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Apromising Alternative in Renal Replacement for End Stage Renal Disease Patients – Nanotechnological Artificial Kidneys

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A B S T R A C T

Background: End Stage Renal Disease (ESRD) is a condition that lacks any specific pharmacotherapy and so we need to look towards other means of treatment, say renal transplantation and dialysis in severely ill patients.
Summary: As decades pass, growth in technology and engineering reflects the potential in advancing treatment options. Nanotechnological means are being experimented on, to produce microchips capable of carrying out the full-blown functions of a human kidney. Miniaturization helps create handy portable artificial substitutes for kidneys.
Key Message: Access to nanotechnology and Artificial Intelligence (AI), will result in improvements in patients' quality of life as well as significant savings for patients and the health system at large. The promising field of nano-nephrology is still underway in development and lacks full consideration for research and needs better attention.

1. Introduction

Kidneys, located in the posterior region of the abdominal cavity are the main organs for excretion in humans. Human kidneys play a great role in the maintenance of the water-electrolyte, and acid-base balance, and it helps in the regulation of blood pressure (P and SK, 2018).

Renal failure occurs when the kidneys fail to function normally. This could be permanent or temporary. This could lead to accumulation of metabolic waste products in the blood (uremia).The homeostasis gets disruptedcausing other organs to shut down – heart, liver, etc. The final implication of renal failure is usually death, unless the blood is filtered by some other alternative mechanisms (Raghavendra, Mallikarjun and Vidya, 2013). When kidney fails to perform their basic functions then there is a necessity of an alternative means for the waste removal and reabsorption of essential nutrients (P and SK, 2018). The bestalternative is to replace the impaired kidneys with a donor kidney. Patients often undergo dialysis before a kidney transplantation (Raghavendra, Mallikarjun and Vidya, 2013). Hemodialysis (HD) has been proved to be a safe and valuable technique to treat patients poisoned with drugs like barbiturates, salicylates, bromide, and other drugs. Dialysis is also a means to treat renal failure when transplantation is not possible (Renal Failure And Thie Artificial', 1960). The prevalence of treating End Stage Renal Disease (ESRD) by means of dialysis is on the rise globally. These patients have a huge burden of comorbidities, multiple drug therapies and difficulty in adapting to lifestyle changes (Gura *et al*., 2016).

Advancements in the field of Artificial intelligence (AI) and machine learning (ML) are transforming medical devices and procedures. It can be tailored to provide great benefits for dialysis as well (Hueso *et al*., 2019). Machines and devices were first experimented to mimic the functions of a kidney. Renal substitution therapy with hemodialysis (HD) or peritoneal dialysis (PD) has been the only successful long-term organ substitution therapy. The lack of wide-spread availability of suitable transplantable organs has made kidney transplantation a difficult solution in most cases of chronic renal failure.Bioengineering of an implantable bioartificial kidney couldbe advantageous to patients by increasing life time, activity and overall quality of life, with lower risk of infection and in being much more economical (Humes, *et al*., 2014) Artificial kidneys can be of better value in treatment of poisoning as well.

1.1 A Smart Alternative

Accumulation of toxins within and around cells in renal failure, disrupts the ratio between internal and external electrolytes causing the net decrease in the kinetic and potential energies at the cell membranes. When this mechanism attains equilibrium, there will be no intrinsic cell activity and thereby decline in the overall functioning of the kidney (Ash, 2006). Patients with End Stage Renal Disease (ESRD) often require dialysis which often affects the patients' quality of life. In view of this, there is a promising rolefor wearable artificial kidneys as alter-

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natives. The development of such a technology will need contributions from new branches of engineering such as Artificial Intelligence (AI) and Machine Learning (ML). Advancements are taking place in the fields of tissue engineering and medicine to provide alternative approaches for the treatment of patients with severe renal failure, using implantable bioengineered kidney structures.

Implantable artificial kidneys can mimic renal morphology and function. This deviceincorporates a silicon nanostructure of kidney cells that will concentrate the ultrafiltrate into urine. The entire arrangement is enclosed in a box that is to beconnected to patient's circulation and urinary bladder.

Another device under development is the wearable artificial kidney, which is a wearable, miniature device with a hemodialysis system that is like a belt to be worn on the waist (Hueso, et al., 2019). Attempts have been made to develop wearable artificial kidney in the past but were limited by the technologies available at the time.Since then, developments in various fields of research have led to the production of lightweight, wearable dialysis systems that are feasible (Topfer, 2016).

