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MINIMUM ALVEOLAR CONCENTRATION OF SEVOFLURANE IN ELDERLY PATIENTS

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SUMMARY

We have determined the minimum alveolar concentration (MAC) for sevoflurane in elderly patients (mean age 71.4 yr). MAC was found to be 1.48 (SEM 0.08)%, which is smaller than the values for children and adults. The magnitude of the change in MAC with age is similar to that for halothane and isoflurane. The calculated anesthetic ED_{95} for preventing 95% of patients from moving was 1.98%.
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KEY WORDS

Anaesthetics, volatile. sevoflurane. Potency, anaesthetic: MAC.

MAC, a measure of anaesthetic potency, is the alveolar concentration of anaesthetic at which 50% of patients do not move in response to a single stimulus of skin incision [1]. It is used for comparison of the pharmacological properties of inhalation anaesthetics. AD_{95} (anaesthetic ED_{95}), the dose that prevents 95% of patients from moving in response to skin incision [2], has greater clinical utility than MAC.

An inverse relationship has been reported between age and anaesthetic requirement for halothane [3], isoflurane [4] and desflurane [5]. MAC of sevoflurane in children and adults also has been reported [6–8]. The purpose of this study was to determine the MAC of sevoflurane in the elderly and to quantify the magnitude of the change with age.

PATIENTS AND METHODS

With Institutional Ethics Committee approval, we studied 20 patients, of both sexes, ASA I–II and aged 63–82 yr, allocated randomly to four groups of five. They did not receive premedicant drugs. The anaesthetic system used was a semi-closed system and anaesthesia was induced by mask with sevoflurane and oxygen (fresh gas flow rate 6 litre min^{-1}). The trachea was intubated with a cuffed tracheal tube without the use of neuromuscular blocking drugs or other agents. After tracheal intubation, the end-tidal sevoflurane concentration was reduced to a predetermined value and held constant for at least 15 min before skin incision. End-tidal sevoflurane and carbon dioxide concentrations were measured continuously from the distal end of the tracheal tube with an infra-red gas analyser (Capnomac, Datex) calibrated against known concentrations of 1.84% and 0.94% sevoflurane in air. The concentrations of sevoflurane were verified by calibration with a gas chromatograph (Shimazu GC-9A, Shimazu, Japan). Spontaneous ventilation was maintained in all patients. Temperature was monitored by a temperature probe in the nasopharynx. The patient's response to skin incision was reported as movement or non-movement. We considered movement to be "gross purposeful muscular movement", usually of the head or extremities. Breath-holding, bucking or grimacing was not considered as movement [1].

The technique used to calculate MAC was adapted from Waud [9]. The doses selected and the sizes of the groups were predetermined to estimate standard error. The mean (SD) end-tidal sevoflurane concentration held constant for more than 15 min was 1.75 (0.03)% (range 1.72–1.78%) in group A1, 1.55 (0.02)% (range 1.53–1.57%) in group A2, 1.36 (0.01)% (range 1.35–1.38%) in group A3 and 1.14 (0.01)% (range 1.12–1.16%) in group A4. Individual observations were fitted to a logistic curve by

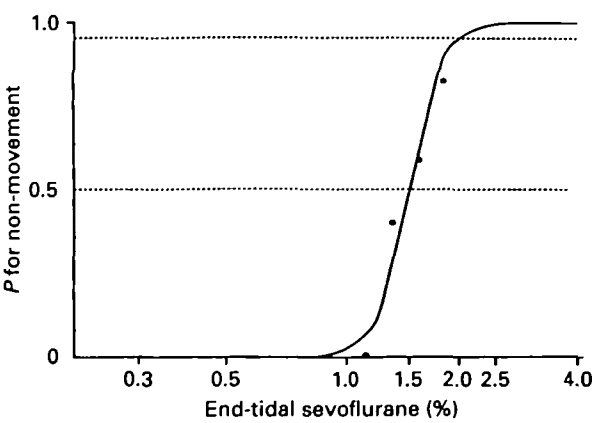

FIG. 1. Percentage of patients within each group who did not move was plotted against the group mean end-tidal concentration of sevoflurane. The dose–response curve was derived directly from individual data in table I: probability of non-movement (not responding to skin incision) plotted against logarithm of the end-tidal concentration of sevoflurane. MAC = 1.483 (SE 0.081)%; AD_{95} = 1.976%; Slope = 10.268 (SE 4.568).

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TABLE I. *Data obtained in the sevoflurane MAC determinations. E = End-tidal concentration of sevoflurane; I = inspired concentration of sevoflurane; Duration = total time for which end-tidal sevoflurane had been held constant at the time of skin incision.*

