3.5</td>
<td>Hypertension, fluid overload, pulmonary oedema, acute exacerbation of chronic renal failure, infantile polycystic kidneys</td>
<td>MD-1</td>
<td>1</td>
<td>Jugular vein</td>
<td>Died 2 days after dialysis of continued septicaemia</td>
</tr>
<tr>
<td>ML 2</td>
<td>30 weeks</td>
<td>3.8</td>
<td>Post-transplant ARF</td>
<td>MD-2</td>
<td>2</td>
<td>Brachial artery</td>
<td>Normal renal function 8 days after transplantation</td>
</tr>
<tr>
<td></td>
<td>(also chronic) (dialysis started at age 13 weeks)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Saphenous vein</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age</th>
<th>Weight (Kg)</th>
<th>Primary Diagnosis</th>
<th>Dialysier</th>
<th>No. dialyses</th>
<th>Blood access</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>WA</td>
<td>4 weeks</td>
<td>3.0</td>
<td>Hypoplastic kidneys</td>
<td>MD-2</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AF</td>
<td>9 weeks</td>
<td>4.0</td>
<td>Congenital glomerulonephritis</td>
<td>MD-2</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>G-3</td>
<td></td>
<td></td>
<td></td>
<td>EDC 30-35</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ML 1</td>
<td>13 weeks</td>
<td>3.5</td>
<td>Dysplastic kidneys</td>
<td>MD-2</td>
<td>48</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Time on dialysis**
- 21 days
- 2 months
- 4 months

**Outcome**
- Transplanted. Died 3 months after transplantation of rejection
- Transplanted. Died 2 days after intrabdominal bleeding
- Transplanted. Died 2 months after 2nd transplantation of pulmonary infections

**Shunt**
- Paediatric upper arm (3 days)
- Paediatric upper arm (4 days)
- Paediatric upper arm (10 days)
- Paediatric upper arm (60 days)
- Paediatric upper arm (59 days)
- Vein revised after 18 days

**ACUTE PATIENTS**

**CHRONIC PATIENTS**

ARF = Acute renal failure
MD = Mini-D dialyser (Cobe Laboratories); Number = Number of layers used
EDC = Paediatric Coil dialyser (Extracorporeal, Inc.)
G-3 = A bad-Gambro 3-layer dialyser (AB Gambro)
to the blood volume of a 1.5 to 2.5 Kg infant or ten times that of our smallest dialyser. We have therefore constructed smaller blood lines which are now commercially available.* The arterial line containing a pump segment of silastic is made of polyvinyl, has a length of 210 cm, and a volume of 5.6 ml. The venous line is 225 cm and contains 8.0 ml with the drip chamber one-third full.

Dialysers:

In developing a paediatric dialyser we have previously described the use of three coil and three parallel flow artificial kidneys (Buselmeier et al, 1971b; Shideman et al, 1972; Shideman et al, 1973). Our goal was a dialyser, that, with blood lines contained less than 10% of our smallest patient's blood volume, as a wide clinical experience from adult haemodialysis suggests that most patients can tolerate the sudden shifts in blood volume of this magnitude at the beginning and end of dialysis. The most versatile of the dialysers with the smallest priming volume, the Mini-D*, is a parallel flow multiple cone support dialyser. BUN clearance and ultra-filtration rates of this dialyser are shown in Figures 1 and 2. This dialyser including small blood lines represents a complete artificial kidney system requiring 23.6 ml to prime, ie about 10% of the blood volume of a 2.9 Kg infant.

![Figure 1. Clearance of blood urea nitrogen versus blood flow for the Mini-D 1, 2, and 3-layer artificial kidneys. N = number of clearance determinations](image)

*Cobe Laboratories, Denver, Colorado.
Dialysate:

Commercial dialysate was used containing electrolytes in normal concentrations except for potassium which was varied between 0 - 4.5 mEq/l depending on the patient's predialysis serum potassium concentration. Acetate was used instead of bicarbonate and the calcium concentration was kept as 3.5 mEq/l. Glucose was used in a concentration of 200, 450, or 700 mg/100ml; the higher concentrations for blood urea nitrogen (BUN) levels of 100 mg/100 ml or greater in order to compensate for the osmolality fall caused by the removal of blood urea nitrogen.

