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Wearable Kidney; Away from Tomorrow but More Real than Dream

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Abstract

A wearable kidney is a device that can relieve patients with renal failure of dialysis. This wearable kidney can be worn on the waist like a belt. It removes the harmful substances from the blood and removes excess water and salt from the body.

Keywords: Wearable kidney, patient, tecnology

INTRODUCTION

Over the past two decades, the number of dialysis patients in the world has doubled. Among them, 80% are treated with hemodialysis (1, 2).

In our country, the spot prevalence of end-stage renal disease that requires renal replacement therapy is 933 per million population, with an incidence of 140. However, in recent years, these figures have reached a plateau (3). In Turkey in 2016, there were 56,687 (70.12%) hemodialysis patients, 3508 (19.17%) renal transplantation patients, and 368 (0.64%) patients receiving hemodialysis treatment at home (3).

Despite technological advances in renal replacement therapies, unacceptable high mortality and poor quality of life persist (4). Although home hemodialysis positively contributes to patient survival, it has its disadvantages such as wide area occupation of dialysis equipment, high-energy costs, and substantial water use (5).

Although kidney transplantation is the best choice in the treatment of end-stage renal disease, it is not possible to respond to all patients due to organ limitation and naturally extending waiting list (2). Therefore, for the treatment of patients with CKD5d, efforts are being made to develop wearable and implantable devices that can increase not only patient survival but also quality of life in the near and distant future (4). While the dream of a wearable kidney was first mentioned in the 1970s, the first animal experiments were carried out in 2005 and human studies in 2007 (6, 7). The wearable kidney should be able to regulate the blood pressure by providing the patient's volume control, and it should be able to provide toxic metabolites of the patient without applying challenging diet programs and reduce the need for medication (8, 9). At the same time, there should be time and cost advantages according to hemodialysis performed at the center (10). For wearable kidneys, three difficult challenges to be overcome are the life of the device, power supply, and the removal of waste materials (4). For a successful wearable kidney, the glomerular membrane should be attached to a tubule membrane designed to re-absorb the ultrafiltrate. Thus, they can provide sufficient nitrogen excretion with only 2 L of filtrate per day. A method similar to that in the reverse osmosis water system can be developed for a tubule membrane that is capable of re-absorbing water and solutes. It can be designed in a way to distinguish which solutes will be reabsorbed and separated, and whether separation has occurred or not (4). In a standard dialysis session, 240 L of ultrapure fluid should be produced and removed again. It is impossible to process all these high amounts by means of a device carried on human. Therefore, newer technology is needed (4). Dialysate regeneration with absorbent substances has long been used to minimize water requirements, but when they are saturated for each process, they require fresh

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reagents. This limits the applicability of sorbent technology to implantation devices (4).

Because wearable kidney will control the complications arising from extracorporeal blood circulation, which should often be opened and closed and will reduce the risk of infection, it can provide more applicability (4).

Two pilot studies have been presented so far (7, 8). The first one was published in Italy in 2008, and ultrafiltering efficiency was proven in congestive heart failure (11). In six hemodialysis patients, ultrafiltration was achieved at a rate of 120-288 mL/h for 4-6h, and the respiratory and circulatory systems of these patients remained stable in these sessions (11).

The second study was performed in eight patients in the UK. The prototype instrument was tried for 4-8h, and the arteriovenous (AV) fistulas that were always used as the vascular access were used in patients (12).

Gura and his team, who were the most experienced in the development of wearable kidneys, developed the first ultrafiltration instrument, and they were able to apply first wearable hemodialysis that could be used for 24h in 2016 (4, 7). Vascular access is the most critical problem for wearable kidneys because coagulation problems are often encountered in classical AV fistulas. Synthetic grafts seem to be more successful in this regard (4).

Hemaport (Hemapure, Uppsala, Sweden) has developed a needle that includes a titanium connector connected to the polytetrafluoroethylene graft, and does not require an AV fistula (13). Life-Site valve, another alternative that includes titanium, stainless steel, and silicon elements attached to the 12-Fr silicone cannula has been developed. It is placed in the central venous system (14).

Other important problems to be overcome are dialysis membranes, dialysate regeneration, power supply, and pump systems. A certain progression has been achieved on this issue (15).

In an article published in 2011 (16), three leading researchers in the field predicted that the following conditions should be met in order to have an ideal wearable artificial kidney.

- The vascular bed should be able to provide a continuous flow of 100 mL per minute.
- The risk of infection should be low. The patient should not have any problem while it is connected or disconnected. A small amount of dialysate solution should be sufficient and reusable. There should be no clotting during the procedures of dialysis. Solute clearance should be 20 mL per second, and ultrafiltration should not be more than 5 mL per minute.
- There should also be fast and safe warning systems for air embolism, and these systems should be able to be applied quickly by the patient when necessary.

Urea clearance is another challenge in the design of wearable artificial kidneys. For this, it seems to be inevitable to develop a system that allows the dialysate to be used repeatedly (16).

Developments in material technology enable transition from silicon-based catheters to polyurethane-based catheters. In fact, both silicon and polyurethane catheters have similar life span and functionality, but polyurethanes are more resistant to pressure and allow more blood to be transported by decreasing material thickness (17).

Parallel to the development of nanotechnology, understanding of the key role of the fibrin sheath in the development of CVC-associated thrombosis and bacteremia has led to the emergence of highly promising CVC coatings. In a recently published in-vitro study, Hugoni et al. evaluated fibronectin, monocyte response, and thrombus formation on two-surface modified polyurethane (18). Advances in nanotechnology will allow the addition of macromolecules inside and outside of the catheter, and the coagulation problem can be reduced (4).

ESSENCE

The ideal wearable kidney should be comfortable, and it should not interfere with everyday life (10, 12, 19). Many technical problems to be overcome continue to exist for wearable kidneys.

The development of an economically accessible wearable kidney seems to be far away yet (16). Although it took more than 50 years to develop the prototype of a wearable artificial kidney for the treatment of patients with CKD5d, the clinical studies of two devices that function as hemodialysis and PD have already begun. The success of these devices will depend not only on the removal of solutes but also on the ability to protect electrolyte, acid-base, and volume homeostasis, and on the tolerance of patient (5).

As a result, wearable kidney seems to be away from tomorrow, but more real than dream.

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