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Formaldehyde Concentration in the Air and in Cadavers at the Gross Anatomy Laboratory in Hiroshima University

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ABSTRACT

The formaldehyde concentration in the air and in various tissues of 35 human cadavers were measured during a gross anatomy course held at the Faculty of Medicine of Hiroshima University in the 2003 educational year. Atmospheric formaldehyde levels were 0.25–0.55 ppm and thus less than the upper limit of the guideline for formaldehyde exposure (0.5 ppm) set by the Japan Society for Occupational Health (1988) except for one out of 10 measurements. The formaldehyde concentrations in tissues were as follows: the lung, 0.12 ± 0.09% (n=29); the liver, 0.12 ± 0.09% (n=29); and the brachioradialis muscle, 0.11 ± 0.09% (n=30). Considerable variation was found among the cadavers and these values were lower than those of Tsurumi University which provided the only other data (average formaldehyde concentrations ranged from 0.27 to 0.32%). At Hiroshima University, blood is allowed to drain during embalming, whereas it is not at Tsurumi University. Differences in the embalming procedure are thus responsible for low and fluctuating formaldehyde concentrations in cadavers at Hiroshima University, and it is conceivable that relatively low formaldehyde levels in the air result from low formaldehyde concentrations in cadavers and good room ventilation (10 room-air changes per hour). However, the Japanese Ministry of Health and Welfare recommended lower formaldehyde exposure levels (0.08 or 0.25 ppm) in 2002. Thus, it may be necessary to further reduce formaldehyde levels in the gross anatomy laboratory by means of such measures as neutralizing formaldehyde with ammonium carbonate; using a locally ventilated dissection worktable, etc.

Key words: *Formaldehyde, Dissection, Cadaver*

Formalin is a colorless and irritative fluid that contains about 37% of formaldehyde, and is widely used as a preserving agent of biological specimens because it is a good and potent fixative at a reasonable price. Recently, however, formaldehyde has attracted much attention due to its health hazards. At medical and dental universities in Japan, formalin has been used for years as an essential component of fixative for the preparation of human cadavers. Formaldehyde concentrations in the air of gross anatomy laboratories are often higher (0.07–2.94 ppm[1)], 0.5–1.5 ppm[5)], 0.16–9.2 ppm[6)], 0.4–1.5 ppm[7)]) than the permissible exposure level of the Japan Society for Occupational Health of 0.5 ppm[2)]. There has been an increasing number of reports that students suffer from various physical symptoms with a high prevalence during gross anatomy dissection practice, including burning eyes, lacrimation, irritation of the airways, and dermatitis[1,6-8,10)]. In a previous study, the formaldehyde levels in the air (10 cm above cadavers) and in cadaveric tissues were measured at Tsurumi University[4)], and the formaldehyde concentrations in tissues were as follows: the lung, 0.27 ± 0.04% (n=4); the liver, 0.28 ± 0.14% (n=5); and the brachioradialis muscle, 0.32 ± 0.06% (n=9). These are the only available data on the concentration of formaldehyde in cadaveric tissues. However, the relationship between the average formaldehyde concentration in room air and in cadaveric tissues is not known. In addition, atmospheric formaldehyde levels are influenced by the

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embalming procedure, the number of cadavers in the class, air ventilation, size and structure of the gross anatomy laboratory, and other factors. To evaluate the risk of health hazards at our facility and, if necessary, to take action to reduce the formaldehyde levels, we measured the formaldehyde concentrations in room air and cadavers at Hiroshima University.

MATERIALS AND METHODS

Embalming procedure

Cadavers were fixed by infusion via the femoral artery on one side (usually right side) first with 3 liters of prefixing solution containing 30 ml of Precoat A (Sunseal Chemical Co.Ltd, Tokyo, Japan), 250 ml of Precoat CC (Sunseal Chemical Co.Ltd) and 2,720 ml of tap water. This solution contains 0.42% formaldehyde, 0.88% methanol, 0.26% phenol and 0.93% unidentified esters. The cadavers were then perfused with 7 to 10 liters of fixative, where 5 liters consisted of 2 liters of Katoman solution (Katoman, Tokyo, Japan), 500 ml of formalin (37%), 250 ml of glycerin, 250 ml of phenol and 2 liters of tap water and contained 36% ethanol, 5.3% formaldehyde, 6.2% phenol, 5% glycerin and 1.2% thymol. Blood was allowed to drain from the dural venus sinus at the external occipital protuberance, and the cadavers were then incubated in fluid containing 2% formaldehyde, 45% ethanol, 1.5% phenol and 1.5% thymol at 37°C for 2–3 weeks. Finally, they were stored in an air-tight container until utilization in class.