Dialysis procedures:

The patients were dialysed for four to six hours, three to four times per week. Blood priming of the dialyser was used only when the priming volume of the dialysis system exceeded 10% of the patient's calculated circulating volume and the blood was usually transfused back to the patient at the end of dialysis.

In order to avoid 'under dialysis' of the patient due to insufficient removal of uraemic waste or too efficient dialysis leading to disequilibrium and convulsions we introduced a standard clearance method. Previous work has shown a BUN clearance of 2 - 3 ml/min/kg to be safe and effective in
children (Kjellstrand et al, 1971a). Thus a 3 kg infant would be dialysed with a BUN clearance of 6 - 9 ml/min (Figure 1).

To allow prediction of the rapidity of concentration decline during dialysis, empirical curves were constructed plotting concentration decline as function of time (Kjellstrand et al, 1972c; 1973c). In order to make the curves independent of differences in predialysis concentration, differences in clearance rates for different dialysers and different substances, and varied body weight of our patients, we plotted relative concentrations (expressed as a fraction of the initial predialysis concentration) rather than absolute concentrations. The effect of varied clearance and body weight were cancelled by introducing these factors together with time. The resulting curve which plots concentration decline for both BUN and creatinine, against clearance multiplied by the duration of dialysis divided by body weight is shown in Figure 3.

Mannitol, 1 gram per kilogram, was infused intravenously to the patient in order to compensate for the drop in osmolality caused by the rapid removal of urea and other small molecules.

Figure 3. Concentration decline of blood urea nitrogen and creatinine during haemodialysis of children weighing less than 15 Kg. The concentration decline is expressed as fraction remaining (f) of predialysis concentration versus the term 'cleared blood', (clearance x duration of dialysis/body weight). One single curve accurately describes concentration decline both for BUN and creatinine. Of 41 determinations of creatinine only five (13%) were outside ± 0.1 of the curve; of 80 determinations of BUN only 11 (14%) were outside these limits. Thus, the curve is a useful clinical guide for either the determination of remaining concentration or the length of dialysis necessary to produce a certain concentration decline. The interrupted line is the best fit curve of plots, solid lines are ± 0.1 of the best fit curve.
Regional heparinisation was used when necessary as previously described (Kjellstrand & Busemeier, 1972b). Otherwise, heparin in a dose of 100 units per kilogram supplemented by small doses as required maintained the Lee-White clotting time at approximately twice normal.

Weighing procedures:
During dialysis the patients rested on an electronic bed scale accurate to ± 3 grams (Potter Bed Scale, Model 33B). The scale meter readout was kept at zero (Kjellstrand et al., 1971a; Kjellstrand et al., 1973b).

Other monitoring equipment:
Acutely ill babies were treated in an infant warmer or incubator placed on the bed scale. ECG, pulse rate, and rectal temperature were monitored continuously. An electronic pressure monitor* was used.

Feedings and medications:
Most of the acute patients were too sick to tolerate oral feeding and 10 - 50% intravenous glucose, sometimes supplemented with intravenous amino acids, was then used.

All patients were given high potency water soluble vitamins intravenously or orally. Oral aluminium hydroxide solution was used for hyperphosphataemia.

The patients tolerating oral feeding received a formula containing Similac PM 60/40, 75% by volume, (Ross Laboratories) and electrodialysed whey (Wyeth Laboratories) with added lipid and carbohydrate, 25% by volume (Levine & Winklestein, 1967), to provide 120 calories and 2 grams protein/kg/day. Occasionally diarrhoea ensued due to the high solute load of this formula. In these instances there was a tendency to hyponatraemia which was corrected by adding sodium to the patient's diet. Periodic hyperkalaemia was treated with exchange resins. Alpha-methylldopa was used for hypertension in some patients.

