Abstracts

Increasing maternal FiO_2 increases fetal PaO_2

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The ideal anaesthetic technique for Caesarean section under general anaesthesia has not been identified. Although current anaesthetic practice is to use 50 per cent $\text{N}_2\text{O}/\text{O}_2$ supplemented with low-dose vapour, some anaesthetists use 100 per cent O_2 , supplemented with either halothane or enflurane. Therefore, a study comparing fetal arterial PO_2 and anaesthetic techniques was done.

Methods

A retrospective chart survey of Caesarean sections under general anaesthesia between January 1985 and July 1986 was done. Only charts complete enough to allow analysis of type of anaesthesia, urgency, fetal cord gases and Apgar scores were reviewed.

Group I consisted of those patients who received 100 per cent O_2 supplemented with either halothane or enflurane, and Group II consisted of those who received 50 per cent $\text{O}_2/\text{N}_2\text{O}$ supplemented with either halothane or enflurane. All patients received thiopentone and succinylcholine for induction. No narcotics were given prior to cord clamping. Fetal cord gases were determined from a doubly clamped segment of umbilical cord at the time of delivery. Arterial and venous cord gases were stored on ice and determined within 15 minutes. Maternal haemoglobin concentrations were routinely measured preoperatively and 48 hours postoperatively. Apgar scores and fetal weights were obtained from the neonatal intensive care staff who routinely attend all Caesarean sections. One-tailed unpaired t tests were used to compare fetal blood gases, Apgar scores, weights, maternal preoperative and postoperative haemoglobins. A p value of ≤ 0.05 was considered statistically significant.

Results

A total of 123 charts were considered complete enough to allow inclusion; 61 had received 100 per cent O_2 /vapour (Group I) and 62 $\text{N}_2\text{O}/\text{O}_2$ /vapour (Group II). Fetal blood gases are summarized in the Figure. The mean fetal arterial PO_2 was 20.8 ± 7.0 mmHg (mean $\pm$ SD) in Group I and 18.4 ± 7.2 mmHg (mean $\pm$ SD) in Group II, a statistically significant difference. When the groups were analyzed with respect to urgency of Caesarean section, a trend to higher mean fetal PO_2 's in the group receiving 100 per cent O_2 was evident. For emergency Caesarean sections, the difference again reached statistical significance, 19.7 ± 8.9 vs 14.8 ± 5.2 mmHg.

No differences were demonstrable in other fetal arterial or venous gases, Apgar scores, maternal preoperative or postoperative haemoglobins.

Discussion

General anaesthesia for Caesarean section is sometimes indicated, but the ideal anaesthetic management is not clearly defined. This retrospective survey demonstrated a significant increase in fetal arterial PO_2 in those women having Caesarean section under 100 per cent O_2 /vapour anaesthesia. The trend was evident in all sub-groups, but only reached statistical significance in the emergency Caesarean section group. The increase in arterial PO_2 in the emergency subgroup would reflect an increase in fetal oxygen delivery if umbilical cord blood flow and fetal oxygen consumption remained constant.

The anaesthetist's role in stabilization of the critically ill child

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FIGURE Fetal arterial PO_2 . Group I O_2 /vapour. Group II $\text{N}_2\text{O}/\text{O}_2$ /vapour.

Airway compromise often either initiates or complicates serious illnesses in children. Anaesthetists therefore, with their specialized airway skills, should have an important role in the care and stabilization of these seriously ill children. However, our anecdotal clinical experience suggested anaesthetists were not usually involved in either initial stabilization or treatment of these children in community settings. In an effort to document the problems that might cause serious illness in childhood and document the anaesthetist's role in the community hospital in the care of these children, we reviewed the hospital charts and transport records of all children transported by an organized team to this centre from 1982 to 1985. We chose to review the transport records because the documentation of the child's clinical status, diagnosis, and long-term outcome was easily available and previously analyzed and because we believed

these children likely represented the most seriously ill group seen in a community hospital setting.

Methods

The transport data and hospital records of all patients aged two weeks to 15 years who were transported to our institution during the period January 1982 to December 1985 were reviewed. The following information was obtained from the charts: presenting problem at initiation of the transport (i.e., coma, airway obstruction, trauma, cardiac arrest, or shock), specialty of the referring physician (i.e., family/emergency physician, paediatrician, anaesthetist), type of airway intervention offered (i.e., bag-mask ventilation, or tracheal intubation), presence or absence of anaesthesia specialty consultation, presence or absence of further airway intervention by the transport team, including tracheal intubation and initiation of assisted ventilation.

Results

Thirty-nine children, aged three weeks to 12 years were transported by a physician-assisted transport team between 1982 and 1985 and had their charts reviewed. Seven children died as a result of their illness. The presenting problem, diagnostic category and other relevant data obtained from the charts are presented in the Table.

TABLE Results

Diagnosis	Patients	Anaesthesia involvement		Further airway intervention by team
		Primary physician	Consultative physician	
Coma	16	0	4	8 (50%)
Airway obstruction	18	0	6	4 (22%)
Cardiac arrest or shock	5	0	0	0 (0%)
Total	39 (100%)	0 (0%)	10 (26%)	12 (31%)

Of the 12 children who required further airway interventions one required the addition of positive end respiratory pressure, five required tracheal intubation and assisted ventilation and the remaining six required further increases in assisted ventilation.

Discussion

We reviewed the charts of transported critically ill children to this centre in an effort to document the causes of serious illnesses in childhood and the anaesthetist's role in their care. Our data suggest that coma and airway obstruction are common causes of serious illness and referral to tertiary care centres. However, despite these presenting problems, the anaesthetist was not involved in the initial assessment and stabilization of these children. Our data also suggests that current management is inadequate as a substantive number of children (31 per

cent) still required further sophisticated airway intervention, of a type familiar to practising anaesthetists. Prompt and complete airway management is mandatory to minimize hypoxic ischaemic brain injury, which can produce long-term morbidity in children who survive their primary illness. To our knowledge this is the first examination of the role of the anaesthetist in the initial care of seriously ill children in Canadian community hospitals. Our data present a strong case for the early involvement of a multidisciplinary team to manage these children, and especially including someone with advanced airway skills. We believe the community-based anaesthetist is the ideal physician to fill this role and also to aid in areas such as pharmacologic control of seizures and brain protection.

Analgesic efficacy of eutectic mixture of local anaesthetics (EMLA) vs intradermal infiltration prior to venous cannulation in children

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Fear of needles and pain associated with venipuncture make IV cannulation prior to the induction of general anaesthesia a traumatic experience for awake children. Recently an eutectic mixture of the local anaesthetics lidocaine and prilocaine (EMLA) has become available. EMLA is able to penetrate the intact skin. It has been shown to be effective in preventing pain associated with venipuncture in studies that compared EMLA to either a placebo or nothing at all.^{1,2} This study was designed to compare prospectively the analgesic efficacy and acceptability of EMLA versus intradermal infiltration with lidocaine (skin wheal) prior to venous cannulation in children.

Methods

The study was approved by the Institutional Review Board, and informed consent was obtained in every case. Twenty-three ASA physical status I patients aged 7 to 12 years were randomly assigned to one of two groups. All children agreed to accept awake venous cannulation in lieu of preoperative phlebotomy by technicians for required laboratory testing. Group I patients had 2.5 grams of EMLA applied to the dorsum of their hand, and covered with a Tegaderm occlusive dressing for 60 minutes. Children in Group II had the dorsum of their hand infiltrated at the anticipated venipuncture site with 0.2 ml of one per cent lidocaine using a 30-gauge needle. Venipuncture was performed by one of the investigators using a 20-gauge cannula in all cases. The patient's response was scored by the anaesthetist performing the venipuncture, an independent observer and the child using a 0-10 visual analogue pain scale. Differences in the response of the two groups to venipuncture were examined. The data was analyzed using Spearman's rank correlation to compare agreement between pain scores by the patient, anaesthetist and observer. Analysis of variance techniques were used to show significant differences between the observers' and patient's assessment of pain intensity during cannulation.

