Cost-Effective Dialysis for the Developing World

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INTRODUCTION

There is a massive unmet need for dialysis for acute and chronic renal failure in developing nations. Not only is the number of patients immense, but the resources available are severely limited. There are major difficulties in purchasing and maintaining conventional hemodialysis equipment. Peritoneal dialysis is generally of limited help because of difficulty providing sterile dialysate and problems with infection.

TENTATIVE APPROACH—PASSIVE FLOW DIALYSIS

Hemodialysis can be carried out without the need for a conventional mixer-monitor ("dialysis machine"). This was standard in the days of atrioventricular (AV) shunts and Skeggs-Leonard and Kiil dialyzers. With suitable choices of vascular access, dialysate delivery systems, and dialyzers, simple, inexpensive hemodialysis should be possible. Examples of two prototype dialysis delivery systems are shown in Figure 1. Several potential difficulties, however, must be addressed.

Obtaining Adequate Blood Flow

For acute renal failure, AV shunts offer relatively low resistance to flow and can provide adequate blood flow (over 200 mL/minute) through a number of dialyzers of relatively low blood flow resistance. For maintenance dialysis in end-stage renal failure, providing adequate blood flow to the dialyzer is more challenging but should be possible from an arteriovenous fistula by compressing the fistula between the arterial and venous needles. At a blood flow of 200 mL/minute, the pressure drop across 15-gauge arterial and venous needles is each ≈30 mm Hg. The pressure drop across the blood compartment of a Fresenius F8 dialyzer is also ≈30 mm Hg. Thus a mean arterial pressure of 90 mm Hg could drive blood through this dialyzer at 200 mL/minute. For patients with lower mean arterial pressure than this, wider needles or a redesigned dialyzer configuration would be necessary.

Is it safe to compress a fistula to or close to the point of occlusion for the duration of a dialysis session? Evidence on this point is limited, but we have compressed fistulae that were no longer needed in 3 patients in a deliberate attempt to occlude them. In no case did the fistula thrombose. It appears that in the absence of prolonged hypotension, infection, or fistula stenosis a mature fistula is tolerant of occlusion for several hours. Obviously more information is needed to define safe limits for fistula compression.

Obtaining Adequate Dialysate Flow

Using 4.5-mm internal diameter polyvinyl chloride tubing connected via Hansen connectors to a Fresenius F8 dialyzer, a pressure head of 60 cm created a flow of ≈200 mL/minute with each of the 2 delivery systems. This is a feasible pressure head for a practicable apparatus, and a higher dialysate flow can be achieved with slightly wider caliber tubing, if desired.

Regulating Dialysate Flow

The dialysate flow is determined by the pressure difference between the dialysate source and the sink and by the resistance of the dialysate tubing. The tubing diameter can be chosen to provide the requisite flow resistance to suit the pressure head employed. In the first prototype, the pressure head is maintained constant by a valve that maintains the dialysate level constant in the upper container. In the second prototype, when the dialysate level falls in the source

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