EFFECTS OF INCREASING ENFLURANE CONCENTRATIONS ON INTRAOCULAR PRESSURE

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During ophthalmic surgery, a variety of anaesthetic techniques are used in an attempt to prevent increases in intraocular pressure (IOP) (Lynch, Wolf and Berlin, 1974). Among the volatile anaesthetics, enflurane is of particular interest (Radtke and Waldman, 1975) since Runciman and colleagues (1978) confirmed that 1% enflurane reduces IOP consistently, whereas halothane, in equipotent concentrations (0.5%), gave unpredictable results. The aim of this study was to define the effects of increasing enflurane concentrations on IOP.

PATIENTS AND METHODS

The study was undertaken in 15 patients (mean age ± SEM: 25.1 ± 1.3 yr; ASA I or II) undergoing plastic or orthopaedic surgery. None of the orthopaedic patients had a tourniquet applied during either anaesthesia or the surgical procedure. Informed consent was obtained from all patients. Patients with previous ophthalmic problems such as glaucoma, or with contraindications to the use of enflurane, were excluded.

The patients were premedicated with hydroxyzine 100 mg i.m. 45 min before anaesthesia was induced with thiopentone 7.5 mg kg$^{-1}$. Pancuronium 0.1 mg kg$^{-1}$ was administered and, after tracheal intubation, ventilation was controlled using a Logic 06 ventilator delivering a minute volume of 120 ml kg$^{-1}$ with a mixture of 50% nitrous oxide in oxygen. Carbon dioxide tension was measured (capnography) and ventilation was adjusted to maintain Pco$_2$ between 4.7 and 5.3 kPa. Enflurane was then added to the inspired gas mixture via an open breathing system using a newly calibrated vaporizer (Cyprane Ltd). Three concentrations of enflurane were used successively: 0.5%, 1%, 1.5%, each for 10 min.

The IOP was measured with a Schiotz-Winter tonometer after the instillation of local anaesthetic solution to the conjunctival sac. In all patients, measurements were made on the day before the intervention (control), before the induction of anaesthesia and during anaesthesia, after administration of 0.5%, 1.0% or 1.5% enflurane. Enflurane in combination with general anaesthesia and controlled ventilation (Pco$_2$ 4.7–5.3 kPa) caused a significant decrease in IOP. The decrease was more marked (44%) with 1% enflurane than with 0.5% enflurane (21%). The change in IOP was comparable with 1.0% and 1.5% enflurane; however, systolic arterial pressure decreased more with enflurane 1.5%. Increasing the inspired concentration of enflurane from 1% to 1.5% did not appear to be associated with any further decrease in IOP.

SUMMARY

The effects of enflurane at various concentrations on intraocular pressure (IOP) were studied. In 15 healthy patients, intubated and mechanically ventilated, IOP was measured the day before surgery, after premedication and during anaesthesia, after administration of 0.5%, 1.0% or 1.5% enflurane. Enflurane in combination with general anaesthesia and controlled ventilation (Pco$_2$ 4.7–5.3 kPa) caused a significant decrease in IOP. The decrease was more marked (44%) with 1% enflurane than with 0.5% enflurane (21%). The change in IOP was comparable with 1.0% and 1.5% enflurane; however, systolic arterial pressure decreased more with enflurane 1.5%. Increasing the inspired concentration of enflurane from 1% to 1.5% did not appear to be associated with any further decrease in IOP.
measurement of IOP. All measurements were obtained by the same clinician.

For statistical analysis of the results, analysis of variance and Student’s paired t test were used. Differences were considered significant when $P < 0.05$.

RESULTS

Results are presented in table I. After premedication, IOP increased slightly, but the difference was not statistically significant. Whatever the enflurane concentration, IOP decreased significantly compared with control values: 21% with 0.5% enflurane ($P < 0.05$); 44% with 1.0% enflurane ($P < 0.001$) and 41% with 1.5% enflurane ($P < 0.001$) (fig. 1). There were significant decreases in IOP between 0.5% enflurane and 1.0% enflurane ($P < 0.001$), and between 0.5% and 1.5% ($P < 0.001$). The IOP values between 1% enflurane and 1.5% enflurane did not achieve significance.

