

UPTAKE OF ISOFLURANE DURING CLINICAL ANAESTHESIA *Servo-control of liquid anaesthetic injection into a closed-circuit breathing system*

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SUMMARY

Twenty-six patients were anaesthetized with isoflurane (Forane) in oxygen using a completely closed-circuit breathing system to which liquid isoflurane was injected. The rate of injection was controlled to maintain the end-tidal concentration at a pre-set value (1.5% = 1.3 MAC). The rate of injection of anaesthetic was recorded and from the data the uptake of anaesthetic by the patient was measured. It was found to average 44.5 ml of vapour at 2 min, 23.7 ml at 10 min and 19.4 ml at 30 min. Attempts were made to correlate the data with anthropometric measurements.

The rate of uptake of volatile anaesthetic agents is of considerable interest and notable contributions have been made by Mapleson (1963), Eger (1974) and Lowe and Ernst (1981). However, most of this work has been of a theoretical nature.

Direct measurements of anaesthetic uptake have been made during clinical anaesthesia and the results correlated with a variety of anthropometric measurements. Uptake was measured using a totally closed-circuit breathing system into which liquid isoflurane (Forane) was injected, a procedure which facilitated accurate measurement. Body nitrogen stores were maintained. Oxygen was added at the rate required to maintain a constant volume in the system (that is, basal oxygen requirement). Nitrous oxide was not used.

Although isoflurane has not yet been released in the United Kingdom, the first published account of its use in man was by Dobkin and colleagues in 1971. An extensive multicentre clinical evaluation has been reported recently (Forrest et al., 1982). It is the least metabolized of commercially available volatile anaesthetic agents and the most expensive. For this reason it is particularly suitable for use in the totally closed circuit. Isoflurane, unlike halothane, is stable in the presence of soda-lime (Vitcha, 1971; Sharp, Trudell and Cohen, 1979).

PATIENTS AND METHODS

Apparatus

A description of the apparatus used was first presented in 1981 (Hawes et al., 1982) and is further described in detail in this number (Ross et al., 1983). Liquid isoflurane was injected to the system by a servo-control syringe driver and the amount injected was automatically recorded in units of 8.2 µlitre using a chart recorder. The servomechanism was controlled by the end-tidal concentration of isoflurane as measured by the Engstrom Emma anaesthetic gas meter, and the apparatus was set to maintain an end-tidal concentration of 1.3 MAC (1.55% of isoflurane). The second channel of the recorder was used to record the isoflurane concentration throughout the respiratory cycle. Intermittent positive pressure ventilation was used in all patients at a rate of 10 b.p.m. This slow rate ensured accurate measurement of end-tidal anaesthetic concentration by the Emma. The tidal volume was set using the Nunn Blood Gas Predictor (Nunn, 1962) to maintain end-tidal PCO_2 at 5.3 kPa. In addition, 100 ml was added to each tidal volume to compensate for circuit compliance. The ventilator built into the circuit was an Air Shields Ventimeter Controller having a vertically mounted bellows which descended during inspiration. This arrangement ensured that the pressure in the system was always greater than atmospheric, so that any leaks were outward and, more importantly, the height to which the bellows ascended was a constant visual check that the circuit volume was being maintained constant.

Patients

Twenty-six patients were selected who were:

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adults less than 70 years of age, free from respiratory, cardiovascular and metabolic disease, and having surgery lasting longer than 30 min. The patients were having elective general, orthopaedic or gynaecological surgery.

A Clinical Trials Exemption Certificate for using isoflurane was obtained, and after discussion with the Chairman of the Ethics Committee at Northwick Park Hospital it was decided that no consent would be required as the closed circuit is a standard technique and isoflurane is a recognized and extensively investigated agent already in use in the United States and Canada (Forrest et al., 1982).

Patient height, weight and standard skinfold thicknesses (Weiner and Lourie, 1969)—mid-biceps, mid-triceps, subscapular and supra-iliac were recorded before operation, and the following variables calculated: (body mass)^{2/3} (Guyton, Jones and Coleman, 1973); body surface area (Du Bois and Du Bois, 1916); body fat content (Durnin and Womersley, 1974); fat-free body mass (Garrow, 1982).

