Short Communication

Pilot Study of a Dissection Table for Gross Anatomy Laboratory Equipped with a Photocatalytic Device that Decomposes Formaldehyde

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Recently, there has been concern about the effect of formaldehyde (FA) on the human body. The International Agency for Research on Cancer (IARC) has reported that exposure to FA can induce cancer in humans¹. FA is also classified by the Japan Society for Occupational Health as “a substance that is considered to cause cancer in human beings and there is evidence that it does cause cancer”². FA is also a potent contact sensitizer and can elicit contact dermatitis and respiratory symptoms, probably through irritant mechanisms³.

Gross anatomy laboratory is a compulsory subject in most medical and dental schools and is used for studying the normal structure of the human body. Cadavers for the gross anatomy laboratory are generally injected with embalming fluid, which contains FA as a principal component. Since long periods in the gross anatomy laboratory are required to learn human body structures in detail, it is necessary for the cadavers to be fixed and preserved. Antisepsis using FA is used for this purpose because no better method exists at present. To reduce exposure to FA, the Japanese Ministry of Education, Culture, Sports, Science and Technology has released “The improvement plan for the dissection course in medical and dental schools”⁴ which requires a reduction of FA concentrations in gross anatomy laboratories.

To prevent significant sensory irritation in the general population, the World Health Organization (WHO)

recommends an air quality guideline value of 0.1 mg/m³ (0.08 ppm) as a 30-min average for FA⁵. The American Conference of Governmental Industrial Hygienists (ACGIH) has set a ceiling limit for FA of 0.3 ppm⁶. The current occupational Permissible Exposure Limit (PEL) for FA set by the Occupational Safety and Health Administration (OSHA) is 0.75 ppm for an 8-h time-weighted average exposure (TWA) and 2 ppm for a 15-min short-term exposure limit (STEL)⁷. In Japan, the Ministry of Health, Labour and Welfare (MHLW) has set an air quality guideline defining two limit values for environmental exposure to FA: 0.08 ppm as an average for general workplaces and 0.25 ppm for specific workplaces such as an FA factory⁸. Gross anatomy laboratories are classified as specific workplaces.

In the gross anatomy laboratory at our university in 2003, average indoor FA concentrations during the 4th, 10th and 18th laboratory sessions were 0.45, 0.38 and 0.68 ppm, respectively, ranging from 0.23 to 1.03 ppm⁹. FA concentration levels in the laboratory always exceeded the guideline of 0.08 ppm for the general indoor environment specified by the WHO⁵ and of 0.25 ppm for specific workplaces specified by the MHLW⁸. Some levels even exceeded the guideline of 0.5 ppm set by the Japan Society for Occupational Health² and of 0.75 ppm for an 8-hour TWA set by the U.S. OSHA⁷. Further, our previous report⁹ showed that if a person is close to the cadavers during the gross anatomy course, his/her personal exposure levels are 2 to 3-fold higher than the mean indoor FA concentration. These results suggest that medical students are exposed to higher concentrations of FA than the guideline values given above. We previously reported physical symptoms such as eye, throat and/or nasal irritation under these background circumstances, which are similar to allergic symptoms induced by exposure to FA¹⁰. It is possible that IgE production is evoked during gross anatomy laboratories. In order to test this hypothesis, we examined the relationship between personal FA exposure levels and plasma IgE levels in a gross anatomy laboratory course¹¹.

It is important to consider taking appropriate countermeasures directed at the source of the contamination and to install an air-conditioning system. We have started to reduce the indoor FA concentrations by designing and building a prototype dissection table that inducts and breaks down FA emitted from cadavers during gross anatomy laboratories. We are also trying to improve the environment during gross anatomy laboratories by reducing the level of exposure through the use of fewer cadavers during the dissection course¹².

Photocatalyst technology¹³ is expected to mitigate air pollution because the photocatalyst decomposes volatile organic compounds (VOCs) into carbon dioxide and water. Studies of the efficiency of removal of VOCs have been reported^{14–16}. However, there are few scientific

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Fig. 1. Diagram of the dissection table equipped with a photocatalytic device that decomposes formaldehyde. The FA concentration in the room was measured at five locations, (A) on the special dissection table, (B) under the table or exhaust outlet, (C) at the corner of the room, (D) blowout aperture and (E) induction aperture.

reports that target the decomposition performance of the photocatalyst for gross anatomy laboratories, and it has yet to be evaluated.

In this paper, we report on a measure of we have taken to improve the environment in gross anatomy laboratories through the installation a special dissection table equipped with a photocatalytic device that decomposes FA using a photocatalyst.