Results

The two groups did not differ in regards to age (mean 9.9 yr), and there was no correlation between age and pain score. Twenty-two children obtained satisfactory analgesia for IV cannulation. One child in the EMLA group had inadequate analgesia by all three assessments. Group I children self-scored a mean of three (range 0–10) on the analogue scale while Group II scores were 3.5 (range 0–10). There was no correlation between age and pain score. The children in both Group I and Group II rated their pain and discomfort significantly higher than did the health care professionals ($p < 0.05$). Spearman's rank correlation showed a significant agreement in pain scores awarded by the anaesthetist and observer ($r = 0.81 \pm 0.1$) and the health care professionals and the children ($r = 0.61 \pm 0.14$).

Discussion

EMLA and skin wheal infiltration both provided effective analgesia for venous cannulation in children. While there was a significant correlation between the visual analogue pain scores of the three observers, children uniformly rated the pain and discomfort associated with venous cannulation significantly higher than did either the anaesthetist or the observer. This higher score may be a function of the emotional component of pain which children associate with this event. The major drawback associated with EMLA is the 60-minute period of skin contact required for the cream to reach full efficacy.

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Tracheo-bronchial angles in neonates

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Kubota *et al.*¹ reported that the left tracheo-bronchial angle is greater than the right in infants and children. However, neonates were not included in their study, and there are few reports examining the tracheo-bronchial angles of neonates.^{2,3} We measured the tracheo-bronchial angles in neonates, including both premature and mature infants.

Methods

Seventy-four neonates (39 males and 35 females) between the gestational ages of 24 and 42 weeks who were admitted to the neonatal ICU were studied. Neonates with an anatomical anomaly in the chest such as pneumothorax, diaphragmatic hernia or mediastinal disease were excluded. Chest x-ray films were taken with all neonates in the supine position. The right and left

bronchial angles (RBA, LBA), which consisted of the axis of trachea and each main stem bronchus, and the total bronchial angle (TBA) were measured from the films. The neonates were divided into two groups according to gestational age, i.e., premature infants (<37 weeks) group (PI) and mature infants (≥ 37 weeks) group (MI). Student's *t* test was utilized for statistical analysis and $p < 0.05$ was considered significant.

Results

The left tracheo-bronchial angle ($47.4 \pm 5.8^\circ$) is significantly greater than the right ($31.6 \pm 5.6^\circ$) in neonates. The RBA, LBA and TBA showed no significant differences between premature and mature infants.

TABLE Results. Tracheo-bronchial angles (degrees) (mean $\pm$ SD)

Group	n	RBA	LBA	TBA
PI	39	32.1 ± 5.8	47.8 ± 6.4	79.9 ± 9.2
MI	35	31.1 ± 5.6	47.2 ± 5.0	78.0 ± 7.1
Total	74	31.6 ± 5.6	47.4 ± 5.8	78.9 ± 8.3

Discussion

These results are similar to those reported previously in neonates (RBA 30° , LBA 47°)² and infants and children (RBA $31 \pm 5^\circ$, LBA $46 \pm 5^\circ$).¹ Placzek and Silverman³ also reported identical observations in 19 neonates. Since there were no differences in the angles between premature and mature infants, we conclude there is little change in the angles during maturation.

In conclusion, even in premature infants, LBA is greater than RBA, and the incidence of inadvertent right endobronchial intubation should be higher than that of the left.

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End-tidal PCO₂ measurements in infants and children ventilated with the Sechrist infant ventilator

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In a previous study, end-tidal PCO₂ (PETCO₂) measurements in infants and children ventilated with an Air-Shields Ventimeter were accurate only if sampled from the distal end of the endotracheal tube (PETCO₂-d).¹ However, in another study, measurements of PETCO₂ sampled from the proximal end of the endotracheal tube (PETCO₂-p) were accurate in infants weighing <8 kg ventilated with a Siemens-Elema "Servo" 900-C.² The present study compares the accuracy of PETCO₂-d and

FIGURE The relationship between $\Delta\text{PCO}_2(\text{a-et})$ and body weight.

$\text{PETCO}_2\text{-p}$ measurements in infants and children ventilated with the Sechrist Infant Ventilator (SIV).

Methods

After approval from our Committee on Human Research, 27 healthy infants and children scheduled for elective surgery were studied. The induction of general anaesthesia was followed by controlled ventilation with an SIV and Mapleson D breathing circuit. Ventilatory parameters and fresh gas flows were adjusted to provide a $\text{PETCO}_2\text{-d}$ within the clinical range (28–44 mmHg). PETCO_2 was measured continuously by infra-red analysis at a sampling rate of $150\text{ ml}\cdot\text{min}^{-1}$. $\text{PETCO}_2\text{-d}$ measurements were obtained using a #16 or #19 Deseret Intracath[®] inserted through the Luer-lok[®] port of a clear plastic elbow. $\text{PETCO}_2\text{-p}$ measurements were sampled from an adapter placed between the endotracheal tube and the breathing circuit. Temperature corrected arterial PCO_2 measurements (PaCO_2) were sampled simultaneously with $\text{PETCO}_2\text{-d}$ and -p . The gradients between PaCO_2 and $\text{PETCO}_2(\text{a-et})$, -d and -p were compared to body weight using least squares linear regression analysis and the coefficient of determination (r^2). The $\Delta\text{PCO}_2(\text{a-et})$ values for -p and -d groups were compared using Student's t test for unpaired data.

Results

The infants and children varied in weight from 1.3 kg to 24.5 kg (mean $\pm$ SD = 10.6 ± 6.6 kg). There was no statistically significant correlation between $\Delta\text{PCO}_2(\text{a-et})$ and body weight in either the -d or -p groups (Figure). Likewise, there was no significant difference in mean $\Delta\text{PCO}_2(\text{a-et})$ values between the two groups ($\Delta\text{PCO}_2(\text{a-et})\text{-d} = 0.7 \pm 1.9$ mmHg and $\Delta\text{PCO}_2(\text{a-et})\text{-p} = 1.3 \pm 1.8$ mmHg).

Discussion

This study shows that both $\text{PETCO}_2\text{-d}$ and $\text{PETCO}_2\text{-p}$ approximate PaCO_2 in infants and children ventilated with the SIV. Distal sampling catheters, however, may be unavailable, may cause increased airway resistance in endotracheal tubes <4.0 ID (unpublished data), or become obstructed with secretions. By contrast, proximal sampling is easily available, avoids

increased airway resistance, and is less likely to obstruct. Therefore, the SIV is a useful ventilator for infants and children who require accurate PETCO_2 monitoring.

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Radionuclide ventriculography and 2D echocardiography as predictors of left ventricular performance during aortic vascular surgery

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Myocardial infarction accounts for 50 per cent or more of the postoperative mortality associated with abdominal vascular surgery.¹ Aortic cross-clamping is accompanied by changes in cardiac index and SVR, which may be poorly tolerated in patients with coronary artery disease.² Non-invasive methods, employing radionuclide gated imaging (MUGA) and two-dimensional echocardiography, have been used to measure left ventricular ejection fraction (LVEF). The objectives of this study were to assess the correlation between LVEF and changes in left ventricular performance during aortic vascular surgery.

Methods

Following institutional ethical approval, 16 ASA physical status II–III patients booked for elective aortic vascular surgery underwent preoperative Goldman multivariate risk analysis and LVEF determination with MUGA scans and 2D echocardiography. Diazepam $0.15\text{ mg}\cdot\text{kg}^{-1}$ was administered orally 90 minutes before surgery. Following insertion of radial and pulmonary artery (PA) catheters under local anaesthesia, induction with fentanyl $3\text{--}6\text{ }\mu\text{g}\cdot\text{kg}^{-1}$ and thiopentone $2\text{--}3\text{ mg}\cdot\text{kg}^{-1}$ was employed. Muscle relaxation was obtained with pancuronium $0.1\text{ mg}\cdot\text{kg}^{-1}$ IV. Anaesthesia was maintained with 70 per cent $\text{N}_2\text{O}/30$ per cent O_2 and 0.5 per cent isoflurane under normocapnic conditions. Measured values included heart rate, BP, cardiac output, CVP, PCWP and PA pressures while derived indices included cardiac index, LVSWI and SVR. Measured and derived data were obtained before and after induction, aortic cross-clamping, and unclamping. PCWP was maintained between 10–15 mmHg and hypertension >20 per cent of baseline was controlled with nitroglycerin infusion. Changes in cardiovascular parameters were analysed using Wilcoxon matched-pairs test. Correlation between LVEF and measured/derived data was analysed using Kendalls Tau nonparametric correlation. $p < 0.05$ was considered significant.

