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Comparison of Rapid and Conventional Inhalation Inductions of Halothane Oxygen Anesthesia in Healthy Men and Women

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In modern practice, anesthesia is usually induced in adults with intravenous drugs which rapidly and pleasantly produce unconsciousness. However, there are situations where an intravenous induction may not be ideal, and, yet, where rapid induction is still desired. We have previously shown that a rapid inhalation induction can be accomplished safely in adult volunteers with a vital capacity breath of 4% halothane in oxygen.[1] Wilton and Thomas have now shown that this technique, with the addition of nitrous oxide, is readily applicable to ASA physical status I and II patients.[2] They induced anesthesia in 100 unpremedicated patients with a single vital capacity breath of 4% halothane in 66% nitrous oxide and 33% oxygen.

The current report compares a single-breath induction with an induction consisting of three vital capacity breaths of 4% halothane in oxygen, and with a more conventional induction using gradually increasing concentrations of halothane. We have shown that induction is even more rapid with the triple-breath induction than with the single-breath induction, and that both of these are more rapid than a conventional induction.

METHODS AND MATERIALS

After protocol approval by our Clinical Investigation Committee, we recruited 12 healthy men and women ranging in age from 25–45 yr. These volunteers signed a detailed consent form which included a specific reference to the possibility of liver disease following exposure to halothane.[3] All had a normal complete blood count and normal liver chemistries including HB_sAg, HB_eAg, SGOT, and bilirubin. All had fasted for at least 8 h prior to the experiment. They were not premedicated.

Each volunteer was anesthetized using three different modes of induction in succession in a single day with a recovery period of 15–30 min between awakening and the next trial. The three modes were a single-breath induction, a triple-breath induction, and a conventional induction. The single-breath induction consisted of a vital capacity breath (maximum inspiration from residual volume) of 4% halothane in oxygen held for 60 s followed by 3 min of continued breathing of 4% halothane. The triple-breath induction consisted of a vital capacity breath of 4% halothane in oxygen held until 20 s, followed by a second vital capacity breath at 21 s held until 32 s, and a third vital capacity breath at 33 s held until 60 s, or until unconsciousness occurred (whichever was first). This sequence was followed by an additional 3 min of breathing 4% halothane in oxgyen. The "conventional" induction consisted of the volunteers maintaining their resting tidal volume and respiratory rate while breathing increasing concentrations of halothane starting with .5% halothane in oxygen, increasing by .5% every 15 s until 4% halothane was reached. Four percent halothane was continued for an additional 2 ¼ min, making the total anesthetic time 4 min. No assisted or controlled breaths were given at any time. Each volunteer was anesthetized with all three modes in a random order. The overall study was planned as a Latin square design.

Mixtures of halothane and oxygen were delivered by a Drager Vapor vaporizer into a circle system of a Drager Narkomed anesthesia machine. The inspiratory and expiratory limbs of the circle were attached to a Y connector which contained a two-way valve.‡ This allowed rapid switching of the patient's inspired gas from room air to the anesthetic gases in the circle. Each induction was started with a 10-l/min circle inflow and a full 3-l reservoir bag to allow for each inspiration of a full vital capacity breath. After the first minute of each anesthetic, the inflow was reduced to 5 l/min to avoid excessive positive end expiratory pressure in the circuit. The pop-off valve was open at all times.

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‡ Small free-breathing valve and bypass, #21045, Warren E. Collins, Braintree, MA 02184.

Monitoring included a precordial stethoscope, ECG oscilloscope, automatic noninvasive blood pressure monitor (Dinamap No. 845XT with a Model No. 950 recorder, Critikon),§ and an ear oximeter (BIOX Model No. 11A).[4] Respiratory gases were sampled from the mask at a rate of 60 ml/min into a mass spectrometer (Perkin-Elmer Model MGA 1100A) to continuously monitor mass fragments of 12, 28, 32, and 69 atomic mass units. From these data, carbon dioxide, nitrogen, oxygen, and halothane concentrations were recorded. All data were processed by a DecMinc 11/23 laboratory computer.