Materials and Methods

Dissection table equipped with a photocatalytic device that decomposes FA

A dissection table (Fig. 1; Natsume Seisakusho Co., LTD Tokyo, Japan) equipped with a highly efficient photocatalytic device (Fig. 2) that works via photocatalysis using titanium oxide and ultra-violet (UV) rays was used. This photocatalytic device (Fig. 2) incorporates three photocatalytic filters (245 mm × 295 mm × 15 mm) coated with titanium oxide, twelve ultra-violet (UV) lamps (10 W, 269 nm) and activated carbon (1,500 g).

The dissection table features a design that prevents personal exposure to formaldehyde gas by blocking the FA gas with an air curtain. The photocatalyst decomposes FA gas sucked in from beside the cadaver's head and after decomposing and removing harmful substances, part of the gas is blown into the air via slit-like pores situated above the cadaver's feet, forming an air curtain. The possible amount of air volume emitted under operating conditions is about 4 m³/min by a fan, and most of the air, after photocatalytic decomposition of FA, is emitted into the room.

Environment in which the dissection table was installed

We placed the above-mentioned dissection table with

Fig. 2. Diagram of the photocatalytic device.

a cadaver on it, the body cavity or deep structure of which was being dissected, in the center of a relatively small room (45.32 m³ [3.4 × 4.3 × 3.1 m]) with no ventilation system and measured the indoor concentrations of FA at different locations around the table. The reason we used only one cadaver was because we wanted to exclude the possible influence of another cadaver in the room in order to make an accurate evaluation of the table's effectiveness. The room used in this study was not commonly used for gross anatomy laboratories.

Sampling and analyzing method

Sampling and analysis were done as described below according to TO-11A by the US Environmental Protection Agency (EPA)¹⁷⁾ and NIOSH 2016 by the National Institute for Occupational Safety and Health (NIOSH)¹⁸⁾, with minor modification. Environmental air was collected by a 2,4-dinitrophenylhydrazine (DNPH) cartridge, LpDNPH S10L (Sigma-Aldrich, MO, USA), at a flow rate of 1 L/min using a mini pump, MP Σ 100H (Sibata Scientific Technology Co., Ltd, Tokyo, Japan), installed in the study room for 30 min. The air was collected at 5

Table 1. Formaldehyde concentrations in the each location

	Formaldehyde concentration (ppm) by location				
	A	B	C	D	E
Background	0.026	0.015	0.020	N.M.	N.M.
Before operation	0.458	0.271	0.336	N.M.	N.M.
During operation	0.084	0.057	0.101	0.036	0.947
Reduction (%)	81.66	78.97	69.94	N.M.	N.M.

N.M.; Not Measured.

Reduction; $100 \times \{(\text{Before operation}) - (\text{During operation})\} / (\text{Before operation})$

locations, as shown in Fig. 1.

Acetonitrile at a final volume of 5 ml was injected into the DNPH cartridge and the eluent was used as the sample solution. Analysis of FA was performed via high-performance liquid chromatography (HPLC, SHIMADZU: LC-2010C). For HPLC analysis, a column was used with an elute of $\text{CH}_3\text{CN}/\text{H}_2\text{O}$ -60/40 at a flow rate of 1.2 ml/min and detection was performed at a wavelength of UV 360 nm. This analysis of FA was performed at SRL Inc. (Tokyo, Japan).

Measurement sites

The FA concentration in the room was measured at five locations, (A) 30 cm above the cadaver on the special dissection table, (B) 30 cm above the floor under the table by the exhaust outlet, (C) at the corner of the room, (D) at the blowout aperture, (E) at the induction aperture (Fig. 1). Measurements at these five locations were conducted above floor level at about 1.3 m except for B, which was at 0.3 m. For each location, we collected FA in the room by using two samplers and adopted the average value. Location A corresponds approximately to the height of the breathing zone of students during dissection.

Results and Discussion

There are various ways of trying to deal with personal exposure to FA. One approach is to find a chemical substitute for FA. However, to date no suitable chemicals have been found. A different approach is to provide protective equipment to individuals exposed to the gas, such as goggles or a mask. However, some instructors and students feel uncomfortable using such equipment. A further approach is to modify the ventilation system but this is expensive as it requires modification of a large-scale ventilation system that extends from the room located in the building to the rooftop of the building and also requires maintenance following the modification. We have therefore developed a dissection table that enables a reduction in FA exposure. This dissection table is likely to cost less than modifications to the ventilation system. Coleman¹⁹⁾ suggested a similar idea, namely a dissection table containing a motor to create a downflow to suck all