FIGURE Results - CI, SVR.

Results

Induction of anaesthesia was associated with significant decreases in MAP, PCWP, CO and CI and with a highly significant decrease ($p = 0.0006$) in LVSWI. Cross-clamping of the aorta was associated with a significant increase in MAP and SVR. Ejection fraction was associated with a significant decrease in SVR. Ejection fraction values ranged from 34–67 per cent. There was no significant difference between ejection fractions measured by radionuclide ventriculography and echocardiography. Ejection fraction correlated poorly with changes in indices of left ventricular performance seen intraoperatively.

Discussion

Preoperative LVEF has been advocated as a method of categorising cardiac risk and the need for PA catheterisation.² In our study, preoperative resting nuclear angiography and echocardiography did not predict intraoperative left ventricular performance. Patients with ischaemic heart disease may have normal LVEF at rest but in such cases significant impairment of left ventricular function may follow stressful surgical interventions. Preoperative exercise scanning may prove more informative.³

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Influence of nitrous oxide on high energy phosphates in rabbit myocardium

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Nitrous oxide (N_2O) depresses left ventricular function,¹ and in a canine model can induce apical segment dysfunction in both normal and ischaemic myocardium.² The mechanism for these

FIGURE ^{31}P spectrum of rabbit myocardium. See text for abbreviations.

effects has not been determined. The present study was undertaken utilizing ^{31}P magnetic resonance spectroscopy (MRS) to assess the effect of N_2O on myocardial high-energy phosphate levels (ATP, 2, 3DPG, phosphocreatine (PCr)), and inorganic phosphate (Pi) in the rabbit myocardium *in vivo*.

Methods

Ten New Zealand white rabbits were anaesthetized with pentobarbitone, N_2O (50 per cent), halothane (1–3 per cent inspired), and incremental doses of fentanyl to maintain apnoea. Heart rate and blood pressure were monitored via a cannula placed in the right carotid artery. The sternum was excised, a 16 mm surface coil was placed over the lateral surface of the left ventricle and the animal placed in a 1.9 Tesla Oxford Instruments 20 cm bore superconducting magnet. ^{31}P spectra collected over 12 min were obtained with 100 per cent oxygen at least 15 min after N_2O had been turned off, then again 15 min after the introduction of 50 per cent N_2O . A typical ^{31}P spectrum is illustrated; the areas under all the peaks were added together to give the total ^{31}P area, and each peak was then expressed as a percentage of the total signal. The change in β ATP, PCr, 2, 3DPG + Pi (because there is insufficient resolution between the two peaks), and PCr/ β ATP ratio were calculated and compared between the two conditions using paired Student's *t* tests. A *p* value of 0.05 was considered significant.

Results

The Table illustrates the mean percentage of intracellular high-

TABLE Effect of N_2O on intramyocardial phosphates (mean $\pm$ SD; abbreviations explained in text)

	100% O_2	50% N_2O	
Pi + 2,3DPG (%)	24 $\pm$ 4	26 $\pm$ 3	NS
PCr (%)	26 $\pm$ 2	26 $\pm$ 1	NS
β ATP (%)	15 $\pm$ 2	14 $\pm$ 2	NS
PCr/ β ATP ratio	1.79 $\pm$ 0.23	1.82 $\pm$ 0.3	NS
Total signal	3370 $\pm$ 737	3253 $\pm$ 560	NS

energy phosphates with and without N_2O present, and show no significant effect of N_2O . There were no significant changes in blood pressure or heart rate induced by N_2O .

Discussion

The results provide *in vivo* evidence that N_2O does not induce alterations in myocardial high-energy phosphates, suggesting that the biochemical basis of myocardial depression by N_2O is unlikely to be via an effect on these compounds. The absence of an effect of N_2O on pulse or blood pressure does not preclude an effect on contractility; monitoring of the latter parameter was not possible in this model. A previous MRS study in an isolated heart preparation showed no effect of halothane on myocardial phosphates.³ An effect on ionic content or fluxes suggested in the latter study may be a more likely basis for the myocardial effects of anaesthetic agents.

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Isoflurane and metabolism of oxygen-derived free radicals

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Oxygen-derived free radicals (ODFR) are inevitable by-products of oxidative metabolism. ODFR relax contracted isolated arterial rings. This relaxation is more pronounced in vessels with endothelium than in denuded ones. ODFR affect the turnover of endothelium derived relaxing factor.¹ Isoflurane can attenuate the contraction of isolated coronary artery rings challenged with mediators of vasospasm, but this effect depends on the presence of endothelium.² The study was designed to determine whether the endothelium-dependent vascular effect of isoflurane could be mediated by an action on the metabolism of ODFR. Therefore, we measured the effect of isoflurane on vascular relaxation induced by ODFR which were generated by the action of xanthine oxidase on xanthine *in vitro*.

Methods

Twenty-four epicardial coronary rings approximately 4 mm long were removed from the left anterior descending and circumflex coronary arteries of six dogs. The endothelium was mechanically removed in half the rings. Rings were then placed in organ chambers filled with modified Krebs-Ringer bicarbonate solution at 37°C, connected to strain gauges for measurement of contractile force and aerated with 95 per cent O_2 -5 per cent CO_2 , either without (control) or with 2.3 per cent isoflurane (1.5 MAC in the dog). Indomethacin (10^{-5} M) was added to

Figure 1 WITH ENDOTHELIUM

Figure 2 WITHOUT ENDOTHELIUM

FIGURES 1 & 2 Effect of isoflurane on relaxation of contracted coronary artery rings by ODFR. Blood vessels were treated with indomethacin (10^{-5} M), prostaglandin $F_{2\alpha}$ (2×10^{-6} M) and xanthine oxidase ($0.1 \text{ u} \cdot \text{ml}^{-1}$). After stabilization of the contraction, xanthine (10^{-5} M to 10^{-4} M) was added to the organ chamber. Changes in isometric tension are expressed in percentage of the contraction before the administration of xanthine.

inhibit the synthesis of endogenous prostaglandins. Then prostaglandin $F_{2\alpha}$ (2×10^{-6} M) was used to contract the rings. Xanthine oxidase was added to the chambers ($0.1 \text{ u} \cdot \text{ml}^{-1}$) followed by increasing doses of xanthine (from 10^{-5} M to 10^{-4} M). Ring tension was measured.

Results

Rings, both with and without endothelium, exhibited concentration-dependent relaxation following addition of xanthine. This response was unchanged with isoflurane. Figure 1 shows that both control and isoflurane treated rings relaxed following addition of xanthine. The lines are virtually superimposed indicating absence of isoflurane effect. Likewise, in Figure 2, rings denuded of endothelium relaxed and again this effect was not modified by isoflurane.

Discussion

Oxygen-derived free radicals generated by xanthine oxidase

and xanthine have a direct inhibitory effect on coronary vascular smooth muscle tension. They also evoke endothelium-mediated relaxation.¹ Since isoflurane had no effect on the responses, we conclude that in this *in vitro* model it does not interfere with the metabolism of ODFR.

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Anaesthesia for cryoablation of accessory ventricular conduction pathways: a review of 112 cases

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Pre-excitation disorders have an estimated prevalence of 0.31 per cent. In addition to paroxysmal tachyarrhythmias producing dyspnoea and syncope, subsets of this population are at risk for sudden death.¹ Advances in electrophysiological mapping and the increasing sophistication of surgical techniques results in an increasing role for definitive surgical treatment. Between June 1981 and July 1985, we performed 112 surgical cryoablation procedures in 105 patients. A retrospective chart review was undertaken to examine our experience.

Results

Mean age of the patients was 31.1 years (range 6-66 years) with a preponderance of males (64 per cent). Associated cardiac disease including Ebstein's anomaly, mitral or aortic disease, diffuse cardiomyopathy, and atrial septal defect were found in eight (7.6 per cent) patients. The initial 31 (28 per cent) cases were performed using an endocardial open-heart approach.² The subsequent 81 (72 per cent) procedures employed a closed-heart epicardial approach.³ The open technique necessitates full cardiopulmonary bypass (CPB) and cardioplegic arrest, whereas the closed technique is performed with normothermic CPB on a beating heart. Ten per cent of the closed-heart cryoablation procedures, in which the pathway was located on the right ventricular free wall, did not require CPB.