Developments in biomedical engineering have made it possible to design circuits on a single chipallowing miniaturization and enhancing portability. This technology has allowed the development of the wearable artificial kidney based on dialysate-regenerating sorbent technology (Hueso, *et al*., 2018).

A wearable artificial kidney has the following basic components: a dialysis membrane, a power source and a pump system.These devices are intended to improve patient's quality of life. It can have the advantages of eliminating patients' dietary restrictions, need for dietary supplements and medications for patients (Topfer, 2016). Artificial organs also mostly include interfacial membranes. Transport of urea, creatinine, phosphorus, and other moieties across the membranes to dialysate solution takes place also in an artificial kidney (Ash, 2006). A wearable artificial kidney may also reduce the time and costs associated with travel to health care centers for treatments. However, whether patients will comply with wearing a dialysis unit continuously or for long durations of time may need to be considered (Topfer, 2016).

1.2 Nano-Nephrology-Miniature Kidneys

Nanotechnology is used is several aspects of healthcare such as nano-medicine, nano-diagnostics and nano-pharmaceuticals.Nano-nephrology is the use of nanotechnology to improve diagnoses and therapies in renally impaired patients, as well as promotes the study of renal function (Soriano, Rodríguez-Benot and Valcárcel, 2018).

A device thatmatches the function of ultrafiltration by the kidneys has been developed for the purpose of hemodialysis (Roy, *et al*., 2011). They used silicon nanopore membranes with specific pore size to mimic ultrafiltration (Fissell, *et al*., 2009) and proximal tubule like cells to improve reabsorption. The device showed promising results with respect to an implantable artificial kidney (Attanasio, *et al*., 2016) (Paoli and Samitier, 2016). Particles manufactured by nanotechnology seems to have the ability to inhibit infections, decrease inflammation, and also increase the initial formation of tissue that will help to prolong life of implants (Teoh, *et al*., 2015).

An artificial organ is generally intended to be implanted or integrated into a human body to compensate the failure of an organ in conjunction with living tissue. These artificial organs could be made using plastic polymers, living cells, metals, biodegradable polymers or a mixture of these materials. Two-nozzle 3D bioprinting, Additive combined molding, Decellularized organ regeneration are few technologies that can be used in manufacturing artificial organs (Wang, 2019).

Thedevelopment of an implantable artificial kidney that reduces the need for renal transplantation has a large impact in the field of nano-nephrology. The artificial kidney may beused as an external or internal device (Soriano, Rodríguez-Benot and Valcárcel, 2018). The wearable artificial kidney basically means that it is removable and portable. They are like belts that have the machinery to perform hemodialysis. Like any other means of dialysis, they require a vascular access. In 12–14 hours it performs thefunction of an ordinary dialyzer in 3–4 hours (Guraet al., 2016).

Also, artificial kidney could be an internal one in that is can be implanted surgically. Another artificial kidney, that is an implantable kidney in a chip combines micro andnanotechnology using the same approach as the previousmacro model: combination of filter nanotechnology and living kidney cells (Soriano, Rodríguez-Benot and Valcárcel, 2018). The contributions of nanotechnology have been huge in the fields of tissue engineering can impact the world of renal replacement therapy. Nano-fluidic systems and nano-membranes capable of been selective filtration of fluids have been developed (Thekkedath, *et al*., 2017).

The field of microfluidics has come a long way since the first effort to reproduce the functional unit of a kidney on a single chip (Paoli and Samitier, 2016). Henceto replicate the full functions of a kidney itis necessary to include several nanotechnological microchips. Such a technology isin under consideration for experimentation.Nanotechnology has promising features to be capable of development as artificial kidney in a simple and comfortable manner (Soriano, Rodríguez-Benot and Valcárcel, 2018).

2. Conclusion

End Stage Renal Disease is a condition that lacks any specific pharmacotherapy and so we need to look towards other means of treatment, say renal transplantation and dialysis. As decades pass growth in technology and engineering reflects the potential in advancing treatment options. Miniaturization helps create handy portable artificial substitutes for kidneys. Access to such a technology, will result in improvements in patients' quality of life as well as significant savings for patients and the health system at large. The promising field of nanonephrology is still underway in development and lacks full consideration for research and needs better attention.

Conflict Of interest

None

Ethical Approval

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