Will Nephrologists Use a Wearable Artificial Kidney?

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W illem Johan Kolff, despite shortages of materials under the oppressive World War II German occupation of the Netherlands in 1942, designed and fabricated the world’s first practical artificial kidney. In his 1947 recounting of initial trials of the artificial kidney, aptly titled “New Ways of Treating Uraemia,” Kolff restricted treatments to those who had acute kidney injury, believing that “chronic nephritis is no indication for treatment with the artificial kidney, although an acute exacerbation of a chronic uraemia might be an indication in some cases” (1).

Tentatively limiting dialysis to 50 ml of blood withdrawn from a vein, Kolff gradually increased the volume of blood aliquots to 100 ml in intermittent treatments that lasted as long as 17 h at estimated urea clearances of 140 ml/min and removed as much as 268 g of urea during a single dialysis session. Lacking pressure control of circulating blood within the dialyzer, fluid was extracted by raising dialysate osmolality with glucose added to the salt and bicarbonate mixture. Sixteen patients underwent hemodialysis between March 1943 and July 1944, 15 of whom died; a sole survivor may have benefited from dialysis. After a 14-mo hiatus enforced by the last battles of World War II, Kolff, on September 11, 1945, performed an 11.5-h dialysis on 80 L of blood, enabling his 17th patient, a 68-yr-old woman in coma attributed to the hepatorenal syndrome, to become the first long-term survivor of dialysis.

During a postwar visit to the United States in 1947, Kolff met with Carl W. Walters and John P. Merrill, who modified his device to be known as the Kolff Brigham artificial kidney, which permitted connection of the patient by surgical cannulas via a split coupling at the inlet and outlet of a rotating drum to prevent twisting of the cellulose membrane tubing. Membrane surface area and dialyzer clearance were adjustable by varying the number of wraps of tubing (2). At a cost of $5600 in 1948, the Kolff Brigham artificial kidney was sold to 40 institutions from Tokyo to Chile, stimulating basic and clinical studies of a now potentially reversible uremic syndrome (3). Teschan’s (4) performance of acute hemodialysis using the Kolff Brigham artificial kidney on the battleground of the Korean War in 1952 showed that hospitalization need not be a prerequisite for dialysis.

Although acute dialysis units were proliferating in industrialized nations throughout the world, it was the extension of dialysis therapy to chronic uremia that both spawned the specialty of nephrology and stimulated its multibillion-dollar cost. Belding H. Scribner, in 1960, conceived a regimen in which a surgically inserted plastic arteriovenous forearm shunt would permit repetitive “chronic dialysis” without the necessity of anticoagulation of the patient between dialysis session. After the first two patients with chronic renal failure, treated twice weekly for 10 to 16 h, survived for months, Scribner’s report startled the “medical establishment,” stimulating construction of dialysis facilities for a continuously growing number of individuals who wanted to escape death in uremia by treatment for “end stage renal disease” (ESRD) (5). During the next nearly half-century, the hemodialysis patient roster grew to more than 1 million, along with cohorts of patients treated with peritoneal dialysis and kidney transplants (6).

The expense of uremia therapy—which now exceeds $80,000 per patient per year in the United States—limits its application to <10% of those who would benefit in terms of life extension (7). The World Health Organization notes the lack of provision of uremia therapy because of its cost but, thus far, has proffered no specific suggestions to improve its availability for most of the world (8). Extracting the dialysis process from high-cost hospital and/or corporate dialysis facilities is an objective of several research efforts, including building smaller, portable, and thus mobile dialysis machines (9) as well as wearable devices.

In this issue, Gura et al. (10) summarize improvements achieved in their enhanced version of a wearable artificial kidney (WAK), which incorporates double-channel pulsatile counter-phase blood and dialysate flow, a large high-flux membrane, and optimized dialysate pH to improve effective creatinine clearance to as much as 27 ml/min in uremic pigs. Delivering what Gura et al. term “an undescribed type of hemodiafiltration,” the authors imply that their device will facilitate daily dialysis, optimizing treatment for ESRD.

The WAK was introduced to improve the lot of patients who have ESRD and are sustained by hemodialysis by proffering two desirable attributes: (1) Enhanced patient mobility, minimizing enforced restriction of treatments at dialysis facilities, and (2) reduced per-dialysis and thus per-patient cost of dialysis therapy. Few investigators have addressed the WAK concept, as evidenced by the retrieval of only 52 literature citations for “wearable artificial kidney” in the Library of Congress PubMed database on July 10, 2009.

Fascinating to note is that the most detailed previous effort to build a WAK was conducted by Kolff’s team at the Cleveland Clinic in 1947 (1).
Clinic and University of Utah (11). Other current active paths to making home dialysis both cost-effective and portable, to the extent of wearability, include the use of sorbent technology to allow online regeneration of dialysis (12) and further clinical trials of a WAK dependent on peritoneal dialysis although this may involve “a quantum leap in technology making the WAK a reality rather than a dream” (13).

A key concern in pursuit of hemodialysis “on the go” is whether even a fully tested, safe, and cost-effective WAK will prove acceptable to clinical nephrologists. Consider the agonal demise of self-care hemodialysis despite the enthusiasm of a dedicated corps of clinicians who adhere to the view that self-care home hemodialysis is the best long-term therapy for chronic uremia (14). As noted by the authors of the nephrologists’ survey, however, “The opinions expressed are far from reality, which we interpret to show that nonmedical factors have a strong impact on treatment allocation.” Patients may also be practicing wishful thinking when stating their preferred choice of ESRD treatment modalities, placing self-care hemodialysis at the top because of “freedom and lifestyle advantages” afforded by the regimen (15). Related to the future broad application of a successful WAK is the current, slow death of home hemodialysis as recently analyzed by Masterson (16). An optimistic expansion of home hemodialysis on the basis of “results with more frequent hemodialysis that is obviously best performed at home and with the development of new, more patient-friendly machines” is predicted by Blagg (17). Clearly, which dialysis modality to prescribe at which frequency and duration to be performed at which location remains a debatable issue. Precisely what role a safe and effective WAK will fill offers an exciting opportunity for empathetic and fulfilling clinical trials.

Disclosures
None.

References