Antiarrhythmics were discontinued in all patients at least 48 hours prior to surgery. No premedication was administered in 20 per cent of cases whereas the remainder received a sedative-hypnotic. In addition to a radial arterial line, 96 per cent of patients were managed with a CVP line while a pulmonary artery catheter was inserted in five cases. Induction of anaesthesia employed either a barbiturate-relaxant (84 per cent) or a narcotic-benzodiazepine (16 per cent) and was uneventful in all cases. In 17 per cent of cases a pure narcotic-relaxant technique was employed for maintenance of anaesthesia, whereas a balanced technique with isoflurane (16 per cent), enflurane (34 per

cent), or halothane (33 per cent) and supplemental narcotic was utilized for the remainder. D-tubocurarine was used in 23 per cent and pancuronium in 73 per cent of cases. There was no significant correlation between intraoperative arrhythmias and type of anaesthetic employed, as determined by Chi-square test. Two patients developed ventricular fibrillation and four patients required cardioversion for supraventricular tachyarrhythmias during surgery. Vasopressors, including phenylephrine or epinephrine, were administered in ten per cent of cases, particularly during electrophysiological mapping with dislocation of the heart. Duration of CPB was 70 ± 15 min in the closed-heart vs 103 ± 12 min in the open-heart group. Average heparin dosage was $375 \text{ units} \cdot \text{kg}^{-1}$ in the closed-heart group during normothermic CPB. Surgical misadventures included three left atrial tears and three coronary sinus tears. Fifty-nine per cent of the closed-heart groups required no blood products while the remainder received an average of 1.9 units of packed red cells and 1.2 units of fresh frozen plasma. Average time to extubation was 9.7 ± 2.5 h while 11 per cent of patients were extubated in the immediate postoperative period. There was no perioperative mortality in either group.

Discussion

Definitive surgical treatment of various pre-excitation syndromes is increasingly being undertaken. As a group these patients are often younger and without associated disease compared with a population undergoing coronary artery surgery. Although the incidence of associated cardiac anomalies is higher in this group, the majority can be managed successfully using standard anaesthetic techniques.

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QTc interval changes during induction of anaesthesia

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Patients with congenital or acquired prolonged QTc syndrome are at increased risk for dysrhythmia and sudden death. The QTc is affected by drugs or changes in heart rate.¹ However the pharmacological effects of anaesthetic agents on the QTc are not well known. QTc has been shown to be prolonged after thiopentone and succinylcholine, but no correlation was made between QTc and the changes in heart rate that occurred during induction.² Therefore we undertook a randomized clinical study to measure QTc changes during the induction of anaesthesia and to compare the effects of succinylcholine and atracurium.

TABLE I QTc interval (msec)

Group	Time							
	Preop	0'00"	1'00"	2'45"	4'15"	6'00"	8'00"	10'00"
Atracurium	400	407	412	434*	454*	461*	452*	441
Succinylcholine	405	413	418	440*	447*	455*	448*	438

* $p < 0.05$ compared to value at time 0.

Methods

After approval by the Research Committee and informed written consent, 40 male patients ASA physical status I, aged 20 to 50 years, were randomly divided into an atracurium group or a succinylcholine group. After premedication with morphine, anaesthesia was induced with atracurium $0.05 \text{ mg} \cdot \text{kg}^{-1}$ (0'00"), thiopentone $5 \text{ mg} \cdot \text{kg}^{-1}$ (2'00") and atracurium $0.5 \text{ mg} \cdot \text{kg}^{-1}$ or succinylcholine $1.5 \text{ mg} \cdot \text{kg}^{-1}$ according to each group (3'00"). Patients were intubated (4'30") and ventilated with oxygen, nitrous oxide and isoflurane. Blood pressure and ECG rhythm strip were monitored continuously. Using a Marquette PC, a total of eight 12 lead ECG's were recorded during the study: before premedication (preop), and during induction at 0'00", 1'00", 2'45", 4'15", 6'00", 8'00", and 10'00". The QT interval was measured by the computerized ECG recorder and the QTc was calculated using Bazett's formula. Statistical analysis was done with the Student's *t* test and analysis of variance. A $p < 0.05$ was considered statistically significant.

Results

The groups were similar for age, weight, height and serum potassium level. Heart rate and systolic blood pressure values were not different between groups. Both groups had similar prolongation of QTc at induction (Table I). During this time period, the heart rate also increased. To find out whether this QTc prolongation was secondary to a pharmacological effect of thiopentone or to an increase in heart rate, we compared the QTc observed in our study with the QTc predicted for the changes in heart rate found in our population using the Simonson equation:³

$$QT = 0.2423 + (0.140)RR + (0.0003) \text{ age}$$

Table II shows observed and predicted QTc during the time period prior to muscle relaxation. At time preop and at 0'00", the observed QTc was 9 msec higher than the predicted values ($p < 0.001$). After thiopentone, this difference increased to 25 msec ($p < 0.00001$). For a change in heart rate from 68 bpm at 0'00" to 80 bpm after thiopentone, the predicted QTc would

TABLE II Predicted and observed QTc (msec)

Time	Heart rate	Predicted	Observed
Preop	61 $\pm$ 12	393 $\pm$ 12	402 $\pm$ 15*
0'00"	68 $\pm$ 15	401 $\pm$ 16	410 $\pm$ 17*
2'45"	80 $\pm$ 12	412 $\pm$ 13	437 $\pm$ 17†

* $p < 0.001$
† $p < 0.00001$ } compared to predicted.

normally increase by 11 msec but the observed QTc increased by 27 msec.

Discussion

Administration of thiopentone results in a significant prolongation of the QTc above the normal limit. This is probably of no clinical consequence in healthy patients. However, during anaesthesia for patients with prolonged QTc syndrome, thiopentone may increase the risk for arrhythmia and sudden death.

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A comparative study of the onset and duration and haemodynamic effects of intubating doses of atracurium, d-tubocurarine, pancuronium and vecuronium in children

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It is reported that in addition to having a shorter duration of action than other neuromuscular blocking agents, atracurium and vecuronium may provide more haemodynamic stability. This has not been fully documented in paediatric patients.^{1,2} A comparative study in children of the four commonly used agents, atracurium, d-tubocurarine, pancuronium and vecuronium, under identical anaesthetic conditions was undertaken. The haemodynamic effects of intubating doses and subsequent onset and recovery times were measured.

Methods

With institutional approval, forty ASA physical status I children aged one to eight were studied. No premedication was given. After intravenous induction with thiopentone, $4-6 \text{ mg} \cdot \text{kg}^{-1}$ (without atropine) and an equilibration of period of spontaneous ventilation with 1.5 per cent halothane in 60 per cent nitrous oxide, one of the four muscle relaxants, randomly and blindly selected, was injected over 60 seconds. Measurements of blood pressure and heart rate were recorded each minute for five minutes after injection, using a Dinamap recorder. The end-tidal CO_2 was controlled by mask ventilation to between 35 and 45 mmHg and normothermia was maintained.

The dose of muscle relaxant given was two times the ED95: atracurium $0.4 \text{ mg} \cdot \text{kg}^{-1}$, d-tubocurarine $0.8 \text{ mg} \cdot \text{kg}^{-1}$, pancuronium $0.12 \text{ mg} \cdot \text{kg}^{-1}$ or vecuronium $0.07 \text{ mg} \cdot \text{kg}^{-1}$. The neuromuscular response was monitored with an integrated evoked electromyographic recorder (Puritan-Bennett Datex NMT 221), using train-of-four stimulation of the ulnar nerve and EMG recording of the adductor pollicis. The time to maximum twitch depression and to 25 per cent recovery of T_1/T_c were recorded.

FIGURE 1 Change in heart rate expressed as per cent change from control: atracurium Δ - Δ , d-tubocurarine $\bullet$ - $\bullet$, pancuronium $\circ$ - $\circ$, and vecuronium $\blacktriangle$ - $\blacktriangle$ (mean value $\pm$ SD).

FIGURE 2 Change in systolic blood pressure SBP expressed as per cent change from control: atracurium Δ - Δ , d-tubocurarine $\bullet$ - $\bullet$, pancuronium $\circ$ - $\circ$, and vecuronium $\blacktriangle$ - $\blacktriangle$ (mean value $\pm$ SD).

