Establishment of an ambient air sevoflurane measurement method using ECD-GC

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In order to measure the exposure of medical care workers to sevoflurane, we established a method to determine its level in the air of operating rooms, which may be polluted with anesthetic gas. The level was measured using a gas chromatograph with an electron capture detector (ECD). Vacuum sampling bottles were filled with air, and sevoflurane was vaporized in the bottles. In Experiment 1, we measured the sevoflurane concentration. The peak area was calculated using data analysis software. Statistical analysis was performed and a favorable correlation was observed. In Experiment 2, we investigated the optimum measurement condition of sevoflurane. Changes in the peak area with changes in the sample inlet temperature were investigated. Statistical analysis showed that the peak area at 200°C was significantly larger than those at other temperatures. (J Osaka Dent Univ 2017; 51: 95-98)

Key words: Sevoflurane; Electron capture detector

INTRODUCTION

Operating rooms may be heavily polluted with anesthetic gas. The American Society of Anesthesiologists (ASA) has warned against the health damage of long-term exposure to anesthetic gas.¹ In order to determine the sevoflurane exposure of medical care workers, we established a method of measuring the sevoflurane level in the air.

MATERIALS AND METHODS

The experiments were performed using a gas chromatograph (GC 2014; Shimadzu Corporation, Kyoto, Japan) equipped with an electron capture detector (ECD) (Fig. 1), and a medium polar column (Rtx*-200; Restek Corporation, Bellefonte, PA, USA) with chemically bonded trifluoropropyl methyl polysiloxane as a liquid phase. Experimental samples were prepared by adding sevoflurane into 1 L vacuum sampling bottles (GL Sciences, Tokyo, Japan) filled with indoor air using a micropipette (Eppendorf, Hamburg, Germany). After waiting for the sevoflurane (Maruishi Pharmaceutical, Osaka, Japan) volatilization at room temperature, 20 μL of the sample from the sampling bottle was injected into the gas chromatograph using a micro syringe (Terumo, Tokyo, Japan).

Fig. 1  Electron capture detector (ECD)-equipped gas chromatograph GC 2014 (Shimadzu, Kyoto, Japan).
Experiment 1: Sevoflurane concentration measurement using gas chromatography

Samples at different concentrations were measured, and a calibration curve was prepared from the peak areas and sevoflurane concentrations. The measurement conditions were set as follows referring to reports of Kovatsi et al.\textsuperscript{2} and Ghimenti et al.\textsuperscript{3}: Nitrogen (TI Medical, Osaka, Japan) was used as the carrier gas; nitrogen inflow pressure, 80 kPa; full flow, 23.2 mL \cdot min\textsuperscript{-1}; and column flow, 0.96 mL \cdot min\textsuperscript{-1}. The sample inlet temperature was 200°C; column thermostat temperature, 40°C; detector temperature, 250°C; and split ratio, 1 : 20. The peak area was calculated using data analysis software (GCsolution Ver. 2.4; Shimadzu Corporation). Using a micropipette, 6, 30, 60, 90, 120 and 150 μL were added to adjust the sevoflurane concentration in the sampling bottles at 10, 50, 100, 150, 200 and 250 ppm, respectively. Measurements were repeated 5 times for each sevoflurane concentration, for a total of 30 times. The correlation was statistically analyzed.

Experiment 2: Optimum condition for sevoflurane measurement using gas chromatography

The relationship between the sevoflurane peak area and the measurement conditions was investigated. Changes in the peak area determined from the peaks as described in Experiment 1 were investigated using changes in the sample inlet temperature (160, 170, 180, 190 or 200°C). Statistical analysis was performed using repeated measures ANOVA and SNK, with \( p < 0.05 \) regarded as significant.