RESULTS AND DISCUSSION
Survival results:
All the patients died. Of the seven patients dialysed for acute problems, two patients (KE and ML) regained sufficient renal function for dialysis to be discontinued. KE died of septicaemia three weeks after the last dialysis. None of the deaths in the acute group were due to technical problems of the dialysis procedure. Four of the patients GF, GS, KE and CL died of septicaemia. BJ died from hyaline membrane disease and massive intracranial

* Arteriosonde, Roche Laboratories
haemorrhage, and IF died from an unknown central nervous system disease.

All three patients dialysed for end-stage chronic disease survived the entire dialysis period and died at varying times after receiving kidney transplants. Similar results of infant dialysis are reported by others (Table I).

Blood access:

There were no problems with blood access routes in the acute patients. To achieve a BUN clearance of 15 ml/min, the highest required for any of our patients according to our standard clearance method, a blood flow of only approximately 20 ml/min was needed and was easily obtained in all patients. In contrast, we encountered several problems with blood access for the patient in need of chronic dialysis. The first such patient (WA) required no less than three shunts in a three week period. The first two shunts placed in the brachial artery and cephalic vein in the arm lasted only three and four days after which they clotted. This problem has not been encountered since silastic shunts with wings have been used. WA received an adult shunt in the superficial femoral artery and saphenous vein, but the shunt incision dehisced and became infected. However, the shunt lasted until the patient was transplanted.

The second patient (AF) received a paediatric groin shunt in the profunda femoral artery and saphenous vein which lasted for 60 days.

The third long-term patient (ML) first received a paediatric groin shunt which had to be removed after 14 days. The next shunt between the brachial artery and cephalic vein lasted for 50 days until it was removed after the first transplant. A third shunt functioned for 39 days.

We have experienced no signs of cardiac insufficiency with these shunts.

We believe that the paediatric shunt has been of importance in providing long-term blood access while awaiting transplantation. The paediatric shunt prevents cardiac decompensation (Potter et al, 1970) and does not require constant heparin infusion.

Biochemical results:

The predialysis BUN averaged between 40 and 70 mg/100 ml even after nephrectomy. The serum creatinine averaged 4 - 6 mg/100 ml in the nephrectomised newborn dialysed 4 - 6 hours 3 to 4 times weekly. A six hour dialysis gives a 'cleared blood' factor of 12 - 18, a postdialysis BUN between 0.3 and 0.5 of the predialysis concentration, and creatinine averaging 0.4 to 0.6 of the predialysis concentration.

Predialysis calcium concentration remained normal when patients were dialysed against 3.5 mEq/l of calcium. However, phosphorus levels fluctuated widely depending on food and aluminium hydroxide intake, and it
was frequently necessary to dialyse these patients against a dialysis bath containing phosphorus (Boelens et al, 1970).

**Major complications of dialysis:**

Once the patient was stabilised on dialysis there were no episodes of cardiac failure or pulmonary oedema. We encountered no episodes of pericarditis, severe neuropathy, or bone disease. Although two deaths occurred in connection with dialysis, they were not due to any technical problems related to the dialysis process itself. Patient BJ had had several cardiac arrests before dialysis and continued to have them while being dialysed. Patient GS, the second premature infant to be dialysed, underwent one dialysis as a preparation for emergency surgery, was operated on, and returned to dialysis the next day in irreversible shock, acidosis, and hypokalaemia. The dialysis was stopped after $1\frac{1}{2}$ hours.

None of the acute patients without previous seizures had convulsions on dialysis but patient GS, with previous convulsions, continued to have seizures while being dialysed. One chronic patient (ML) had a short episode of apnoea while on dialysis which may have been a convulsion. Severe disequilibrium syndrome with convulsions has been described in approximately one-third of these patients and death from this complication has been ascribed to too efficient dialysis (Hickman & Scribner, 1962; Clapp et al, 1962; Kennedy et al, 1964; Rosen et al, 1964; Peterson & Swanson, 1964; Moorhead et al, 1965; Kallen et al, 1966; Chisholm, 1967; Broyer et al, 1972; Grushkin et al, 1972). The institution of a standard clearance for dialysers can decrease this problem considerably. The high glucose baths and the mannitol infusions described here may prevent the disequilibrium syndrome in our patients (Mauer et al, 1972). The absence of severe hypertension, profound shock and pulmonary oedema is also contrary to other reports (Kallen et al, 1966; Chisholm, 1967; Potter et al, 1970; Broyer et al, 1972; Grushkin et al, 1972), and is due to the use of small paediatric dialysis.