Systolic arterial pressure decreased, but not significantly, after the administration of 0.5% enflurane. Enflurane 1% and 1.5% produced significant decreases in systolic arterial pressure of 15% ($P < 0.001$) and 21% ($P < 0.001$), respectively (fig. 2). The difference in systolic arterial pressure between 1.0% enflurane and 1.5% enflurane was significant ($P < 0.01$).
DISCUSSION

The changes in intraocular pressure observed in this study may be considered to be a result of the administration of the enflurane. Ventilation was controlled under conditions comparable to those used by other workers for this kind of study (Runciman et al., 1978), such conditions ensuring normocapnia, or even hypocapnia (Nunn, 1960). No comparison with any state of anaesthesia in which enflurane was not present was performed, because the aim of this study was to compare three different concentrations of enflurane during anaesthesia. Moreover, previous studies had shown that IOP was not altered much by the other anaesthetic agents used: hydroxyzine (Farnati et al., 1967), thiopentone or pancuronium (Al-Abrak and Samuel, 1974; Runciman et al., 1978). Because the increase in the alveolar concentration of enflurane is rapid in the first few minutes of uptake (Torri et al., 1972), an interval of 10 min between measurements was chosen.

An applanation tonometer would be more accurate than the Schiotz tonometer to measure IOP. However, the main advantage of the tonometer used was its simplicity, and it is still in use in other studies during general anaesthesia (Balamoutsos et al., 1983; Vilardi et al., 1983). To be more accurate and reliable, all the measurements were performed in triplicate and always by the same investigator.

The effects of enflurane on IOP have already been investigated. Radtke and Waldman (1975) reported a decrease in IOP in youths during spontaneous ventilation. In this study, the results may have been influenced by the anaesthetic technique used and by hypercapnia, which tends to increase IOP (Collet, 1960). In conditions comparable to those obtaining in the present study (controlled ventilation, anaesthesia with thiopentone and pancuronium), Runciman and colleagues (1978) established that the administration of 0.5% halothane caused an unpredictable decrease in IOP of 14%, whereas enflurane caused a decrease in IOP of 40% of the control values. On the other hand, Presbitero and co-workers (1980) found no relationship between enflurane concentrations and decreases in IOP.

The results of the present study are in agreement with those of Runciman and colleagues (1978). The decrease in IOP was greater with 1.0% enflurane than with 0.5% enflurane, but the increase in enflurane concentration from 1.0% to 1.5% did not change IOP. The mechanisms of the effect of enflurane on IOP are multiple:

(1) Relaxation of intraocular and extraocular muscles; the greater decrease in IOP with enflurane than with halothane could be the result of the neuromuscular effects of enflurane (Lebowitz, Blitt and Walts, 1970).

(2) Decrease in production of aqueous humour and facilitation of its flow (Duncalf, 1975).

(3) Action on the central nervous system, particularly on the hypothalamus, which plays a role in the control of IOP (Presbitero et al., 1980).

(4) Variations of systemic arterial pressure which may alter IOP (Duncalf, 1975; Philajaniemi and Helve, 1977). The decrease of systolic arterial pressure shown in the present study could partly explain the decrease in mean IOP which was, however, much more marked than the change in arterial systolic pressure. The values of systolic arterial pressure remained greater than 90 mm Hg, a value which usually does not affect IOP (Adams and Barnett, 1966).

(5) In our study central venous pressure (CVP) was not monitored, but none of the orthopaedic patients had a tourniquet applied that could have led to changes in CVP. Furthermore, no changes in CVP after induction in comparable conditions of anaesthesia were observed by Runciman and colleagues (1978). A decrease in IOP could result from a decrease in CVP (Jantzen et al., 1986), but increasing the enflurane concentration during controlled ventilation produces an increase in right atrial pressure (Calverley et al., 1978), so the decrease in IOP is probably not explained by changes in CVP.

To conclude, enflurane in combination with nitrous oxide, muscle relaxation and thiopentone, during controlled ventilation and normocapnia, caused a decrease in IOP, and this may decrease the risk of vitreous loss during intraocular surgery; but it does not seem necessary to administer a concentration greater than 1.0%. The increase in the concentration of enflurane from 1.0% to 1.5% did not alter IOP, but decreased arterial pressure. This decrease in arterial pressure, although sometimes desirable, may be hazardous on occasions. The results of the present study were observed in healthy adults. The effects of enflurane on IOP could be different in patients with preoperative modifications of IOP such as glaucoma.
REFERENCES