Unconsciousness was defined as the point at which the volunteers no longer opened their eyes on command. The command was repeated every 10 s during each induction. We compared the time from the first breath containing halothane until unconsciousness among the three modes of induction using the F-test and Duncan's multiple range test in the analysis of variance for repeated measures.[5] The rate of rise of end-tidal halothane over time was similarly compared.

Results

Each volunteer lost consciousness on all trials except for two subjects who remained awake at the end of the 4-min "conventional" induction. Onset of unconsciousness was most rapid with the "triple-breath" induction (68.6 ± 31.6 s) (mean ± SD), intermediate with the "single-breath" induction (112.4 ± 22.6 s), and slowest with the "conventional" induction (165.9 ± 31.6 s). Lengths of induction differed from each other at a significant level of $P < .01$.

During the typical conventional induction (fig. 1), inspired halothane rose slowly with time according to the prescribed protocol. End-tidal halothane rose in a similarly slow fashion and, at 2 min, the end-tidal value did not exceed .76%. Unconsciousness was followed by tachypnea.

Typically, all volunteers taking a single vital capacity breath of 4% halothane held their breaths for a least 60 s. Sometimes, the volunteer lost consciousness and breath was held slightly longer (fig. 2). End-tidal CO_2 was elevated for the first few breaths following the breath hold, and tachypnea ensued as anesthetic depth increased. End-tidal halothane concentration of 1.6% was reached by 120 s.

Much variability was seen in the performance of the triple-breath inductions as volunteers were partially anesthetized while trying to respond to instructions for the second and third breaths. Although the protocol

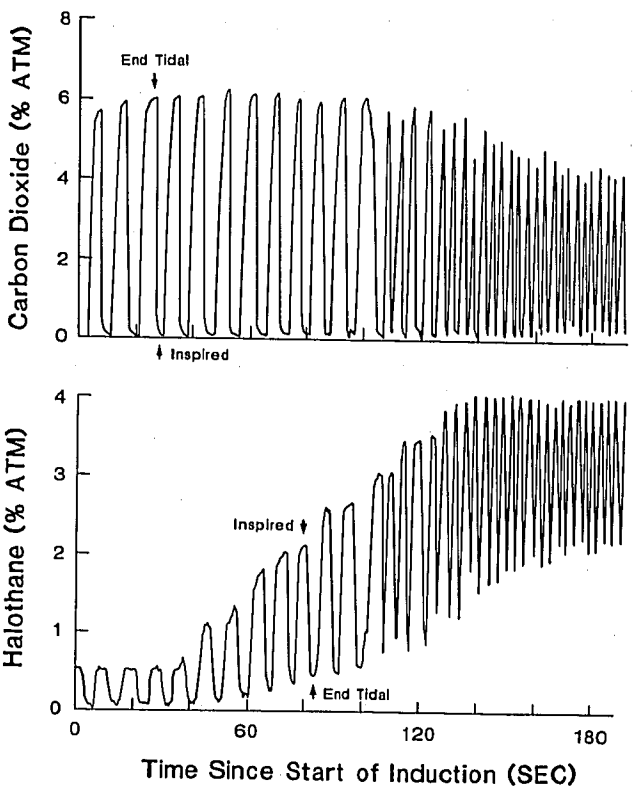

FIG. 1. Respiratory carbon dioxide and halothane concentration *versus* time in a typical volunteer during a conventional induction. End-tidal CO_2 is the peak plateau reached on the upstroke of the curve. Conversely, end-tidal halothane is the trough reached on the downstroke of the curve at the same point in time. Inspired CO_2 is the minimal value reached between successive end-tidal values. This corresponds to the maximum inspired halothane during a given breath. End-tidal halothane at 60 and 120 s is 0.2% and 0.8%, respectively. Zero time indicates the beginning of the breathing of the halothane mixture.

required breaths at 0, 21, and 33 s, only the first breath was consistently taken at the prescribed time. For example, the volunteer in fig. 3 took the second breath at 45 s and the third breath at 50 s. In general, the second and third breaths were less than vital capacity. Again, regular tachypneic respirations were seen after unconsciousness. An end-tidal concentration of 1.7% was seen at 120 s. End-tidal CO_2 rose after the breath hold and decreased with tachypnea.