the FA fumes from the cadaver into the table where they would be adsorbed by special active carbon filters. Clark²⁰⁾ has also detailed how FA concentrations can be reduced using fume cupboards for handling large volumes of FA and mixing embalming solutions. Kawamata and Koder²¹⁾ examined the reduction of FA by ammonium carbonate in cadavers and *in vitro*. They reported that the reduction of FA by ammonium carbonate seemed very useful, was easy to perform, and was also relatively inexpensive. However, there have been no suggestions for reducing FA concentrations in gross anatomy laboratories by introducing an efficient photocatalytic device that uses titanium oxide and UV rays and the formation of an air curtain blowing part of the decontaminated air into the air through slit-like pores situated above the cadaver's feet.

We have therefore built such a dissection table and evaluated its ability to decompose FA using photocatalysis.

Table 1 presents the concentrations of FA measured at each of the five locations (A–E). The background FA concentrations when the cadaver was not dissected or opened in the room were 0.026, 0.015 and 0.020 ppm at locations A, B and C, respectively.

The FA concentrations gradually increased as the bag containing the cadaver was opened. When the cadaver's bag was totally open and FA had spread into the room, the FA concentrations were increased to 0.458, 0.271 and 0.336 ppm at locations A, B and C, respectively. These levels exceeded the guideline level of 0.25 ppm for specific workplaces set by the MHLW⁸⁾.

When we used the highly efficient photocatalytic device, the FA concentrations were dramatically decreased to 0.084, 0.057 and 0.101 ppm at locations A, B and C, respectively. If we focus on location A, we can see a dramatic change in which the FA concentration decreases from 0.458 to 0.084 ppm during operation of the photocatalytic device. Location A is comparable with the value for personal exposure to FA. From these results, it was concluded that personal exposure to FA could be reduced using the modified dissection table. This study was performed in a room without ventilation; the effect

would be greater if a ventilation system were active in the room.

The FA concentration at location E was 0.947 ppm, which was higher than at location D (0.036 ppm) during operation of the photocatalytic device. This is because the airflow of the dissection table blew the FA gas from location D to E, forming an air curtain, where it was eventually sucked in beside the cadaver's head. The concentrations of FA at the blowout aperture (D) and exhaust outlet (B) were lowered as the FA gas was decomposed by the photocatalytic device. At location D, the FA concentration was 0.036 ppm, which is below the guideline level of 0.08 ppm set by the WHO⁵⁾ and the ceiling limit of 0.3 ppm set by the ACGIH⁶⁾. This dissection table enables relatively clean gas to be blown from the apertures above the cadaver's feet.

During operation of the photocatalytic device, the FA levels at locations A, B, C and D did not exceed the ceiling limit of 0.3 ppm set by the ACGIH⁶⁾, nor did it exceed the 0.25 ppm for specific workplaces set by the MHLW⁸⁾. Therefore, this dissection table enables us to reduce exposure to FA and to ensure safer practices during gross anatomy laboratories.

At locations A, B and C, the photocatalytic device enabled reductions in FA concentrations of about 82, 79 and 70%, respectively (Table 1). The FA level was reduced by about 80 percent through the use of the photocatalytic device. If you tried to improve the air ventilation system of the dissection room to reduce the FA concentration by about 80 percent it would be more expensive. Our solution, the dissection table equipped with a photocatalytic device, is less expensive, is easy to implement and is proven to be of use.

Although we reduced the risk of personal exposure to FA during a gross anatomy laboratory, there is still a residual risk of FA exposure that cannot be avoided, even when using the photocatalytic device. In this study, FA levels at all points except E approached the guideline of 0.08 ppm set by the WHO⁵⁾ during operation of the photocatalytic device.

In our study, FA levels were successfully decreased using a dissection table equipped with a photocatalytic device capable of decomposing FA. As the Japanese Ministry of Education, Culture, Sports, Science and Technology has directed measures for a reduction of FA concentrations in gross anatomy laboratories⁴⁾, we expect that the dissection table used in our study will be utilized by governments and staff involved in anatomical studies to improve air quality in gross anatomy laboratories.

In conclusion, the new dissection table enables us to work in an environmentally improved dissection room by reducing the FA level during gross anatomy laboratories. Although this was a pilot study, it is thought that a dissection table that enables the reduction of FA not only around the perimeter of the table itself, but also

throughout the whole dissection room is of much use. This paper shows that reductions in FA levels can be achieved effectively in gross anatomy laboratories and we expect that the dissection table, which eliminates FA thereby protecting everyone's health during gross anatomy laboratories, will be widely used.

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