The haemodynamic data were expressed as percent-change from control. The data were analyzed using ANOVA and Scheffé's F test. P values < 0.05 were considered significant.

Results

There were 11 patients in the atracurium and pancuronium groups, ten in the vecuronium group and eight in the d-tubocurarine group. There were no significant differences in age, height, weight, initial systolic blood pressure or heart rate.

Heart rate was significantly elevated by pancuronium (+32

to 41 per cent) and d-tubocurarine (+18 to +45 per cent). Slight but insignificant slowing of heart rate was noted with vecuronium (-2 to -4 per cent) and the least change occurred with atracurium (-0.9 to +1.6 per cent) (Figure 1).

Elevation of blood pressure was greatest with pancuronium (+11 to +15 per cent) and blood pressure least changed by atracurium (± 3 per cent). Systolic blood pressure was more variable with vecuronium than atracurium but mean change was less than five per cent and not statistically significant. The BP changes in the d-tubocurarine group were most varied with mean values demonstrating an initial fall in systolic blood pressure (-12 per cent) and then a return to baseline by the third minute post-injection (Figure 2).

Mean time to maximum twitch depression was not different between groups. They ranged from 2.2 ± 1.5 minutes for d-tubocurarine to 2.6 ± 1.0 minutes for atracurium. Recovery time to T_1/T_c 25 per cent following vecuronium (27.5 ± 6.3 minutes) was significantly shorter than after atracurium (37.8 ± 7.7 minutes), and was greater than 60 minutes in both the pancuronium and d-tubocurarine groups.

Discussion

Rational choice of neuromuscular blocking agents in paediatrics should be made by consideration of their haemodynamic effects and other pharmacodynamic properties. Children given atracurium or vecuronium are haemodynamically very stable. Pancuronium causes significant elevation of systolic blood pressure. The variable effects of d-tubocurarine with initial hypotension and then recovery to baseline appear to depend on a compensatory tachycardia. Vecuronium has the shortest duration of action.

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Scopolamine butylbromide as a substitute for atropine in edrophonium reversal of d-tubocurarine in infants and children

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Atropine has been used to block the muscarinic effects of edrophonium when it is used for reversal of non-depolarizing agents. However, decrease in heart rate has been reported after administration of an edrophonium-atropine mixture in infants and children.¹ Fry² advocated scopolamine butylbromide as an IV parasympatholytic agent, because of its rapid onset and strong vagolytic action. We used an edrophonium-scopolamine butylbromide mixture for reversal of d-tubocurarine in infants and children, and evaluated its effect on heart rate.

Methods

Twenty-four ASA physical status I and II infants and children who underwent elective inguinal hernia repair were the subjects of the study. At the end of surgery under N_2O-O_2 -pentazocine-d-tubocurarine anaesthesia, edrophonium $1 \text{ mg} \cdot \text{kg}^{-1}$ -atropine $0.01 \text{ mg} \cdot \text{kg}^{-1}$, or edrophonium $1 \text{ mg} \cdot \text{kg}^{-1}$ -scopolamine butylbromide $0.4 \text{ mg} \cdot \text{kg}^{-1}$ mixture were given IV over 30 sec. E-A and E-S groups: 12 patients each, age 5.3 ± 5.3 , 5.1 ± 5.6 months, weight 6.8 ± 2.0 , $6.3 \pm 2.4 \text{ kg}$ (mean $\pm$ SD), respectively. Heart rates were recorded up to five minutes after injection. Student's *t* test was utilized for statistical analysis, and $p < 0.05$ was considered significant.

Results

TABLE I Heart rate, beats $\cdot \text{min}^{-1}$, mean $\pm$ SD

Group	During injection			
	0 s	10 s	20 s	30 s
E-A	169 ± 17	168 ± 15	142* ± 27	147* ± 18
E-S	166 ± 16	165 ± 16	168 ± 14	175* ± 13

Group	After injection						
	20 s	40 s	60 s	2 m	3 m	4 m	5 m
E-A	162 ± 19	172 ± 21	174 ± 17	175 ± 18	172 ± 19	169 ± 17	167 ± 23
E-S	182* ± 13	184* ± 13	185* ± 14	185* ± 16	183* ± 18	180* ± 18	176 ± 19

* $p < 0.05$ vs 0 s.

TABLE II Heart rate changes (mean $\pm$ SD)
(fastest HR — slowest HR, beats $\cdot \text{min}^{-1}$)

E-A group*	53 $\pm$ 26
E-S group†	28 $\pm$ 14

*In E-A group; initial decrease in HR and marked HR changes were observed.

†In E-S group; no decrease in HR and lesser HR changes were observed.

$p < 0.01$

Discussion

Scopolamine butylbromide is a quaternary derivative of scopolamine which has been widely used for its spasmolytic effect on the GI tract. When administered IV, its onset of action is rapid, and the duration of action is short.³

HR changes can be minimized by use of an E-S mixture reversal, instead of an E-A mixture, or by giving atropine 30 sec

prior to edrophonium.¹ It may be a good alternative to mix a rapid onset, short-acting parasympatholytic agent like scopolamine butylbromide with a rapid-onset short-acting edrophonium.

In conclusion, scopolamine butylbromide can be used as a substitute for atropine in edrophonium reversal of non-depolarizing agents in infants and children.

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The dose-response of atracurium in morbidly obese patients

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Anaesthesia for morbidly obese patients may be complicated by postoperative respiratory complications. To minimize this occurrence it is essential that muscle relaxants are administered judiciously intraoperatively. Due to its intermediate duration of action, atracurium is particularly suited for use during anaesthesia for morbidly obese patients. However, the dose-response of atracurium in obese patients is not known. The purpose of this clinical study is to establish the ED₅₀ and ED₉₅ of atracurium in morbidly obese patients.

Methods

The study was approved by the institutional Human Ethics Committee. Twenty-eight patients, aged 20–50, and free of neuromuscular disease, were studied during gastroplasty for morbid obesity (defined as 45 kg above ideal weight). Anaesthesia was standardized using thiopentone $4\text{--}5 \text{ mg} \cdot \text{kg}^{-1}$ and succinylcholine $1 \text{ mg} \cdot \text{kg}^{-1}$ for induction with the rapid-sequence technique. The measurement of dose-response was carried out during stable anaesthesia maintained with intermittent fentanyl, nitrous oxide, oxygen, and isoflurane (0.5 per cent inspired corresponding to 0.3 per cent end-tidal). The response to atracurium was quantified by monitoring the integrated evoked electromyogram (Detex NMT) recorded with surface electrodes over the hypothenar aspects of the hand in response to a supra-maximal stimulus applied to the ulnar nerve at 2 Hz every 20 seconds. In all patients the electromyogram was allowed to return to baseline control and at least 30 minutes had elapsed since succinylcholine administration before atracurium was given. Two studies were carried out. In the first study, 21 patients were divided into three groups of seven, with the groups receiving 0.05, 0.10, and $0.15 \text{ mg} \cdot \text{kg}^{-1}$ of atracurium respectively. The dose response was then constructed using a linear

FIGURE Dose response for atracurium.

regression analysis based on the probit-log dose scattergram. In the second study seven patients were studied and each patient received 0.05, 0.10, and 0.15 mg·kg⁻¹ of atracurium in a cumulative fashion successively. The maximum blockade was noted prior to the administration of the next dose. The dose response curve was then again constructed as described above. The ED₉₅ and ED₅₀ were then calculated according to the regression equations derived.

Results

The two regression lines constructed from the dose response are shown in the Figure. There was no apparent difference between the two lines. Based on the group study (first study), the ED₉₅ is 0.14 mg·kg⁻¹ and the ED₅₀ is 0.06 mg·kg⁻¹. In the cumulative study (second study), the respective ED₉₅ and ED₅₀ are 0.13 and 0.06 mg·kg⁻¹.

Discussion

The previously reported ED₉₅ for atracurium in non-obese patients is 0.2 mg·kg⁻¹.¹ Our results indicated that the dose requirement on a weight basis is reduced by approximately 30 per cent in morbidly obese patients. Although, in our study, due to ethical reasons, intubation was facilitated with succinylcholine and anaesthesia was supplemented with low dose isoflurane (0.3 per cent end-tidal), and these factors may potentiate the action of atracurium, it is unlikely that they could account for the large difference observed. We conclude that the dose requirement of atracurium in morbidly obese patients is reduced compared to non-obese patients, probably on the basis of reduced muscle mass/weight ratio and that the ED₉₅ is 0.13 mg·kg⁻¹ under the clinical setting studied.

