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Ergonomic Problem in Surgical Smoke Control During Surgery

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ABSTRACT

Surgical smoke is the plume and air contaminants produced by energy devices during the surgery. Surgical smoke consists of fine particles containing pathogenic microorganisms and chemical substances poses a health risk to medical personnel during the surgery. The COVID-19 pandemic has highlighted the importance of surgical smoke control. As a surgical smoke protection on the medical personnel side, personal protective equipment (PPE) such as N-95 high-performance masks are widely used. Wearing a mask for a long time poses problems such as fatigue, hypercapnia and loss of concentration. Increasing the smoke evacuation efficiency of a surgical instrument-mounted smoke evacuation device poses problems such as deterioration of operability and patient temperature maintenance. It is important to enlighten medical workers about the importance of surgical smoke control, and to improve the smoke exhaust system considering maintenance of physiological environment and ergonomic problem.

Keywords: Surgical smoke control, Surgery, Ergonomics

INTRODUCTION

Surgical smoke is the plume and air contaminants produced by energy devices such as electrocautery, ultrasonic coagulating sears and laser scalpels during the surgery. Surgical smoke consists of fine particles containing pathogenic microorganisms and chemical substances from high-temperature carbonized tissues and dissected tissues, and poses a health risk to medical personnel during the surgery. The COVID-19 pandemic has highlighted the importance of surgical smoke control. We investigated the current status and ergonomic issues of the instruments currently used for surgical smoke countermeasures.

Status and Ergonomic Problems of Personal Protective Equipment

Wearing a mask in the operating room has long been a routine, and N95 masks were also used when treating patients with infectious diseases even before the pandemic of COVID-19. Head and neck pain occur when wearing a mask. Furthermore, when wearing an N95 mask for a long time, the burden on medical workers is greater than that of wearing a conventional mask, such as an increase in hypercapnia and a decrease in concentration. There are also spacesuit-like surgical gowns that completely cover the upper body with a ventilated hood for surgeries that require a high degree of cleanliness, such

Figure 1: Scenes of open surgery (a) and endoscopic surgery (b).

Figure 2: N95 mask (a) and Flyte personal protection system^{TM}, Styker (b).

as artificial joint replacement surgery. This is also effective as a countermeasure against surgical smoke, but its use in all surgeries is not realistic due to complexity, fatigue and cost when wearing it (see Figure 1 and Figure 2).

Status and Ergonomic Problems of Smoke Evacuation Equipment

Many of the smoke evacuation devices for conventional open-surgery are made by integrating a conventional electric cautery with a smoke suction tube. The ergonomic issues of these devices include an increase in size and weight due to integration with suction system, and deterioration in operability (see Figure 3).

In current surgery, endoscopic surgery is rapidly increasing as well as conventional open-surgery. Endoscopic surgery is performed by inserting an endoscope and small-caliber surgical instruments into a body cavity through a small incision.

Endoscopic surgery creates a working space by insufflating carbon dioxide into a abdominal cavity. Its insufflation process is called pneumoperitoneum. Since endoscopic surgery is performed based on endoscopic visual information, smoke evacuation is essential to secure the field of view (Wu, 1997). The insufflation instrument (pneumoperitoneum system) which integrates the pneumoperitoneum function and the surgical smoke evacuation function is also in use. In endoscopic surgery, surgical smoke is expelled

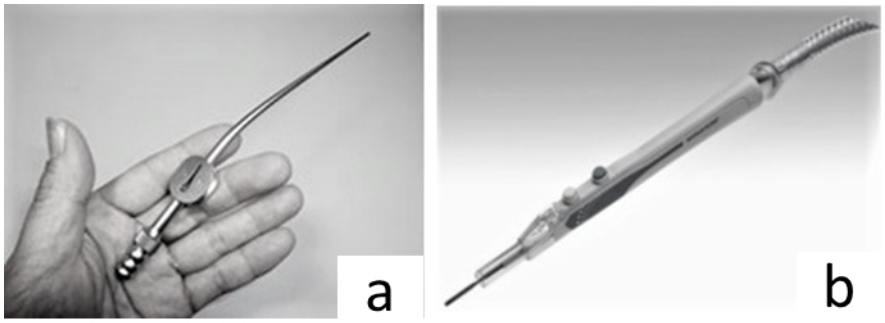

Figure 3: Conventional suction device (a) and electric cautery with a smoke suction tube, PortaPlume^{TM} (b).

through the pneumoperitoneum system, so it is easy to evacuate surgical smoke without diffusing into the operating room. In the case of surgical smoke countermeasures in endoscopic surgery, there is little increase in weight and size of surgical instruments. Also deterioration in operability due to smoke suction system is reduced compared to the open surgery. However, if the amount of suction from the abdominal cavity is increased, the amount of CO2-insufflation to maintain the operating space also increases, resulting in dryness of the abdominal cavity and hypothemia.

DISCUSSION

Energy devices such as electrocautery, laser scalpels and ultrasonic coagulating sears are indispensable medical equipment for modern surgery, but they generate surgical smoke from carbonized tissue and incised tissue during tissue incision and coagulation (see Figure 4). Surgical smoke contains toxic chemicals such as carbon monoxide, hydrogen cyanide, acrylonitrile and benzene (see Table 1). These toxic substances can cause both acute and chronic health effects such as pharyngitis, conjunctivitis, chronic bronchitis, asthma, emphysema etc., and also have carcinogenic effects (Barret, 2003). Also, it has been reported that viable bacteria and virus such as HIV, hepatitis B and

Table 1. Chemicals in surgical smoke.