RESULTS

Experiment 1

When the sevoflurane concentration was 10 ppm, the sevoflurane peak areas were 4,408, 4,623, 4,442 and 4,078; they were 22,152, 23,245, 23,950, 22,416 and 22,885 for 50 ppm; 31,135, 32,186, 32,741, 30,857 and 30,148 for 100 ppm; 41,373, 41,415, 45,636, 47,787 and 47,184 for 150 ppm; 52,637, 54,859, 61,805, 59,802 and 50,615 for 200 ppm; and 61,588, 62,935, 67,709, 70,540 and 77,778 for 250 ppm. The calibration curve prepared from the sevoflurane concentrations (X ppm) and the above values (Y) was \( Y = 252.6X + 5905.5 \). A strong positive correlation was noted (\( r = 0.993 \)) (Fig. 2).

Experiment 2

When the temperature condition was 160, 170, 180, 190 or 200°C, the sevoflurane peak areas were 18,016±626, 18,121±780, 17,990±1,078, 16,053±1,849, and 31,413±932 (mean±SD), respectively. The peak area at 200°C was significantly greater than at the other temperatures (\( p < 0.05 \)) (Fig. 3).

![Fig. 2](image1.png) Peak area at each sevoflurane concentration and approximate curve. The line indicates a favorable positive correlation.

![Fig. 3](image2.png) Changes in the peak area with changes in the sample inlet temperature. The peak area at 200°C was significantly larger than at the other temperatures (\*\( p < 0.05 \) vs 200°C).
DISCUSSION

The blood/gas partition coefficient of sevoflurane is the third lowest following that of nitrous oxide and desflurane, and induction and arousal are rapid.\textsuperscript{4} The use of nitrous oxide tends to be avoided because of its greenhouse effect and ozone layer depletion.\textsuperscript{5} The most frequently used inhalation anesthetic is sevoflurane. Sevoflurane was used in 1,108 institutions certified by the Japanese Society of Anesthesiologists in 2008; it was used in 97.6% of cases where inhalation anesthetics was used for general anesthesia.\textsuperscript{6} It is not possible to avoid diffusion of a trace amount of inhalation anesthetic during general anesthesia in operating rooms. The exposure of medical care workers to sevoflurane is considered problematic,\textsuperscript{7} and long-term sevoflurane exposure has been reported to be detrimental to health.\textsuperscript{8,9} We attempted to establish a sevoflurane measurement method to investigate its exposure to medical care workers during surgery under general anesthesia.

Gas chromatography/mass spectrometry (GC/MS) is frequently used to measure the sevoflurane level in exhalation.\textsuperscript{10,11} GC/MS is useful for analyzing highly volatile components, and is capable of qualitative and quantitative determination of trace amounts down to 1 ppbv.\textsuperscript{3} However, GC/MS requires very expensive experimental equipment. We attempted to measure the sevoflurane level using ECD-equipped gas chromatography, which is less expensive than GC/MS. ECD was used because sevoflurane is a halogenated compound containing 7 fluorine elements in its structural formula (Fig. 4),\textsuperscript{12} and ECD is highly sensitive for halogen-containing compounds.\textsuperscript{13} We set the detection limit for sevoflurane in the air at parts per million referring to the report of Hasei et al.\textsuperscript{14}

The Japan Society for Occupational Health and the American Conference of Governmental Industrial Hygienists (ACGIH) have specified the acceptable concentrations and threshold limited values (TLV) for substances that through exposure induce adverse events in the human body. Although there are slight differences in the definitions, these are judged as having no negative influence on health in most workers when the toxic substance exposure level is lower than the specified value after working for 8 hours per day and approximately 40 hours per week. Although the ACGIH specified a TLV for nitrous oxide and halothane of 50 ppm, no limits have been specified for isoflurane, sevoflurane or desflurane.\textsuperscript{15} Hasei et al.\textsuperscript{14} detected a maximum of 15.91 ± 22.64 ppm of sevoflurane during surgery. Based on this, we assumed that an acceptable sevoflurane concentration would be 10 ppm. We found a lower limit of 1,894 in Experiment 1, which corresponds to 4.4 ppm. Therefore, the method established in this study is sufficient to measure a level lower than the acceptable concentration. We demonstrated that this method is capable of measuring sevoflurane in the atmosphere in parts per million, establishing this as an efficient way of measuring sevoflurane in the air at a low cost compared with conventional methods.

REFERENCES

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