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³¹P NMR measured exercise-induced skeletal muscle acidosis in MHS individuals

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A profound acidosis is known to develop during a malignant hyperthermic crisis. Malignant hyperthermia sensitive (MHS) individuals' complaints of exercise-induced myalgias, muscle cramping or febrile reactions may indicate exercise-induced abnormalities of skeletal muscle metabolism. MHS individuals have been shown to have a slower than normal return to resting values of venous lactate following exercise.

³¹P NMR allows us to measure the pH of skeletal muscle noninvasively and accurately *in vivo*. This study was undertaken to determine whether MHS individuals exhibit abnormalities in skeletal muscle pH during a standardized exercise-recovery protocol.

Methods

Thirteen biopsy-positive MHS and 17 patients free of neuromuscular disease and without a family history of MH were studied. MHS individuals were divided into two groups on the basis of muscle biopsy results - MH-CK (positive response to both caffeine stimulation and combined caffeine-halothane stimulation, n = 4), and MH-K (positive response to combined caffeine-halothane stimulation only, n = 9).

The subject's forearms were inserted into the bore of the NMR magnet. The radiofrequency coil was placed over the forearm flexors. The exercise protocol involved squeezing a rubber bulb connected to an anaeroid manometer every two seconds to a level of 100 mmHg for five minutes, and then to a level of 300 mmHg for 2.5 minutes. Spectra were obtained (1) at rest, (2) every 72 seconds during exercise level one, (3) every 72 seconds during exercise level two and (4) every 36 seconds during recovery. The pH was calculated from the chemical shift of inorganic phosphate (P_i). The lowest pH measurement obtained during each of the exercise levels was used for analysis. Data were compared using a two-way analysis of variance.

Results

TABLE Calculated pH values

Time	MH-CK	MH-K	Normal controls
Rest	7.038 ± 0.036	7.034 ± 0.037	7.055 ± 0.033
Exercise 1	6.846 ± 0.328	6.927 ± 0.185	6.981 ± 0.109
Exercise 2	6.768 ± 0.242	6.725 ± 0.236	6.813 ± 0.153
Recovery	6.560 ± 0.296	6.401 ± 0.339*	6.641 ± 0.237

*p < 0.05 compared to normal controls.

All groups showed a progressive decline in skeletal muscle pH levels with exercise, and reached their lowest levels in the

early recovery phase. The pH of the MH-K patients decreased the most to 6.401 ± 0.339 vs 6.641 ± 0.237 in the controls ($p < 0.05$). While the pH in MH-CK also decreased to a lower value than seen in controls (6.560 ± 0.296 vs 6.641 ± 0.237), this difference was not statistically significant.

Discussion

Our results indicate that patients with MH-K develop a more profound acidosis in skeletal muscle during exercise than do controls. Although MH-CK patient's muscles also became more acidotic than did controls, this difference did not reach statistical significance. The degree of fatigue experienced by subjects varied tremendously. More profound differences in pH might be seen if our protocol were to include exercise to fatigue. Conditioning may also be a factor in the less profound pH drop seen in the MH-CK (vs MH-K) group since all in this group were physically active men.

These findings suggest that skeletal muscle in MH-K individuals has a metabolic abnormality which is exhibited during exercise.

Determination of equipotent doses of edrophonium and neostigmine as antagonists of atracurium and pancuronium blockade

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Atracurium is a non-depolarizing relaxant which is eliminated relatively rapidly. Therefore, the doses of edrophonium and neostigmine required to reverse atracurium blockade might be smaller than for longer acting neuromuscular relaxants. The purpose of this study was to establish dose-response curves 5 and 10 min after the administration of edrophonium and neostigmine, after either atracurium or pancuronium neuromuscular blockade.

Methods

The protocol was approved by the Hospital Ethics Committee. In 80 ASA physical status I or II patients, anaesthesia was induced with thiopentone, 3–5 mg·kg⁻¹, and maintained with nitrous oxide 70 per cent and enflurane 0.5–1 per cent inspired, in oxygen. The patients received either atracurium, 0.4 mg·kg⁻¹, or pancuronium, 0.06 mg·kg⁻¹. Train-of-four stimulation was applied to the ulnar nerve every 12 sec, and the force of contraction of the adductor pollicis muscle was recorded. When first twitch height recovered to ten per cent of its control value, the patients were assigned randomly to receive either neostigmine (0.005, 0.01, 0.02 or 0.05 mg·kg⁻¹), or edrophonium (0.1, 0.2, 0.4 or 1 mg·kg⁻¹). Neuromuscular monitoring was continued for at least 10 min, after which more anticholinesterases were given if needed. Dose response curves were constructed by linear regression of the logit transformation of first twitch height and train-of-four ratio 5 and 10 min after administration of the reversal agent, on the logarithm of the dose.¹ The effective doses for 50 and 80 per cent response (ED₅₀ and ED₈₀) were evaluated, with the standard error of estimate for the mean as an index of dispersion.

TABLE Doses of edrophonium and neostigmine (mean $\pm$ SEM) required to produce 80% twitch height recovery (ED₈₀) 5 and 10 min after administration of reversal agent

Drugs	ED ₈₀ at 5 min (mg·kg ⁻¹)	ED ₈₀ at 10 min (mg·kg ⁻¹)
Atracurium-edrophonium	1.12 ± 0.32	$0.23 \pm 0.056^*$
Pancuronium-edrophonium	0.79 ± 0.19	0.49 ± 0.077
Atracurium-neostigmine	0.17 ± 0.025	$0.014 \pm 0.0018^*$
Pancuronium-neostigmine	0.15 ± 0.022	0.040 ± 0.006

*Atracurium significantly different ($p < 0.05$) from pancuronium.

Results

Five minutes after the injection of the reversal agent, the recovery obtained after atracurium was not significantly different from that after pancuronium (Table). However, the potency of neostigmine and edrophonium 10 min after their administration was markedly higher if the relaxant used was atracurium (Table). The doses of edrophonium required to produce 50 per cent recovery of train-of-four ratio in 10 min were 0.25 ± 0.04 mg·kg⁻¹ with atracurium and 0.77 ± 0.11 mg·kg⁻¹ with pancuronium ($p < 0.05$). Corresponding values for neostigmine were 0.020 ± 0.003 mg·kg⁻¹ and 0.031 ± 0.004 mg·kg⁻¹ respectively ($p < 0.05$).

Discussion

During the first 5 min after administration of either edrophonium or neostigmine, there was no detectable difference in the degree of recovery if atracurium had been used as the relaxant instead of pancuronium. However, there was a large difference after 10 min. Thus, these results are consistent with the hypothesis that recovery consists of two parts: spontaneous recovery due to elimination of the relaxant, plus the action of the reversal agent. Shortly after administration of the reversal agent (<5 min), the greater spontaneous recovery of atracurium is not yet apparent, whereas it is quite noticeable after 10 min. Clinically, small doses of neostigmine (0.02 mg·kg⁻¹) or edrophonium (0.3–0.5 mg·kg⁻¹) may be effective to reverse atracurium blockade, but only after at least 10 min.

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Does administration of pancuronium or vecuronium contribute to myocardial ischaemia during induction of anaesthesia for coronary artery bypass surgery?

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Recent work suggests the muscle relaxant pancuronium may contribute to the development of abnormal haemodynamics and myocardial ischaemia during induction of anaesthesia for coro-

nary artery bypass graft (CABG) surgery.^{1,2} Vecuronium has been shown to have less cardiovascular effect than pancuronium in patients having cardiac surgery.³ This study examines the incidence of ischaemia in the prebypass period in patients receiving either pancuronium or vecuronium.