Acrolein	Creosols	Methane
Acetonitrile	Ethane	Phenol
Acrylonitrile	Ethene	Polyaromatic
Acetylene	Ethyl Benzene	Hydrocarbons
Benzaldehyde	Ethylene	Propene
Benzene	Ethynyl benzene	Propylene
Benzo nitrile	Formaldehyde	Pyridine
Butadiene	Furfural	Pyrrole
Butene	Hydrogen cyanide	Styrene
Carbon disulfide	Indole	Toluene
Carbon monoxide	Isobutene	Xylene

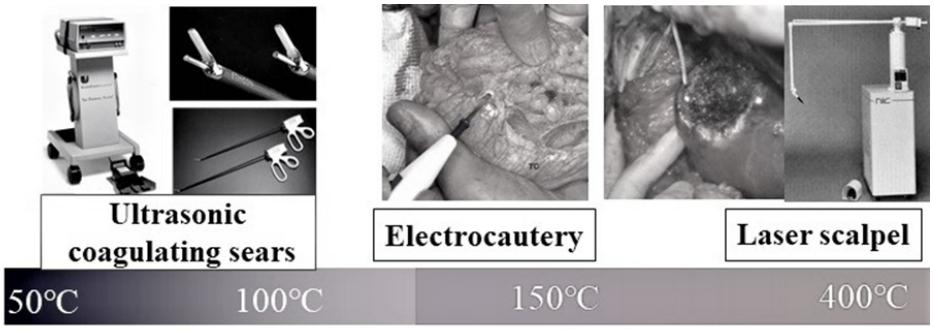

Figure 4: Operating temperature of energy device for surgery.

HPV in the tissue are dispersed as surgical smoke when tissue is incised by energy devices, and there is a risk of infection and carcinogenic virus transmission (Okoshi, 2015). Surgical smoke is hazardous for the health of operating room personnel, so medical personnel in the United States have recognized the importance of surgical smoke control (NIOSH, 2015). In Japan as well, the importance of surgical smoke control has been reaffirmed as a result of the pandemic of COVID-19. There are various types of PPE such as N95 masks for medical workers to prevent surgical smoke. Since there is a trade-off between protective function and ergonomic load when worn, PPE itself needs further improvement.

There are international standards for air conditioning in operating rooms, such as ventilation temperature, speed and frequency (see Figure 5). However, since surgical smoke directly hits the medical personnel who are close to the patient, air conditioning system for operating room alone is not sufficient to prevent surgical smoke. Surgical smoke should be aspirated directly at the site of origin and properly evacuated out of the operating room. In the open-surgery, a suction tube is placed close to the source of the smoke and the surgical smoke is suctioned directly. However, an assistant person who

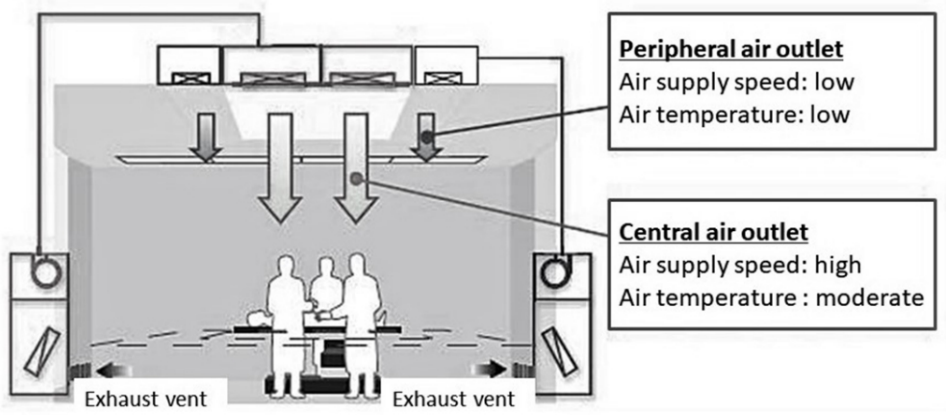

Figure 5: Air conditioning system for operation room.

manipulates a suction device is required for the smoke evacuation, and the suction device can interfere with the surgical operation. In the smoke exhaust equipment attached to surgical instruments, there is a trade-off between smoke evacuation efficiency and ergonomic operability such as compactness and weight reduction.

In endoscopic surgery, increased suction volume causes hypothermia in the patient and tissue desiccation. As a countermeasure, the automatic control function of the temperature and humidity in the abdominal cavity is also important.

CONCLUSION

Current status and ergonomic issues of the instruments currently used for surgical smoke control were investigated. It is important to enlighten medical workers about the importance of surgical smoke control, and to improve the smoke exhaust system considering maintenance of physiological environments and ergonomic problems.

REFERENCES

Barrett WL, Garber SM, Surgical smoke: A review of the literature, (2003). Surg Endosc. 17:979–987.

NIOSH, (2015). NIOSH Study Finds Healthcare Workers' Exposure to Surgical Smoke Still Common. (Nov 3, 2015): https://www.cdc.gov/niosh/updates/upd-11-03-15.html.

Okoshi K, Kobayashi K, Kinoshita K, Tomizawa Y, Hasegawa S, Sakai Y. (2015). Health risks associated with exposure to surgical smoke for surgeons and operation room personnel. Surg Today. 45(8):957–965.

Wu JS, Luttmann DR, Meininger TA, Soper NJ, (1997). Production and systemic absorption of toxic byproducts of tissue combustion during laparoscopic surgery, Surg Endosc. 11:1075–1079.