Measurement of formaldehyde levels in the air

The gross anatomy laboratory has dimensions of 15.5 × 23.4 × 3.0–3.2 m. The room air was controlled at a temperature of 23 to 24°C and ventilated 10 times per hour without air recirculation. Thirty-eight dissecting worktables with one cadaver each were orderly and evenly aligned in 4 rows in the room, and thirty-five cadavers were dissected during this study. When not in use, the cadavers were covered by a plastic sheet. Air samples were collected at five sites: the center and the 4 corners of the room at the crossings of walkways between two tables. One liter of air at a height of 80 cm above the floor was passed through Kitagawa gas detector tubes 171SC (As One, Tokyo, Japan) and formaldehyde concentrations were judged from color changes in the tubes, though the concentrations were occasionally difficult to precisely determine. The maximum error was estimated as less than ± 1/2 scale (-0.1 to +0.25 ppm), and each measurement took more than 10 min. Formaldehyde levels in the air were evaluated on two separate days of the dissection course. The first measurements were performed when the skin of the upper limbs and trunk was removed, and the second when the thoracic and abdominal cavities of most cadavers were opened. The formaldehyde levels before and during the dissection practices were also compared for the same day.

This study was conducted after we received written permission from the donors and their surviving relatives and did not involve any specific issues that required approval from the ethics committees of our institution. The present study conformed to the provisions of the Declaration of Helsinki in 1995 (as revised in Edinburgh in 2000).

Measurement of formaldehyde levels in cadavers

Thirty-two cadavers were used to measure the formaldehyde concentrations in the lung, liver and the right or left brachioradialis muscle, but 8 samples were excluded due to inappropriate tissue conditions. Specimens (1 to 2 g each) were removed from the central portion of organs or muscles to minimize the effect of formaldehyde evaporation during the dissection course, which lasted 7 to 9 weeks (dissection class of 5 days per week) before tissue sampling. The specimens were always packed in air-tight plastic bottles and stored in a refrigerator until further processing. Details on the measurement of formaldehyde concentrations were described in a previous study[4]. In brief, the tissue fluids were separated by centrifugation using a tube for filtration, appropriately diluted (1:1,000 to 1:10,000), colored by 3-methyl-2-benzothiazolinone hydrazone hydrochloride (MBTH) using a LR-FOR formaldehyde detection kit (Kyoritsu Chemical-Check Lab, Tokyo, Japan) and quantified with a spectrophotometer UVmini 1240 (Shimadzu, Kyoto, Japan).

An additional 3 cadavers were used for detailed measurements to evaluate differences in the formaldehyde levels among portions of the same cadaver. The liver, right lung, right kidney, bilateral brachioradialis muscles, bilateral rectus femoris muscles and bilateral gastrocnemius muscles were sampled and measured as described above.

RESULTS

Formaldehyde concentration in the air

For the first measurements when the skin of the upper limbs and trunk was removed, the formaldehyde concentration at the center of the room before and 15 min after the start of dissection was 0.05 and 0.55 ppm, respectively, and the levels at the 4 corners of the room during practice were 0.37, 0.35, 0.35 and 0.3 ppm. For the second measurements, when all thoracic cavities and most abdominal cavities had been opened, the levels were 0.3 ppm at the center of the room and 0.3, 0.3, 0.3 and 0.25 ppm at the 4 corners. When the dissection practice of the day was almost over and

Table 1. Formaldehyde concentrations in cadavers (%)

Cadaver No.	Lung	Liver	Right brachio-radialis muscle	Left brachio-radialis muscle
1	0.036	0.036		0.010
2	0.047	0.039	0.030	
3	0.16	0.18		0.11
4	0.07	0.024	0.055	
5	0.36	0.38	0.34*	0.34
6		0.078		0.013
7	0.088	0.10	0.067	
8	0.026	0.033	0.009	
9	0.11	0.10		0.10
10	0.090	0.10		
11	0.30	0.25		0.15
12	0.22	0.20	0.22	
13	0.15	0.12	0.14*	
14	0.19	0.19		0.091
15	0.036	0.027		0.037
16			0.040	
17			0.19	
18	0.053	0.044		0.093
19	0.047	0.053		0.064
20	0.10	0.12	0.13	
21	0.13	0.11	0.12	
22	0.077	0.059		
23	0.30	0.22	0.25	
24	0.13	0.16	0.056	
25	0.10			
26	0.22	0.19	0.16	
27	0.030	0.032		0.039
28	0.033	0.036		0.035
29	0.12	0.10		0.11
30	0.15	0.18	0.15	
31	0.017	0.020	0.024	
32	0.18	0.24	0.13*	
mean ± SD	0.12 ± 0.09	0.12 ± 0.09	0.11 ± 0.09	