**Minor complications of dialysis:**

The incidence of minor complications of dialysis, transient hypo- or hypertensive episodes, and vomiting is outlined in Table III. We encountered no hypertensive episodes during dialysis in our acute patients but the incidence was 15% in those patients on chronic dialysis prior to bilateral nephrectomy.

Transient hypotensive episodes occurred in no less than 42% of the acute dialyses. The incidence in chronic dialysis was only 18%, indicating that many of the hypotensive episodes in acute dialysis were due to extreme illness of these infants rather than to the dialysis process per se.
Table III. Summary of minor complications during 92 haemodialyses of newborn infants

<table>
<thead>
<tr>
<th>Complication</th>
<th>Hypertensive Episodes</th>
<th>Hypotensive Episodes</th>
<th>Regurgitation-Vomiting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute dialysis</td>
<td>0/12 (0%)</td>
<td>5/12 (42%)</td>
<td>0/12 (0%)</td>
</tr>
<tr>
<td>Chronic dialysis</td>
<td>12*/80 (15%)</td>
<td>14/80 (18%)</td>
<td>24/80 (30%)</td>
</tr>
</tbody>
</table>

*All before nephrectomy

Chromically uraemic infants frequently vomited on dialysis, and in the ward, but no more frequently in infants than in our adults (Kjellstrand, 1972a).

During haemodialysis using tap water as dialysate diluent, the blood methaemoglobin levels rose from a normal level of less than 2% of total haemoglobin to 5 - 10% by the end of dialysis; this resulted in intensely dark blood and clinical cyanosis. This phenomenon was completely abolished by the use of distilled water as dialysate diluent, whereas it persisted with water purified by reverse osmosis. The offending substances in tap water have been shown to be chloramines, added by the Water Department to suppress bacterial growth. The problem can also be avoided by neutralising the chloramines by the addition of ascorbic acid to the dialysate (Kjellstrand et al, 1973a).

Serum protein and haemoglobin levels:

During the first few dialyses serum albumin was brought to normal levels through infusion of human serum albumin.

Once the patient with chronic renal failure had stabilised on haemodialysis, blood priming was used only in patient AF, using a high volume dialyser. AF received 100 ml packed cells during her two months on dialysis. Her haematocrit was maintained at the level of 30 - 40% with this method. Blood priming was not used on patient ML. This patient received a total of 619 ml of packed cells during 50 haemodialyses or a mean of 14 ml packed cells per dialysis. This patient’s haematocrit using this approach was maintained between 28 - 32%.

Effect of dialysis on growth and development:

Only two patients (AF and ML) were dialysed long enough to study these parameters. Patient ML gained 300 g, grew 5 cm, and increased his head circumference $3\frac{1}{2}$ cm during the four month dialysis period. Normal values are approximately 2,000 g, 8 cm, and 4 cm respectively. Patient AF has been described in detail elsewhere (Mauer et al, 1973). This patient’s growth potential was obscured through an error in her feeding formula. The patient grew 2.5 cm in length and 2 cm in head circumference during the
two month period on dialysis; the normal values being 5 cm and 3 cm respectively. Mild muscle wasting, weakness, hypotonia, and hyperreflexia were present in both patients, but electromyography and electroencephalography were normal. Mental development as assessed by the Denver Development Screening Test was normal at age four months shortly before transplantation in patient AF, but patient ML showed evidence of significant psychomotor retardation.

CONCLUSIONS

Through the use of small paediatric arteriovenous shunts, blood lines, and small dialysers containing less than 10% of the infant's circulating blood volume, and using a very accurate weight monitoring technique, haemodialysis in infants need not be technically much more complicated than dialysis in adults.