Group	Age (yr)	E (%)	I (%)	$\frac{(I-E)}{E} \times 100$ (%)	Movement	Duration (min)
A1	64	1.72	2.02	17.9	No	24
1.72–1.78%	75	1.75	2.14	22.3	Yes	17
	74	1.72	2.34	36.0	No	18
	78	1.77	2.31	30 5	No	16
	65	1.78	1.96	10.1	No	39
Mean (SD)		1.75 (0.03)				
A2	75	1.56	1.87	19.6	No	17
1.53–1.57%	76	1 53	1.81	15.7	No	36
	74	1.53	1.75	14.4	Yes	15
	68	1.53	1.81	18.3	Yes	19
	67	1.57	2.13	35.7	No	17
Mean (SD)		1.54 (0.02)				
A3	70	1.35	1.47	9.06	Yes	21
1.35–1.38%	82	1.35	1.65	22.2	No	31
	72	1.38	1.56	15.6	Yes	18
	76	1.35	1.62	20.0	No	17
	66	1.37	1.65	20.4	Yes	30
Mean (SD)		1 36 (0.01)				
A4	75	1 14	1.22	7 02	Yes	20
1.12–1.16%	64	1.15	1.35	17.4	Yes	15
	72	1.14	1.23	7 89	Yes	19
	63	1.16	1.36	17.2	Yes	21
	72	1 12	1.33	18 7	Yes	16
Mean (SD)		1.14 (0 01)				
Overall mean	71.4	—	—	18.8	—	21.3
Overall SD				8.0		7.1

iterative technique, based on a Taylor series expansion. Analyses were performed with a PASCAL (Turbo Pascal: Borland International, Scotts Valley, CA) program that furnished median and slope values with their SE, and an expression for the best fitting logistic curve. The program was translated from an original algorithm written in BASIC language by Waud [9]. AD_{95} was calculated directly from the expression for the best fitting logistic curve.

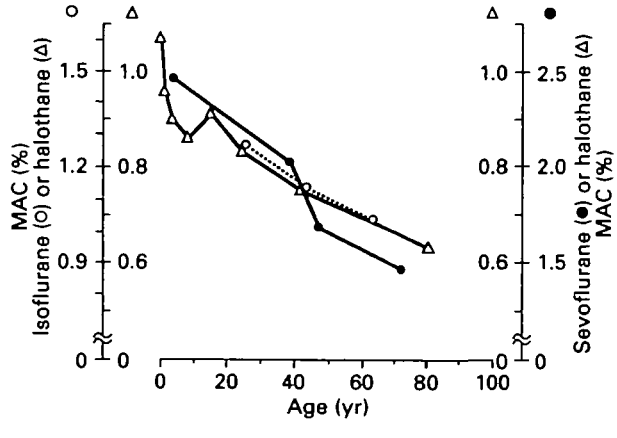

FIG. 2. Halothane (△), isoflurane (○) and sevoflurane (●) MAC at various ages. Halothane data were determined by Gregory, Eger and Munson [3], isoflurane data by Stevens and colleagues [4] and sevoflurane data at younger ages by Katoh and Ikeda [6, 7] and Scheller, Saidman and Partridge [8]. The ratio of the *Y*-axis is 1.5 for isoflurane–halothane and 2.5 for sevoflurane–halothane.

RESULTS

In this study, no patient had severe hypotension, hypothermia or hyperthermia. The end-tidal carbon dioxide partial pressure was in the range 4.65–6.40 kPa in all patients.

MAC of sevoflurane in the elderly patients (mean age 71.4 yr) was 1.48 (0.08)%, AD_{95} was 1.98% and the slope of the logistic function was 10.27 (4.57) (fig. 1). Individual data are shown in table I.

DISCUSSION

We presumed that the end-tidal sevoflurane concentration reflects arterial and brain partial pressures of sevoflurane. The end-tidal concentration was maintained constant for a minimum of 15 min, allowing the partial pressure of sevoflurane in brain to equilibrate with that in arterial blood. The difference between the inspired and end-tidal anaesthetic partial pressure (18.8%) was larger than that for children (6.0%) [6] and adults (9.6%) [7]. This difference was probably caused by the increased solubility of volatile anaesthetics in human tissues with age [10, 11] and changes in body composition, because ageing increases the relative ratio of lipid [12]. The effect of hypoventilation must also be considered, as we maintained spontaneous ventilation. We considered that severe hypoventilation which might produce a great change in F_A/F_I with sevoflurane did not occur in this study, as the end-tidal carbon dioxide partial pressure was 4.65–6.40 kPa in all patients. The low solubility of sevoflurane (similar to that of nitrous oxide) [13]

decreases the influence of ventilation on the increase in F_A/F_I.

In this study, the inspired-to-expired difference in sevoflurane concentration was 18.8 (SE 1.8)% of the expired concentration. Under these conditions, the measured end-tidal partial pressure was approximately 4% greater than the arterial partial pressure [14].

We used Waud's technique to calculate MAC. This technique was first adapted by de Jong and Eger [2] to determine MAC values. We predetermined the doses and the sizes of the group instead of using an "up and down" technique, in order to provide a true estimate of SE by randomizing the doses prospectively.

Many studies have suggested that the anaesthetic requirements of the elderly are smaller than those of children and adults. In this study we found that, as for other inhalation anaesthetics, the elderly required a smaller minimum alveolar concentration for sevoflurane anaesthesia (1.48%). Katoh and Ikeda reported that the MAC of sevoflurane in children (mean age 4.31 yr) was 2.49% and that of adults (mean age 47.5 yr) 1.71% [6, 7]. Scheller, Saidman and Partridge reported the MAC of sevoflurane as 2.05% for adults (mean age 38 yr) [8]. From these reports and our study, we consider that the magnitude of change in MAC value with age for sevoflurane anaesthesia is similar to that for halothane and isoflurane (fig. 2).

Katoh and Ikeda and Scheller, Saidman and Partridge suggested that age differences could be important factors in explaining the discrepancy between their results. Our study supports this explanation.

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