The patients received a standard pre-medication of papaveretum 0.4 mg kg⁻¹ body weight and hyoscine 0.008 mg kg⁻¹ i.m. 1 h before operation. Anaesthesia was induced with thiopentone, and pancuronium 0.08 mg kg⁻¹ was administered to produce neuromuscular blockade. The lungs were ventilated manually with air (Ambu bag) both before

TABLE I. Correlation of anaesthetic uptake with anthropometric measurements

Variable	Correlation coefficient	P
Surface area	0.629	<0.001
(Body mass) ^{2/3}	0.575	>0.001 <0.01
Fat-free body mass	0.574	>0.001 <0.01
Fat body mass	0.292	n.s.
Body weight	0.574	>0.001 <0.01

and after tracheal intubation. Anaesthesia was maintained with increments of thiopentone before attachment of the patient to the closed circuit. When the patient was connected to the system the oxygen concentration decreased to about 70% and remained around this value for the duration of the anaesthetic. This prevented the alveolar oxygen concentration increasing to undesirable values. The patient was connected to the closed circuit when both the patient and the circuit were at the end of expiration.

RESULTS

The ages of the patients ranged from 17 to 70 yr (mean 46 yr) and their weights from 42 to 98 kg (mean 69 kg).

From the recordings of isoflurane uptake with time, the number of strokes of liquid isoflurane injected per minute were counted and equated

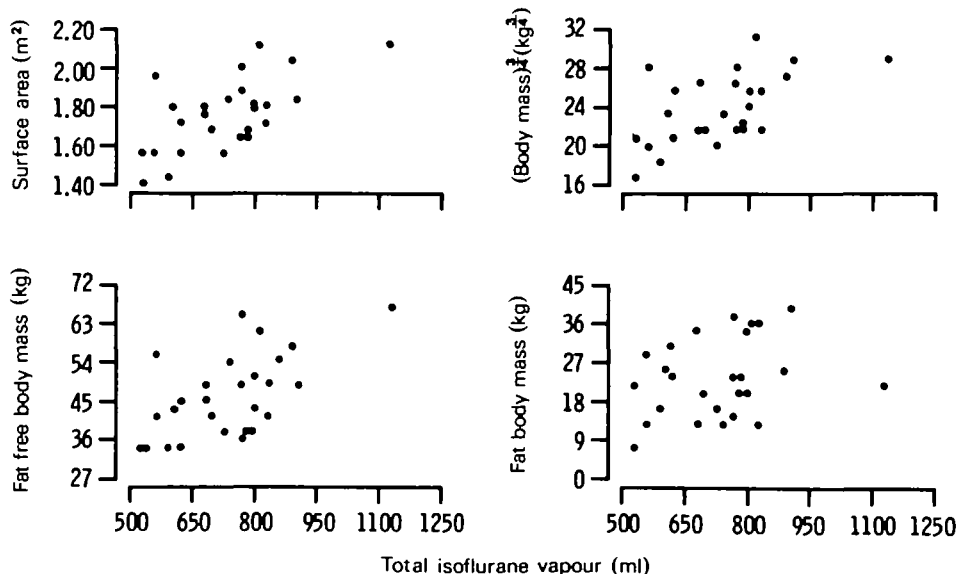


FIG. 1. Correlation between isoflurane uptake and: surface area, (body mass)^{2/3}, fat-free body mass and fat body mass.

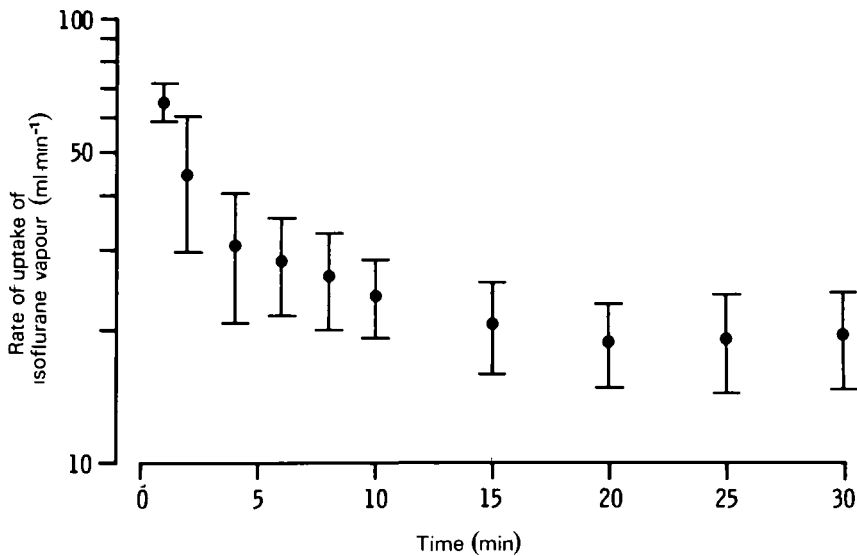


FIG. 2. Mean rate of uptake of isoflurane vapour in 26 patients for the first 30 min of anaesthesia. Bars indicate standard deviation.

with millilitres of vapour isoflurane (one stroke = 8.2 µlitre of liquid isoflurane which produces 1.54 ml of isoflurane vapour at 20°C).

