Implantable Artificial Kidney: An Introduction

Grace Stibie
Dr. Jairo Rondón
Polytechnic University of Puerto Rico - Biomedical Engineering Department
2025

ABSTRACT

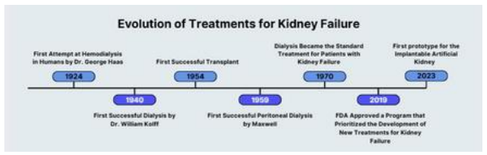
Since 1970, kidney failure treatments have remained limited to dialysis and transplants, with dialysis impacting quality of life and transplants facing organ shortages. To address this, The Kidney Project and UCLA researchers are developing implantable artificial kidneys (IAK)—one bioartificial and one fully mechanical. These innovations aim to reduce dialysis dependence and improve patient independence. Despite challenges like biocompatibility and funding, researchers hope to introduce these life-changing devices by the 2030s.

INTRODUCTION

From the early 20th century until around 1970, there were significant advancements in kidney failure treatments. However, since 1970, progress has slowed, and the main treatments—hemodialysis, peritoneal dialysis, and kidney transplantation—have remained the standard for over 50 years.

While dialysis has been lifesaving, it also has drawbacks, including reduced quality of life, environmental impact, and high medical costs, particularly for Medicare. Kidney transplants are the preferred option, but the demand far exceeds the supply.

Given these challenges, there is a clear need for innovation in kidney failure treatment. In response, two major research groups are working on different approaches to develop an implantable artificial kidney, which could revolutionize care for kidney failure patients.



OBJECTIVES

- Understand the evolution of treatments for kidney failure.
- Understand the function of the Implantable Artificial Kidney (IAK) by comprehending its components and how they resemble the functional parts of the biological kidney.
- Analyze and compare the current projects working on the IAK
- Comprehend the benefits of this potential device

METHODOLOGY

DATA

Finding New Solutions

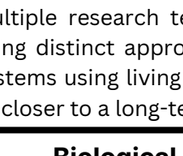
Multiple research teams are working toward the development of artificial kidneys, using distinct approaches to replicate renal function. Some focus on bioengineered systems using living cells, while others explore mechanical alternatives, each bringing us closer to a long-term solution for kidney failure.

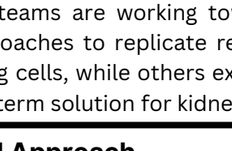
Biological Approach
By The Kidney Project

A project that started over 10 years ago is getting closer to finishing. The team has been working to replicate kidney function by developing a hemofilter that enables the device to operate powered by the patient's blood pressure. Additionally, to emulate the kidney's metabolic functions, they are creating a bioreactor that contains living renal tubule cells. This in turn will enable it to filter waste and perform essential metabolic functions without the need for external power or immunosuppressive drugs

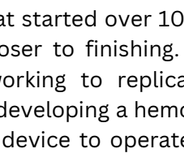
Structural design of IAK (Roy, 2021)

This device has two major components


Hemofilter Module (Roy, 2021)

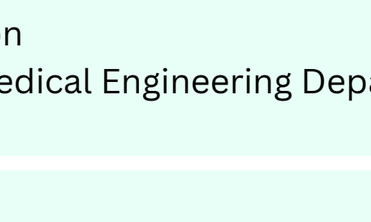

Bioreactor Module (Roy, 2021)

Overall Scheme of Implantation

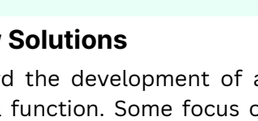

Overall Scheme of Implantation (Roy, 2021)

Mechanical Approach
By UCLA Group

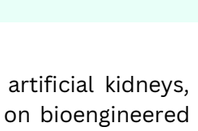
Dr. Ira Kurtz and his team are pursuing a different approach by mechanically simulating kidney function. Their ultimate goal is to develop an implantable artificial kidney. Although still in the early stages, the team has successfully created a more efficient hemodialysis system that reduces water waste and offers patients greater independence.


Overall Components of Device (Kurtz, 2021)

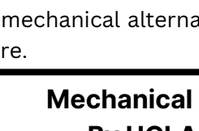
This device has four major components



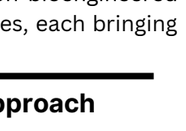
Filters cells and proteins (Kurtz, 2021)



Filters glucose (Kurtz, 2021)

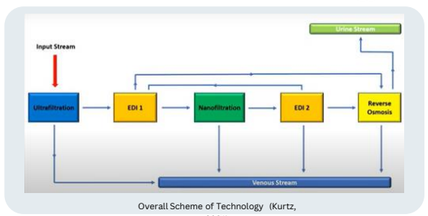


Ion Transport (Kurtz, 2021)



Water Transport (Kurtz, 2021)

Overall Scheme of Technology



Overall Scheme of Technology (Kurtz, 2021)

ANALYSIS AND RESULTS

Comparison Summary

Feature	The Kidney Project	Dr. Ira Kurtz's Project
Approach	Hybrid (biological and mechanical)	Fully mechanical
Cell Usage	Incorporates living kidney cells	No living cells used
Power Source	Patient's blood pressure	Self-contained mechanical systems
Water/Dialysate Requirement	None	None
Immunosuppression Needed	No	No
Current Stage	Preclinical animal studies	Prototype development
Estimated Clinical Trials	In 4–5 years (pending funding)	In ~3 years (pending development)

CONCLUSIONS

Understanding the evolution of treatments for kidney failure allows us to appreciate the technology available today. Recognizing patients' needs helps us innovate new ideas for their improvement. The Implantable Artificial Kidney will be a revolutionary breakthrough for these patients and the medical industry.

FUTURE WORK

Future research will focus on advancing both biological and mechanical designs toward clinical application. For the Kidney Project, efforts will emphasize long-term biocompatibility testing and regulatory approval for implantable use. Meanwhile, Dr. Kurtz's team aims to miniaturize their mechanical system for implantation and further optimize filtration efficiency. Continued innovation, funding, and interdisciplinary collaboration will be essential to transition these technologies from prototypes to viable patient solutions.

REFERENCES

Implantable artificial kidney. (2021). UCLA Health. https://www.uclahealth.org/medical-services/nephrology/clinical-programs/implantable-artificial-kidney

Roy, S. (2021). The Kidney project successfully tests a prototype bioartificial kidney. https://pharmacy.ucsf.edu/news/2021/09/kidney-project-successfully-tests-prototype-bioartificial-kidney

Rondón, J., Muñiz, C., Lugo, C., Farinas-Coronado, W., & Gonzalez-Lizardo, A. (2024). Bioethics in Biomedical Engineering Bioética en Ingeniería Biomédica. Revista Ciencia e Ingeniería. Vol, 45(2).

ACKNOLODGEMENTS

I would like to acknowledge my mentor, Dr. Jairo Rondón, whose guidance and inspiration have been invaluable.