

Green Surgery Realized by Monitor-Free AR: Enhancing Surgeon Performance and Sustainability in Hepato-Biliary-Pancreatic Surgery

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【Purpose】

In the field of hepato-biliary-pancreatic (HBP) surgery, which demands precise procedures, improving clinical outcomes and reducing environmental impact are critical challenges. Laparoscopic and robotic surgery, in particular, rely on large, energy-intensive monitors, posing a barrier to the realization of "**Green Surgery**" (environmentally conscious surgery). The purpose of this study was to develop a monitor-free AR surgical system and to evaluate its clinical utility and sustainable environmental impact reduction effect.

Green Surgery

Green surgery refers to environmentally sustainable surgical practices aimed at **reducing waste**, **minimizing energy consumption**, and **lowering the carbon footprint** of operating rooms while maintaining patient care quality.



【Methods】

The subjects were **10 cases** in HBP laparoscopic and robotic surgery. We developed a system that eliminates the need for external monitors by stereoscopically displaying 3D endoscopic video directly into the surgeon's field of view using an AR headset (Meta Quest 3, Apple Vision Pro). The system's effectiveness was evaluated with the participation of novice and expert surgeons. Evaluation metrics included the surgeon's spatial awareness, efficiency, and ergonomic comfort. A comparative analysis of annual energy consumption (kWh) and CO₂ emissions (kg/year) for the AR headsets and standard monitors was also performed.

How AR-HMD Can Make Endoscopic Surgeries Greener

1. Reduced Energy Consumption

VR headsets use two small, magnified lenses close to the eyes. This setup maximizes the viewing area while minimizing the size of the display, leading to significant energy efficiency. In comparison to large 2D monitors, VR headsets require much less power.



How AR-HMD Can Make Endoscopic Surgeries Greener

2. Minimized Physical Resource Usage

By using VR, we can significantly reduce the physical equipment needed in the operating room. This not only cuts down on electricity usage but also reduces the need for physical movement of surgeons and equipment. This reduction in movement helps decrease CO₂ emissions. Additionally, using virtual data over physical resources further reduces the use of medical supplies.



How AR-HMD Can Make Endoscopic Surgeries Greener

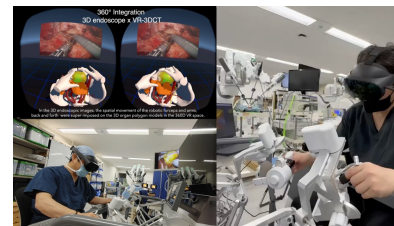
3. Decreased Manufacturing and Disposal

Traditional 2D displays consume a lot of resources and energy in their manufacturing and disposal processes. In contrast, VR headsets have a lower initial cost and are more economical than traditional displays. The reduction in manufacturing and disposal also lessens the environmental impact.



【Results】

- The stereoscopic effect of the AR headset enhanced the surgeon's spatial awareness, making it easier to intuitively understand the depth and spatial relationships of organs, lesions, tumors, and vessels, which in turn facilitated dissection and suturing.
- Consequently, novices demonstrated accelerated skill acquisition, while expert surgeons performed procedures more efficiently and with fewer errors.
- In the quantitative environmental assessment, the Apple Vision Pro's annual energy consumption was 21.9 kWh, an **83.3% reduction** compared to a standard 55-inch LCD monitor (131.4 kWh).
- This also led to a significant reduction in annual CO₂ emissions from 61.2 kg to 6.4 kg.



Comparative Analysis

How VisionPro Can Make Surgery Greener

	Power consumption (W/year)	Annual Power (kWh)	Cost (USD)	CO ₂ emissions (Kg/year)
55-inch LCD Display	120	131.4	50	61.2
27-inch LCD Display	50	54.8	20	43.7
AR-HMD Vision Pro	20	21.9	4	6.4

(6 hrs/365 days)



Green Surgery
Reducing the environmental impact of surgical care

【Discussions & Conclusions】

This study demonstrates that an AR headset simultaneously enhances surgeon performance in HBP surgery and dramatically reduces the operating room's environmental footprint. This is an important and practical step that embodies "**Green Surgery**," a concept that balances high-quality medical care with a **sustainable environmental impact reduction effect**. This system presents a new paradigm shift in minimally invasive surgery.