Correlations were obtained between the total uptake of isoflurane in the first 30 min of anaesthesia with the variables surface area, (body mass)², fat-free body mass and fat body mass (fig. 1 and table I). The best correlation was with surface area. As might be expected, the correlation of uptake with body weight was identical to that with fat-free body mass, but the surprising finding is that the correlation with (body mass)² was not significantly better than the correlation with body mass. (Body mass)² is frequently used as an index of cardiac output (Guyton, Jones and Coleman, 1973). Predictably, the correlation of uptake with fat body mass was very poor.

The mean rate of uptake of isoflurane vapour per unit time for 30 min of anaesthesia in the 26 patients is shown in figure 2. The uptake for the 1st min was limited as the amount injected to the circuit was restricted by the maximum rate at which the syringe-driver could function. Consequently the standard deviation at this point was small. For the remaining points, individual variation was considerable (SD about 30%). The initial uptake was high as isoflurane vapour washed into the functional residual capacity and equilibrated with the vessel-rich and vessel-medium body tissue groups (Eger, 1974). The uptake decreased rapidly with time until at around 20 min the uptake appeared to stabilize.

Typically, for the first 30 min of anaesthesia, 3.9 ml of liquid isoflurane was used and for the first 60 min, 7–8 ml of liquid isoflurane was used.

DISCUSSION

Of the chosen variables the best correlation of anaesthetic uptake was with surface area, but even this correlation was not sufficiently good to permit us to envisage a technique of pre-programmed anaesthesia (that is administration of anaesthetic at a pre-determined rate) by calculation from anthropometric measurements.

Other measurements which might correlate more closely with anaesthetic uptake include cardiac output (Mapleson, 1979) and oxygen consumption.

Comparative studies of uptake of other agents with our apparatus have not been performed. It will be of interest to see if the relative uptake of isoflurane proves to be greater than that of halothane or enflurane as isoflurane differs from these agents in promoting increased muscle blood flow (Stevens et al., 1971).

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LA CAPTATION DE L'ISOFLURANE AU COURS DE L'ANESTHESIE EN CLINIQUE

Asservissement de l'injection de liquide anesthésique dans un circuit respiratoire fermé

RESUME

Vingt six patients ont été anesthésiés par l'isoflurane (Fourane) dans l'oxygène, grâce à un circuit respiratoire complètement fermé dans lequel on injectait de l'isoflurane liquide. La vitesse d'injection était contrôlée de façon à maintenir la concentration de fin d'expiration à une valeur pré-établie (1,5% = 1,3 MAC). La vitesse d'injection de l'anesthésique était enregistrée et d'après ces données, on mesurait la captation d'anesthésique par le patient. Celle-ci approchait 44,5 ml de vapeur à 2 min, 23,7 ml à 10 min et 19,4 ml à 30 min.

ISOFLURANE-RESORPTION WÄHREND KLINISCHER ANÄSTHESIE – SERVOKONTROLLE DER INJEKTION VON ANÄSTHESIE-FLÜSSIGGAS IN EIN GESCHLOSSENES KREISLAUF-BEATMUNGSSYSTEM

ZUSAMMENFASSUNG

Über eine Injektion flüssigen Isofluranegases in ein völlig geschlossenes Kreislauf-Beatmungssystem wurden 26 Patienten mit Isoflurane (Forane) in Sauerstoff narkotisiert. Die Injektionsmenge wurde kontrolliert, um eine endexpiratorische Konzentration von bestimmter Höhe (1,5% = 1,3 MAC) aufrechtzuerhalten. Die Injektionsmenge des Anästhetikums wurde aufgezeichnet und aus den Daten die Resorption durch den Patienten errechnet. Sie betrug durchschnittlich 44,5 ml des Gases bei zwei Minuten, 23,7 ml bei 10 Minuten und 19,4 ml bei 30 Minuten.

CAPTACION DE ISOFLURANO DURANTE LA ANESTESIA CLINICA

Servo-control de la inyección de anestésico líquido en un sistema respiratorio de circuito cerrado

SUMARIO

Se anestesió a veintiseis pacientes con isoflurano (Forano) en oxígeno mediante un sistema respiratorio de circuito cerrado en el cual se inyectó isoflurano líquido. El ritmo de inyección fue controlado con el objeto de mantener la concentración respiratoria-terminal en un valor prefijado (1,5% = 1,3 MAC). El ritmo de inyección del anestésico se registró y a partir de los datos, se midió la captación de anestésico por el paciente. Se comprobó que media unos 44,5 ml de vapor a los 2 min, 23,7 ml a los 10 min y 10,4 ml a los 30 min.