A NOVEL PROXIMAL SMOKE EVACUATION TECHNOLOGY TO ENHANCE SURGICAL VISIBILITY AND ACHIEVE A SMOKE-FREE OPERATING ROOM IN MINIMALLY INVASIVE SURGERY

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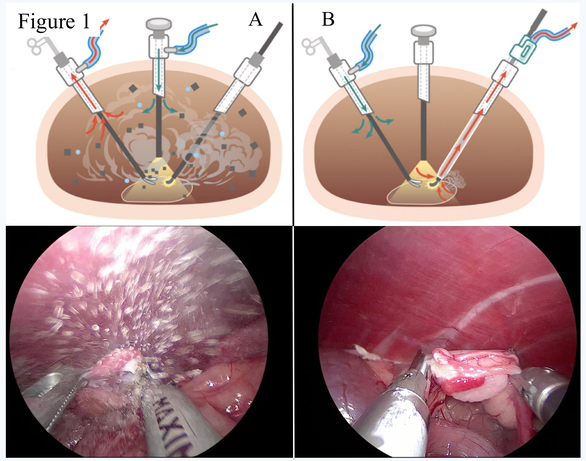
Background

- **The electrocautery devices and ultrasonic scalpels generate a large amount of smoke containing hazardous air pollutants and live pathogens** associated with eye irritation, respiratory tract damage, infection, leukemia, and cancer[1]. Notably, particle concentrations in minimally invasive surgery (MIS) surgery have been reported to be significantly higher than those in open surgery[2].
- Surgical smoke rapidly accumulates within the confined body cavity, particularly in narrow operative fields such as the pelvis or thyroid region. **The poor visibility and frequent camera lens fogging lead to surgical workflow disruption and increased operative risk[3].**
- **Most currently available smoke evacuation systems for MIS are connected to trocar ports.** However, smoke is typically generated deep within the operative field, far from the trocar site, which limits the efficiency of smoke removal (Figure 1).
- This study aims to develop a proximal smoke evacuation system integrated with laparoscopic energy instruments, enabling efficient removal of surgical smoke at its source to improve visual clarity and enhance surgical safety.

Figure 1



Methods

- **A proximal smoke evacuator was designed to fit standard 5-mm laparoscopic energy devices.** When inserted, the gap between the energy device and the evacuator forms a channel that allows surgical smoke to travel directly from the device tip to the suction pump (Figure 2).
- A total of 124 trials (62 monopolar electrocautery and 62 ultrasonic scalpel procedures) were conducted in six live porcine models by 20 surgeons from multiple specialties.
- Under video recording, electrocautery and ultrasonic dissection were performed on highly vascular organs, such as the liver surface. Each procedure was repeated three times using different smoke evacuation pathways: proximal evacuation (smoke evacuator), distal evacuation (trocar port), and no evacuation.
- Outcome measures included in-screen smoke density, smoke clearance time, pneumoperitoneum stability, and levels of cancer-associated particulate matter.

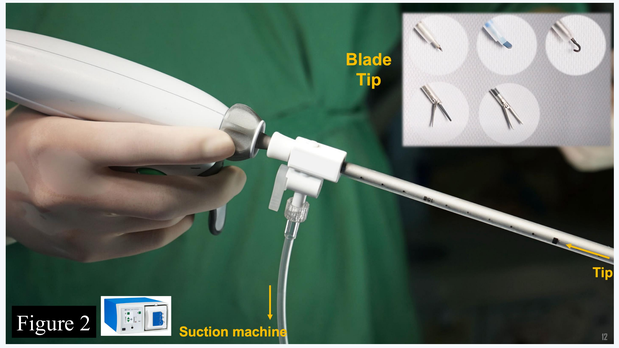
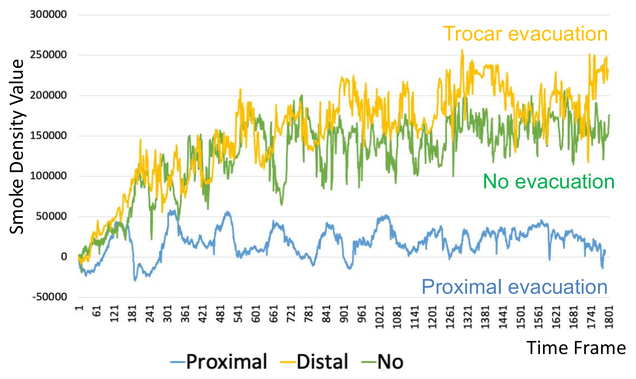


Figure 2

Results

- Visible smoke density was reduced by **86%** with proximal evacuation compared with trocar-based evacuation (Figure 3).
- The time required for complete smoke clearance following electrocautery activation was reduced by **75%**, resulting in improved procedural efficiency.
- Continuous monitoring demonstrated stable pneumoperitoneum pressure throughout the procedures.
- Chemical and aerosol analyses showed that more than **99%** of hazardous particulate matter and volatile organic compounds (VOCs) were removed before dispersing into the operative field (Table 1).
- Surgeon feedback indicated **improved image clarity, reduced frequency of lens cleaning, and smoother surgical workflow**.

Figure 3



Conclusion

- Source-based smoke evacuation may represent a new paradigm for surgical smoke management in minimally invasive surgery.
- By removing surgical smoke at its source, this technology **improves visualization, enhances operative efficiency, reduces exposure to hazardous particles,** and achieves a smoke-free environment.
- This device has received **U.S. FDA 510(k) clearance** and has demonstrated efficacy in real-world animal and human surgical procedures in Taiwan.
- The device is compatible with multiple laparoscopic energy instruments, including **monopolar device, bipolar device, and ultrasonic scalpel**. Investigators interested in participating in future **clinical trials and studies** are welcome to contact: sauronlai@ntuh.gov.tw

Table 1. Concentrations of *VOCs in the confined body cavity

Carcinogenic *VOC	CAS NO	Proximal Evacuator	Trocar Evacuation	No Evacuation
Ethylbenzene	71-43-2	**0.307**	74	83.2
Toluene	108-88-3	**0.809**	138	175
Ethylbenzene	100-41-4	**ND	59	65.6
m,p-Xylene	---	**ND	8.28	10.7
Styrene	100-42-5	**ND	42.7	43.3

*VOC: Volatile Organic Compounds
**ND: Not detected (below limit of detection)

Figure Legend

Figure 1. (Top) Schematic illustration of distal (A) and proximal (B) smoke evacuation pathways during minimally invasive surgery. (Bottom) Representative endoscopic views of right (A) and left (B) oophorectomy in a 4-kg dog model demonstrating the different settings used for smoke evacuation.
Figure 2. Assembled proximal smoke evacuator mounted on a laparoscopic energy device without affecting instrument handling.
Figure 3. Cumulative smoke density in the surgical visual field over time under proximal, distal, and no evacuation conditions. Higher values indicate poorer visibility.

Reference

1. Li AJ, Pal VK, Kannan K. A review of environmental occurrence, toxicity, biotransformation and biomonitoring of volatile organic compounds. J Environ Chem Ecotoxicol 2021;3:91–116.
2. Hsu FL-T, Ho T-W, Chang C, Wu J-M, Lin M-T. Chemical composition of smoke produced by open versus laparoscopic surgery for cholecystectomy. HPB 2022;24: 1335–40.
3. Zhang J, Zhou Z, Ho WS, et al. Methods used for smoke evacuation in laparoendoscopic surgery: a technical review. Surg Today 2025;55: 1513–1523.