Methods

Fifty patients for elective CABG surgery with LVEF >0.4 were studied. Cardiac medications were continued up to the time of surgery and premedication was with diazepam, morphine and scopolamine. ECG leads V₅ and V₉ were applied on arrival in the preoperative waiting area and a continuous Holter recording was obtained from this time until initiation of cardiopulmonary bypass. After insertion of monitoring lines under local anaesthesia, anaesthesia was induced with fentanyl 40 µg·kg⁻¹ given over three minutes. The relaxants were prepared by the pharmacist in identical syringes and were administered in a randomized double-blind fashion. The total dose (t_d) of muscle relaxant was 0.15 mg·kg⁻¹; the patients received 0.2 × t_d 60 seconds prior to the fentanyl and at loss of response to command were given the remainder of t_d over ten seconds. Ventilation was assisted with oxygen and the end-tidal CO₂ levels (infra-red or mass spectrometry) were kept in the normal range. Intubation was performed three minutes after the fentanyl infusion had been completed. Haemodynamic measurements were made before induction, one and ten minutes post-intubation, at sternotomy and at aortic dissection by a non-participating observer. Systolic blood pressure increases or decreases of greater than 20 per cent from ward values were treated with enflurane or phenylephrine respectively. Heart rates of greater than 90 beats per minute were treated with propranolol. Analysis of the Holter recordings was with cardiologist supervision, ischaemia being defined as 1 mm ST segment depression from baseline. Statistical analysis was by ANOVA with Student's *t* test with Bonferroni correction for significant differences. Chi-square analysis with Yates correction was used for proportions. A *p* value < 0.05 was considered significant.

Results

Twenty-two patients received pancuronium and 28 patients received vecuronium. There was no difference in age or incidence of preoperative beta blockade between the two groups. There was a significant increase in heart rate from baseline at intubation in the pancuronium group only and the heart rates were higher at all times after induction in the pancuronium group (Table). The baseline systolic BP was higher in the vecuronium group with a significant decrease from baseline at intubation. Cardiac outputs were greater in the pancuronium group at all measurements post-induction. There was no difference in intraoperative use of beta blockers between groups. Four patients developed ischaemia (eight per cent). One patient had ischaemia for five minutes during monitoring line insertion and no further ischaemia. Two patients (9.1 per cent) developed ischaemia in the pancuronium group vs one patient (3.6 per cent) in the vecuronium group (NS). Ischaemic changes occurred at induction (1), sternotomy (2) and at aortic dissection (1). There were five postoperative MI's by ECG criteria (ten per cent), one in the patient who had preoperative ischaemia. None of the

TABLE Haemodynamic data (mean ± SEM)

		BASE	IND	INT ₁	INT ₂
HR (bpm)	V	61 ± 2	56 ± 2	60 ± 2	51 ± 2
	P	60 ± 3	66 ± 3*	75 ± 3†	66 ± 2*
SBP (mmHg)	V	159 ± 3	136 ± 5	143 ± 5	129 ± 4†
	P	138 ± 5	126 ± 6	134 ± 5	125 ± 3
C.O. (L·min ⁻¹)	V	5.0 ± .2	4.5 ± .2	4.5 ± .2	4.0 ± .2
	P	5.1 ± .3	5.6 ± .14*	5.7 ± .3*	5.3 ± .2*

V = vecuronium, P = pancuronium; BASE = baseline; IND = 1 min post-induction; INT₁ = 1 min post-intubation; INT₂ = 10 min post-intubation.

* = significant difference between groups. } *p* ≤ 0.05.
† = significant change from baseline.

other patients developing MI had prebypass ischaemia. One patient with a perioperative MI died (two per cent).

Discussion

The overall incidence of prebypass ischaemia in this study was eight per cent, with no difference between groups. Myocardial ischaemia did not always occur on induction or intubation but occurred at sternotomy and aortic dissection, i.e., periods associated with "stress" and remote from relaxant administration. The haemodynamic differences between groups were an increased heart rate in the pancuronium group with an associated increase in cardiac output. These differences, however, did not result in increased ischaemia. In conclusion, the choice of muscle relaxant had no effect on the incidence of prebypass myocardial ischaemia in this group of patients.

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Potency of edrophonium and neostigmine as antagonists of atracurium and vecuronium

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Dose-response relationships for relaxant antagonists may be altered by several factors including the degree of spontaneous recovery and type of relaxant employed. This study was designed to establish dose-response curves and potency ratios for edrophonium and neostigmine as antagonists of atracurium or vecuronium at ten per cent spontaneous recovery.

TABLE I Dose ($\text{mg} \cdot \text{kg}^{-1}$) required for 80 per cent recovery of T_1 5, 7 and 10 minutes after edrophonium or neostigmine (mean $\pm$ SEM)

	Atracurium	Vecuronium	p
5 min			
- Edrophonium	1.80 ± 0.83	0.90 ± 0.34	NS
- Neostigmine	0.148 ± 0.020	0.073 ± 0.007	<0.001
7 min			
- Edrophonium	0.90 ± 0.39	0.67 ± 0.24	NS
- Neostigmine	0.061 ± 0.006	0.045 ± 0.004	<0.005
10 min			
- Edrophonium	0.44 ± 0.11	0.46 ± 0.13	NS
- Neostigmine	0.022 ± 0.002	0.024 ± 0.002	NS

TABLE II Dose ($\text{mg} \cdot \text{kg}^{-1}$) required for 50 per cent recovery of T_4/T_1 5, 7, and 10 minutes after edrophonium or neostigmine (mean $\pm$ SEM)

	Atracurium	Vecuronium	p
5 min			
- Edrophonium	0.79 ± 0.14	0.85 ± 0.31	NS
- Neostigmine	0.071 ± 0.007	0.042 ± 0.005	<0.001
7 min			
- Edrophonium	0.65 ± 0.11	0.71 ± 0.37	NS
- Neostigmine	0.043 ± 0.003	0.030 ± 0.003	<0.001
10 min			
- Edrophonium	0.46 ± 0.11	0.65 ± 0.45	NS
- Neostigmine	0.031 ± 0.003	0.023 ± 0.003	NS

Methods

Studies were performed after institutional approval in 80 adult patients undergoing elective procedures. Anaesthesia was induced with thiopentone, 3–5 $\text{mg} \cdot \text{kg}^{-1}$ and maintained with nitrous oxide 70 per cent and enflurane 0.5–1.5 per cent end-tidal. Evoked force of contraction of the adductor pollicis was measured using train-of-four stimulation applied every 12 seconds. After stabilization of twitch recording, patients received either atracurium 0.4 $\text{mg} \cdot \text{kg}^{-1}$ ($n = 40$) or vecuronium 0.08 $\text{mg} \cdot \text{kg}^{-1}$ ($n = 40$). When first twitch height (T_1) recovered to ten per cent of control, patients received either edrophonium (0.1, 0.2, 0.4 or 1.0 $\text{mg} \cdot \text{kg}^{-1}$) or neostigmine (0.005, 0.01, 0.02 or 0.05 $\text{mg} \cdot \text{kg}^{-1}$) in a random fashion. Linear regressions were obtained between the logit transformation of T_1 and train-of-four (T_4/T_1) recovery and log dose five, seven and ten minutes following administration of the antagonist. Calculated doses expected to produce 80 per cent recovery (ED_{80}) of T_1 and 50 per cent recovery (ED_{50}) of T_4/T_1 were compared.

Results

At five and seven minutes, significantly more neostigmine but not edrophonium was required for recovery from similar levels of atracurium compared with vecuronium neuromuscular blockade (Tables I and II). There were no differences at ten minutes. Potency ratios ($\text{ED edrophonium}/\text{ED neostigmine}$) at ten min-

utes for 80 per cent T_1 recovery were comparable for atracurium (20.0 ± 2.4) and vecuronium (19.2 ± 2.6) but were significantly different for T_4/T_1 recovery for these relaxants (15.0 ± 1.7 and 28.4 ± 2.1 respectively, $p < 0.001$).

Discussion

This study demonstrated that neostigmine-assisted recovery of T_1 and T_4/T_1 was initially more rapid with vecuronium than atracurium blockade, but no difference was apparent after ten minutes. This altered pattern may be due to differences in the mechanisms of action of relaxants used. The discrepancy between potency ratios for T_1 and T_4/T_1 indicate that antagonists may also have different mechanisms of action. If given at ten per cent spontaneous recovery, clinical doses of neostigmine, 0.04 $\text{mg} \cdot \text{kg}^{-1}$, and edrophonium 0.5 $\text{mg} \cdot \text{kg}^{-1}$ are not expected to produce adequate recovery until seven to ten minutes after their administration.

The potency of pancuronium at the diaphragm and adductor pollicis muscle in children

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In adults the diaphragm is relatively resistant to the action of pancuronium¹ when compared with peripheral muscle. This study investigated the potency of pancuronium at the diaphragm and the adductor pollicis in children.