* indicates undissected and skin-covered specimens

Table 2. Formaldehyde concentrations in 3 cadavers (%)

Cadaver No.	Right lung	Liver	Right kidney	Right brachio-radialis muscle	Left brachio-radialis muscle	Right rectus femoris muscle	Left rectus femoris muscle	Right gastro-cnemius muscle	Left gastro-cnemius muscle
33	0.15	0.14	0.10	0.13	0.11	0.18	0.097	0.17	0.095
34	0.021	0.029	0.042	0.010	0.015	0.029	0.028	—	0.23
35	0.028	0.020	0.018	0.030	0.063	0.096	0.012	0.10	0.031

about half of the cadavers had been covered by plastic sheets, the formaldehyde concentration at the center of the room was 0.15 ppm.

Formaldehyde concentrations in the cadavers

The formaldehyde concentrations were considerably varied among the cadavers and were 0.12 ± 0.09% (n=29) for the lung, 0.12 ± 0.09% (n=29) for the liver and 0.11 ± 0.09% (n=30) for the brachioradialis muscle (Table 1). Overall, these values were similar for the same cadaver (Tables 1, 2 and Fig. 1). However, considerable differences in formaldehyde levels were occasionally found between muscles in the extremities and other organs in the same cadaver (Tables 1, 2).

DISCUSSION

In the present study, the relationship between the formaldehyde concentrations in the room air and in cadavers was examined under the condition of 10 room-air changes per hour. The formaldehyde concentration in the air ranged from 0.25 to 0.55 ppm during dissection practice, and these values are lower compared with those of other universities[1,5-7,9]. In addition, except for one measurement out of ten, they were within the