If the dialysis efficiency is based on the patient's body weight and if one utilises extra dialysate glucose and intravenous mannitol during dialysis, convulsions can almost be avoided. Blood access remains the main technical problem in infants.

The overall clinical problems in infant dialysis are mainly feeding, growth, and development. Growth has been grossly abnormal in our cases and poor motor development of our patients may have been due to factors which frequent dialysis and good nutrition cannot solve. The same problem of retarded growth, although less severe, was also present in the only other infant dialysed for prolonged periods (Makela et al, 1972).

The ultimate aim of dialysis of babies with chronic renal failure is transplantation which should be delayed until a weight of 7 - 10 kg can be achieved (Najarian et al, 1971). Alternatively, transplantation may be performed using small paediatric donors.

Newborn infants with acute renal failure usually have had catastrophic events precipitating their renal failure with severe involvement of other organs and overwhelming sepsis, which make survival unlikely.

SUMMARY

Nine infants, age less than four months, have been successfully dialysed 92 times at the University of Minnesota. Although all infants ultimately died, there were no major complications due to haemodialysis and minor complications occurred no more often than in adult haemodialysis. We use special shunts, special small dialysers, accurate weighing, and high dialysate glucose and mannitol. We have also introduced a standard clearance for artificial kidneys to avoid both under and over dialysis. The main technical problem has been blood access; the overall clinical problem, retarded
growth. Survival in infants with acute renal failure is at present limited by their basic underlying disease.

ACKNOWLEDGMENT

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OPEN DISCUSSION

M BROYER (Paris): I would like to ask two questions. First, what was the duration of time for which you were able to perform haemodialysis in such babies and for how long each time, and second, have you compared the effect of peritoneal dialysis and of haemodialysis in newborns. Peritoneal dialysis would give an efficient alternative to a sophisticated procedure in this age group.

BUSELMIEIER: The duration of each haemodialysis was from four to six hours. Whether peritoneal dialysis might be a better alternative to haemodialysis can only be answered by a comparative study.

J BROD (Hannover): I would like to ask a question of ethics. We have not seen any data on the prognosis of these newborn children. And I think that dialysis in newborn babies is only justified if we are facing a reversible condition and if we can guarantee to the parents that this child is going to develop normally. Otherwise we only prolong the suffering of the family.

A KENNEDY (Chairman): Instead of 'guarantee to the parents' we might say a 'reasonable chance'. It is extraordinarily difficult to guarantee anything in medicine.
BUSELMEIER: We agree that it is important to do dialysis in reversible renal failure. Whether it is reasonable to dialyse small children with irreversible failure is very difficult to decide. This question has been discussed in relation to childrens' dialysis for several years, and that is now accepted. We hope that a study in our experimental transplant centre will prove its feasibility one way or the other.

R N FINE (Los Angeles): I'd like to come back to Dr. Broyer's point. If you look at the table which Dr Buselmeier presented, all the children he dialysed acutely for short periods of time. In our centre we have dialysed over a hundred children over the past six to seven years. Initially we did use haemodialysis for acute poisonings but we have not required acute haemodialysis in small children over the past four or five years; we have used peritoneal dialysis exclusively. With regard to chronic dialysis you present three patients, two of whom have hypoplastic kidneys. One of them you have only dialysed four times before transplantation. At least in our experience with children of this size with a primary diagnosis of hypoplastic kidneys adequate conservative management has sufficed for at least twelve to eighteen months before haemodialysis and transplantation. We have three children of less than 10 kg, two of them about one year old, who have been transplanted and are now surviving two to four years with adequate development. Although your transplanted patients did not survive, I think transplantation in small children is hopeful - at least in our experience.

BUSELMEIR: We were only presenting our data on children of five kg or less. Of course we transplant the other children and have a higher success rate. In 65 children transplanted since 1963 the five year survival rate is 75 - 80%. Regarding the conservative management of children we only used haemodialysis on those children who could not be managed medically. With regard to the use of long term peritoneal dialysis it may be an adequate and good technique, we just don't happen to use it.