At the end of every 4-min trial, each volunteer had a regular respiratory pattern. The increase in end-tidal halothane concentration was most rapid with the triple-breath induction, less rapid with the single-breath induction, and slower with the conventional induction. Inspired halothane concentrations were maintained close to the 4% level throughout the rapid inductions. No excitement was seen during single-breath and triple-breath inductions, but excitement was seen with the

§ Looney J Jr: Blood pressure by oscillometry. Med Electron 9:57–63, 1978.

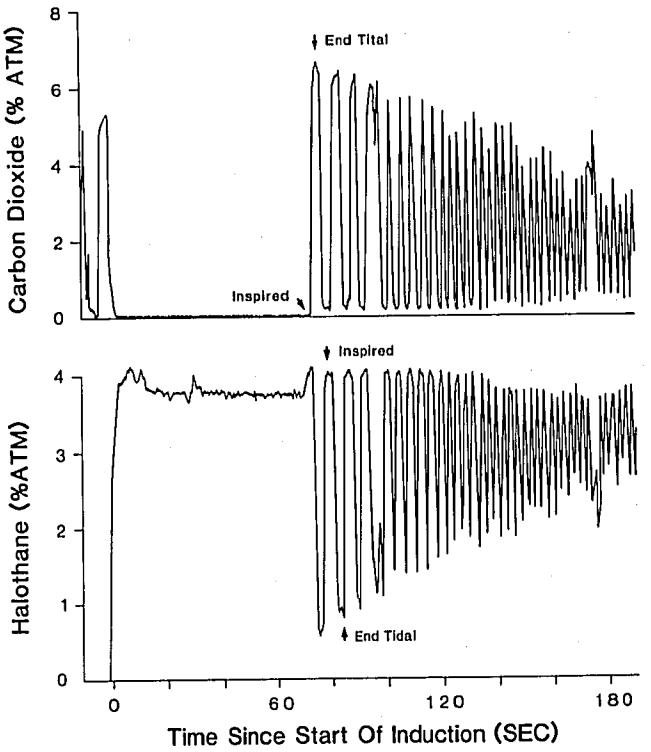

FIG. 2. Respiratory carbon dioxide and halothane concentrations *versus* time in a typical volunteer during a single-breath induction. End-tidal and expired points are defined as in figure 1. At 120 s an end-tidal halothane concentration of 1.6% is reached.

conventional induction in three volunteers. Airway obstruction was uncommon, and was always manageable with jaw elevation. Arterial oxygen saturation (Sa_{O_2}) and arterial pressure were noted before induction, after 2 min of breathing halothane, and after awakening. The lowest blood pressure recorded in any volunteer was 90/53, and the lowest oxygen saturation was 89%. Volunteers rarely remembered the third breath of the triple-breath induction. This suggests that the onset of amnesia is at about 30 s, substantially before the onset of unconsciousness. Our subjects unanimously preferred the more rapid inductions.

DISCUSSION

Although we have previously shown that a rapid-inhalation induction of halothane anesthesia is safe and well accepted in volunteers,[1] this is the first direct comparison with a conventional inhalation induction. A single-breath induction takes only two-thirds as much time, and a triple-breath induction takes only 40% as much time, as a conventional inhalation induction. At 69 s, the speed of the triple-breath halothane induction is close to that of intravenous thiopental. The more rapid techniques may be safer than the conventional technique because there is no excitement phase. These are also more pleasant, in part because of the early onset of amnesia.

The rate of increase of inspired halothane concentration in our conventional induction protocol is somewhat arbitrary, but we followed our usual clinical practice. The timing of the second and third breaths of the triple-breath induction at 21 and 33 s was empirical, and was based largely on early experiments with a single volunteer. Those experiments also showed that, after three closely spaced breaths, the volunteer could no longer follow a command to take an additional breath. Computer simulations of uptake and distribution might further optimize the timing of the breaths and make the induction even faster. One advantage of these rapid inductions is that they do not lead to apnea because the hypocarbic effects of hyperventilation are offset by the breath holding. Adding CO_2 to the inspired mixture might also speed the induction by stimulating deeper second and third breaths.