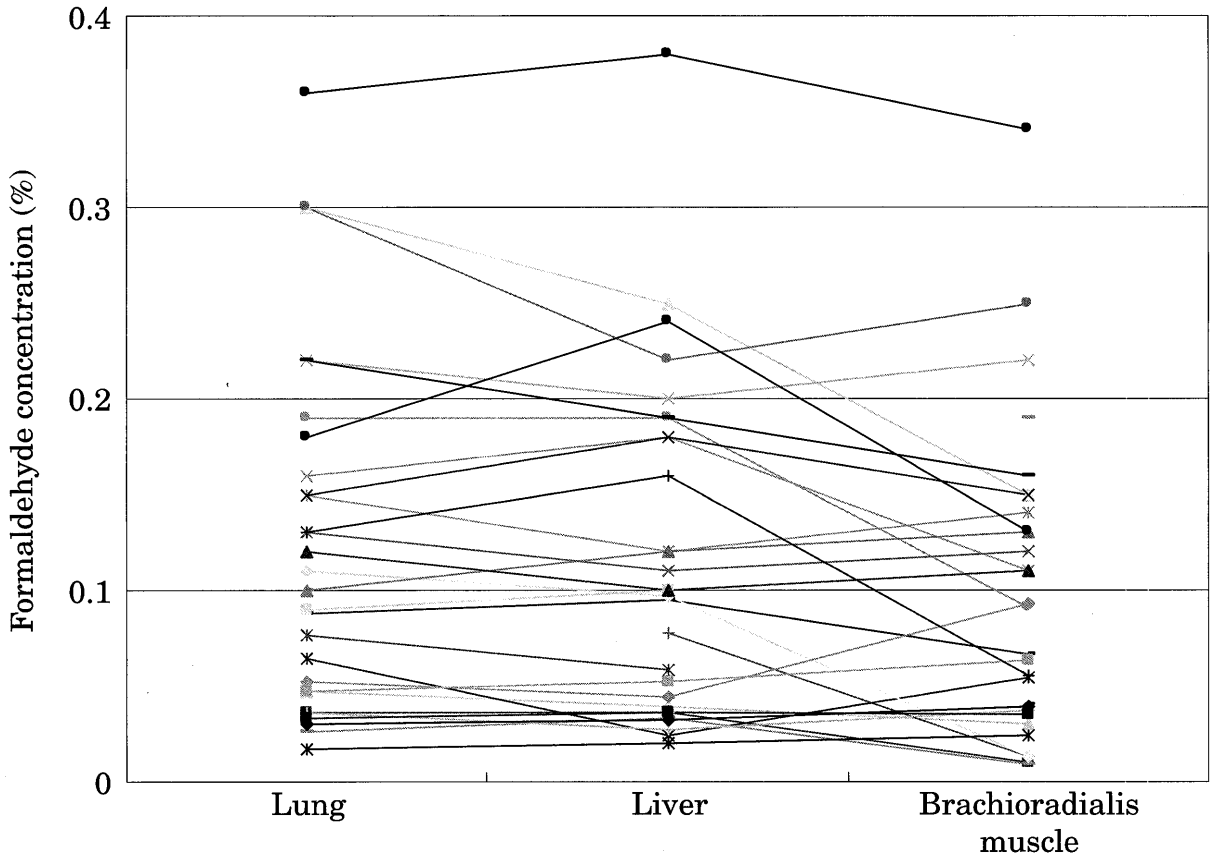

Fig. 1. Formaldehyde concentrations in the lung, liver and brachioradialis muscle of 32 cadavers.
Each line shows different preparations from the same individual. The formaldehyde levels in various tissues are generally similar in the same cadaver, but differ considerably among cadavers.

upper limit of the guideline for formaldehyde exposure set by the Japan Society for Occupational Health (0.5 ppm)[2]. The formaldehyde levels in cadaveric tissues were also lower than those of Tsurumi University[4]. It is unlikely that the low and fluctuating formaldehyde levels in tissue specimens at Hiroshima University resulted from the evaporation of formaldehyde during the dissection class, because the formaldehyde levels of the undissected and skin-covered brachioradialis muscles (Table 1, marked by *) were in good agreement with those of other tissues of the same cadaver. In addition, the formaldehyde concentrations of the lung, liver, and brachioradialis muscle of the same cadaver were often similar. Detailed examination of the formaldehyde concentrations revealed some tissue differences in the same cadaver, especially between muscles in the extremities and other organs (Table 2). This may reflect inhomogeneous perfusion of embalming fluids due to possible vascular lesions in the upper and lower extremities.

Concerning the preparation of the cadavers, blood and part of the embalming fluids are allowed to drain during cadaver treatment at Hiroshima University. On the other hand, at Tsurumi University cadavers are infused with 5 liters of "10% formalin" (3.7% aqueous formaldehyde solution) into the femoral artery without blood drainage. The concentrations of formaldehyde in the fixative of these universities are similar. Thus, the difference in procedure and possibly differences in the composition and volume of the embalming fluids may explain the different formaldehyde levels in the cadavers of the two universities. The relatively low levels in the cadavers at Hiroshima University probably result in low airborne concentrations of formaldehyde. In addition, frequent room-air changes (10 times per hour) further contribute to the lowering of atmospheric formaldehyde levels.

The formaldehyde levels in the air at Hiroshima University were mostly below the permissible level found in the guidelines set by the Japan Society for Occupational Health (0.5 ppm)[2]. However, the breathing zone formaldehyde level is higher than that of the room air[9,10] because students and instructors work in close proximity to cadavers which emit formaldehyde vapor. The airborne levels of formaldehyde 10 cm above cadavers range from 0.2 to 1.0 ppm even when the cadaveric formaldehyde concentrations are equal or lower than those of Hiroshima University[4]. In addition, more reduced levels (0.08 ppm or less for

general indoor conditions and 0.25 ppm or less under special circumstances) are currently recommended by the Japanese Ministry of Health and Welfare[3]. Thus, further reduction of formaldehyde levels may be necessary. Dissection tables with local exhaust ventilation can markedly reduce airborne formaldehyde, but are very expensive. Source control should be a first option for lowering formaldehyde levels. Ammonium carbonate is reported to neutralize formaldehyde by changing it into harmless hexamethylenetetramine, and infusion of 2 liters of saturated ammonium carbonate solution drastically reduces formaldehyde levels in formaldehyde-prefixed cadavers, even at a concentration as low as 0.03% in the liver[4]. Although a method to suppress bacterial and fungal proliferation may be necessary after neutralization of formaldehyde, the application of ammonium carbonate presumably contributes to a further reduction of formaldehyde levels in cadavers and consequently in the air at Hiroshima University.

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