Artificial Organs

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EDITORIAL

Nuclear-Powered Artificial Organs: A Reconsideration, Ten Years Later

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In 2015, I asked in these pages whether it was time to revisit the idea of nuclear-powered medical devices [1]. That editorial was not a prescription to revive them immediately, but rather a reminder that the concept once had real momentum. A decade later, with new technologies emerging and fresh entrepreneurial interest in nuclear batteries, it seems worth reflecting again on what we learned from the past—and where the future might lead.

1 | A Forgotten Frontier

In the 1960s and 70s, the U.S. Atomic Energy Commission and the National Heart Institute invested in nuclear-powered artificial organs. In 1972, Harvard Medical School and Thermo Electron implanted a plutonium-238 powered assist pump into a calf, proving that miniature nuclear power was technically feasible [2,3]. Pacemakers became the most successful application, with nearly 3000 patients worldwide receiving devices powered by plutonium-238 or promethium-147 [4,5]. These implants could last 20–40 years, a stunning improvement over the chemical batteries of the time.

And yet, the field abandoned nuclear solutions by the early 1980s. Concerns about radiation risk, regulatory burdens, and security combined with breakthroughs in lithium-iodine batteries, which suddenly offered safe, reliable lifespans of 5–10 years. At the same time, the nuclear accidents at Three Mile Island and later Chernobyl fueled a cultural backlash that sealed the technology's fate.

It is striking to recall, as Victor Poirier noted in a recent *Artificial Organs* interview, that the idea of using plutonium for pacemaker batteries was first suggested by Edward Teller himself [6]. The artificial heart story has always had unlikely intersections with nuclear physics.

2 | What Has Changed Since 2015

When I revisited the history a decade ago, lithium-ion batteries were the state of the art. Today, even they are being eclipsed. Solid-state batteries and multivalent-ion chemistries promise higher densities, longer lifespans, and better safety. For most implants, these advances leave little room for nuclear solutions [7,8].

But the story doesn't end there. Beta voltaic batteries—devices that harvest beta decay the way solar cells harvest photons—are quietly re-emerging. Their power densities are low, but their half-lives are long, making them attractive for sensors and low-drain implants. A recent report in *IEEE Spectrum* describes Infinity Power's nickel-63 technology, with claims of scalability from microwatts to megawatts. Ambitious? Certainly. But it shows that nuclear-driven power conversion remains on the table.

Meanwhile, percutaneous energy transfer—long pursued as a "wireless" solution for ventricular assist devices—remains an imperfect substitute. It is less tethered but not fully tether-free, and efficiency losses limit its appeal.

3 | Why the Question Still Matters

Artificial organs today are designed around advanced batteries, wireless charging, and biohybrid innovation. Nuclear power no longer sits in the mainstream conversation. Yet the reasons to keep it in mind remain compelling: unmatched energy density, decades of uninterrupted reliability, and freedom from charging cycles.

The barriers are also unchanged: complex regulation, disposal challenges, and persistent public unease. Still, technologies rarely disappear entirely. They resurface when a niche need demands them. For DARPA, NASA, or extreme long-term

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implants where replacement is impossible, nuclear remains a tool worth remembering.

One area I did not address but was a welcomed suggestion by a peer reviewer of my comments is the issue of waste heat generated by any implanted battery, wireless charging, or biohybrid technology. The main issue with waste heat in implanted batteries, wireless charging, and biohybrid devices is the risk of damaging nearby tissue since implants cannot rely on external cooling systems. All excess heat must dissipate through the body, making thermal management critical.

3.1 | Key Challenges

- Tissue damage: Even a 2°C temperature rise can cause inflammation, cell death, or fibrous capsule formation that degrades device function.
- Limited insulation benefit: Low-conductivity casings prevent hot spots but don't reduce total heat absorbed by tissue.
- Miniaturization: Smaller, high-power components create concentrated heat zones.
- External factors: Hydration, health, and environment affect the body's ability to dissipate heat.

3.2 | Device-Specific Issues

- Implanted batteries: Generate steady heat during charging/discharging; overheating can damage the battery or surrounding tissue.
- Wireless charging: Suffers energy losses as heat in tissue and coils; limited by safety standards for specific absorption rate (SAR).
- Biohybrid technologies: Living components like cells and neurons are highly temperature-sensitive; heat can disrupt their integration with synthetic materials.

3.3 | Thermal Management Approaches

- Conductive materials to spread heat more evenly.
- Smart charging systems that adjust power delivery to reduce heating.
- Strategic placement near blood-rich tissues for better cooling.
- Leveraging angiogenesis, the body's own vessel growth response to heat (though not a design solution).
- MRI-safe materials designed to limit RF-induced heating.

3.4 | Overall

Managing waste heat is a central engineering and biological challenge in developing safe, long-lasting implantable and biohybrid medical technologies.

4 | Looking Forward

My editorial 10 years ago was a call to remember. Today my call is to remain curious. Nuclear power for artificial organs may never return as a mainstream option—but its history reminds us that innovation often comes from bold ideas pursued at the edge of possibility. If nothing else, that spirit should continue to inspire us as we confront the energy challenges of tomorrow's medical devices.

Author Contributions

The author takes full responsibility for this article.

Conflicts of Interest

The author declares no conflicts of interest.

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