These rapid induction techniques depend on good cooperation from the patient (or volunteer) and adequate pulmonary gas exchange. Therefore, patients with severe lung disease (especially obstructive disease) or impaired ability to communicate (*e.g.*, because of confusion, poor hearing, or a language barrier) would be unsuitable candidates. Patients with a low cardiac

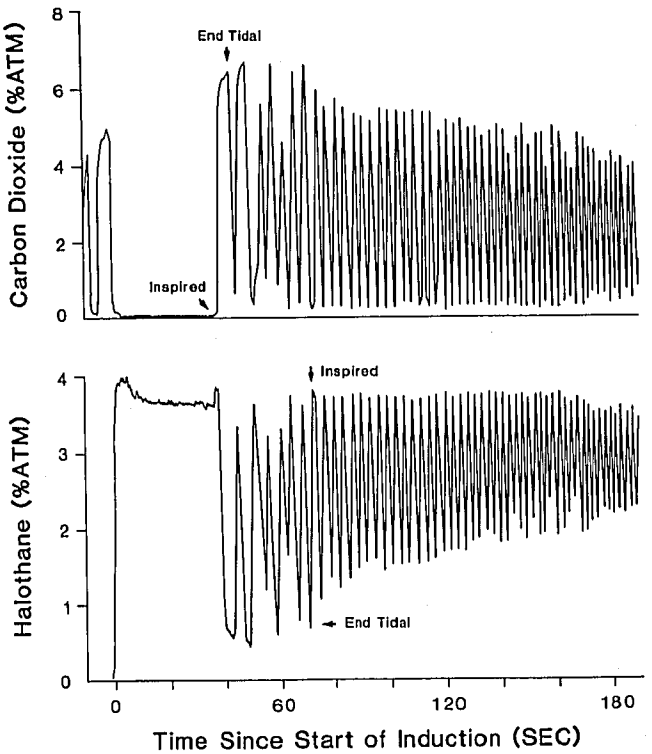

FIG. 3. Respiratory carbon dioxide and halothane concentrations *versus* time in a typical volunteer duirng a triple-breath induction. End-tidal and expired points are defined as in figure 1. At 120 s, an end-tidal halothane concentration of 1.7% is reached.

output, especially in combination with a small functional residual capacity, might be endangered by the rapid rise in alveolar halothane concentration that occurs with the rapid inhalation inductions. Heavy premedication may also compromise these inductions because of respiratory depression and sedation.[6] One of the advantages of the rapid techniques is that they do not require venous access, and our healthy volunteers were managed safely without it. However, in a patient with airway abnormalities, it would obviously be prudent to establish an intravenous infusion prior to induction regardless of what induction technique is to be used.

In theory, induction could be accomplished in one circulation time from lung to brain if the inhaled drug was sufficiently potent, insoluble in blood, and non-irritating to breathe. In fact, the available nonexplosive inhalation drugs are potent but relatively soluble. Halothane is not very irritating to breathe, but is more soluble than enflurane and isoflurane, which are irritating. We anticipate that adding nitrous oxide to the halothane would further speed the triple-breath induction without causing hypoxemia or hypotension. Wilton and Thomas'[2] data support this hypothesis as their average induction time using single-breath halothane, nitrous oxide, and oxygen was 83 s, compared to the 112 s for a single-breath induction in our current study. Use of this method with isoflurane or enflurane is an attractive idea, because these have lower blood solubilities than halothane. Airway irritation and the pungent odor may limit the concentrations that are tolerated during rapid inductions with these drugs. Indeed, Loper *et al.*[7] have reported on a series of patients who had a rapid inhalation induction with either isoflurane or halothane. Although they found that the induction time was significantly shorter in the isoflurane group as compared to the halothane group, they found it necessary to use fentanyl in a dose of 5 μg/kg to inhibit coughing in their patients. Therefore, for a "pure" inhalation induction, halothane appears to be more satisfactory.

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Selective Blind Endobronchial Intubation in Children and Adults

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Double-lumen endobronchial tubes are widely used in thoracic anesthesia, and in emergency situations, such as pulmonary bleeding in adults. However, a double-lumen endobronchial tube for infants and children is not commercially available. Therefore, a bronchial blocker or ordinary endotracheal tube, with or without

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