Methods

Following institutional approval and informed parental consent 12 patients were studied. They were divided into two groups of six aged 1–3 yr, and 3–10 yr. After induction of anaesthesia, intubation was accomplished without the use of muscle relaxants and anaesthesia maintained with nitrous oxide, oxygen and halothane. Train-of-four stimulation was applied to the ulnar nerve at the elbow and the right phrenic nerve in the neck. Twitch tension at the adductor pollicis was measured, and the diaphragmatic EMG was recorded through three surface electrodes in the eighth intercostal space. Cumulative dose response curves were obtained for pancuronium 0.02 $\text{mg} \cdot \text{kg}^{-1}$ followed by 0.01 $\text{mg} \cdot \text{kg}^{-1}$ increments.

Results

The mean (SEM) ED_{50} and ED_{90} doses ($\mu\text{g} \cdot \text{kg}^{-1}$) at the adductor pollicis (AP) and diaphragm (D), and the D/AP ratio in the two groups are shown in the Table.

Discussion

There is a significant reduction in the dose of pancuronium required to produce a given degree of neuromuscular blockade at the thumb or diaphragm in the 1–3-yr-old group compared with the 3–10-yr-old group. However, the ratio of the sensitivity of the diaphragm to thumb remains the same in these two age

TABLE ED₅₀ and ED₉₅ ($\mu\text{g}\cdot\text{kg}^{-1}$) (mean $\pm$ SEM)

		ED ₅₀	ED ₉₅
1-3 yr	AP	34 $\pm$ 3.2	47 $\pm$ 4.2
	D	54 $\pm$ 3.0	81 $\pm$ 5.1
	Ratio	1.64 $\pm$ 0.13	1.75 $\pm$ 0.14
3-10 yr	AP	41 $\pm$ 3.0	62 $\pm$ 4.1
	D	65 $\pm$ 4.0	101 $\pm$ 4.4
	Ratio	1.62 $\pm$ 0.15	1.64 $\pm$ 0.09

groups. Compared with the adductor pollicis, the diaphragm displays a similar resistance to the action of pancuronium as seen in adults. Therefore, in children over 1 yr old, although the dose requirements for pancuronium may change with age, the relative degree of blockade produced at these two sites does not.

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Comparison of the somatosensory evoked potential changes in focal cerebral ischaemia during nitroprusside and isoflurane-induced hypotension

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Both isoflurane and nitroprusside (SNP) are used to induce hypotension during neurovascular surgery. Somatosensory evoked potentials (SSEP) are frequently used as a monitor for cerebral ischaemia. We have therefore compared the SSEP changes seen with focal ischaemia during hypotension induced with these agents.

Methods

Fourteen healthy female macaque monkeys were studied. The anaesthesia sequence was ketamine IM ($10\text{ mg}\cdot\text{kg}^{-1}$), intubation, paralysis (gallamine) and ventilation (O_2/air , FiO_2 0.6) to PaCO_2 35 mmHg. The animals were then divided into two groups. Seven animals received halothane and seven isoflurane anaesthesia. During surgical preparation the halothane or isoflurane were titrated to keep BP in the normal range. Monitoring included intra-arterial pressure, arterial blood gases, SSEP, and temperature.

After transorbital exposure of the middle cerebral artery (MCA), in the halothane group, the inspired halothane concentration was reduced to 0.75 per cent and the mean BP reduced to 45 mmHg by the infusion of SNP. In the isoflurane group, the isoflurane was titrated to reduce mean BP to 45 mmHg.

Stable hypotension was maintained for 22.5 minutes and then the MCA occluded for 45 minutes. After deocclusion, hypotension was maintained for a further 22.5 minutes, i.e., 90 minutes hypotension in total. When normotension was re-established, the wounds were closed and the animals allowed to awaken. On the third postoperative day, they were re-anaesthetized and underwent NMR imaging and SSEP recording. SSEPs were recorded from silver/silver chloride electrodes placed 1 cm lateral to the midline on the coronal suture in response to square wave stimuli delivered to the median nerves using needle electrodes. Band pass filter was set between 5 to 3000 Hz and 256 sweeps of 50 msec were averaged. The SSEP was evaluated according to the peak to trough amplitude of the primary cortical peak.

Results

There were no differences between the groups in BP, PCO_2 , temperature, and duration of hypotension and occlusion. In all animals the SSEP was completely abolished by MCA occlusion. There was no difference in the time to disappear or in the time to return of the SSEP but the rate of disappearance was slower in the isoflurane group ($p < 0.002$).

The NMR lesion sizes were similar in the two groups. The final intraoperative SSEP did not predict the extent of the NMR lesion but, on day three, if the SSEP was more than 50 per cent of the preop baseline then the NMR lesion was less than 20 per cent of the hemisphere ($p < 0.002$).

Conclusion

We conclude: (1) during stable anaesthesia and hypotension there is no major difference in the SSEP changes of ischaemia during SNP or isoflurane induced hypotension; (2) the abolition of SSEP during temporary focal ischaemia does not predict a poor outcome if the SSEP returns after clip removal; (3) preservation of SSEP greater than 50 per cent of baseline does predict the magnitude of the concurrent NMR lesion (<20 per cent).

Role of the α_2 adrenoceptor in spinal anaesthesia

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Epinephrine and phenylephrine are adjuncts used clinically to prolong and intensify tetracaine spinal anaesthesia. Alteration of vascular tone and direct antinociceptive activity are cited as possible mechanisms of action. These mechanisms are believed to be adrenoceptor mediated; however, the site of action has not been demonstrated. The present study was designed to determine the importance of the adrenoceptor and classify the subtype responsible for the prolongation of canine tetracaine spinal anaesthesia with phenylephrine and epinephrine.

Methods

Six mongrel dogs weighing 17-20 kg were studied using a randomized cross-over design. Under thiopentone - $\text{N}_2\text{O}-\text{O}_2$ -

TABLE Results (mean $\pm$ SEM)

Group	Duration of blockade (minutes)	
	Sensory	Motor
Tetracaine	116 $\pm$ 13*	183 $\pm$ 29*
Tetracaine/epinephrine	210 $\pm$ 13	403 $\pm$ 29
Tetracaine/phenylephrine (n = 5)	180 $\pm$ 15	318 $\pm$ 32
Tetracaine/phentolamine	115 $\pm$ 13*	175 $\pm$ 29*
Tetracaine/yohimbine	135 $\pm$ 13*	135 $\pm$ 29*
Tetracaine/epinephrine/phentolamine	102 $\pm$ 13*	123 $\pm$ 29*
Tetracaine/epinephrine/yohimbine	145 $\pm$ 13*	133 $\pm$ 29*
Tetracaine/phenylephrine/yohimbine (n = 5)	133 $\pm$ 15*	129 $\pm$ 32*

n = 6 in each group unless otherwise indicated.

*p < 0.0001 compared to tetracaine with epinephrine or phenylephrine.

isoflurane anaesthesia lumbar punctures were performed (four to five day intervals) at the L₅-L₆ or L₆-L₇ interspace with a #22-gauge spinal needle. In randomized order the dogs received subarachnoid injections (1 ml) of: 0.9 per cent saline solution, phentolamine 2.5 mg in 0.9 per cent saline, or yohimbine 0.8 mg in 0.9 per cent saline. Ten minutes following the initial injection a second injection of tetracaine 4 mg with and without epinephrine 200 μ g or phenylephrine 5 mg was administered. Sensory and motor responses were evaluated at 20-minute intervals for one hour and every 15 minutes thereafter. Duration of motor block was defined as time from intrathecal injection to time of standing unsupported. Sensory block was evaluated using a 25 cm rubber-shod haemostat applied to the proximal third of the tail for one minute or until a reproducible avoidance response was elicited. The data were analyzed using ANOVA for repeated measures, followed by Tukey's test for individual treatment differences.

Results

Summarized in Table. Epinephrine and phenylephrine produced a similar significant prolongation of motor and sensory blockade (p < 0.0001) when added to tetracaine spinal anaesthesia. Pretreatment with yohimbine (α_2 adrenergic antagonist) or phentolamine (α_1 and α_2 adrenergic antagonist) did not affect the duration of motor or sensory blockade observed with tetracaine alone. Pretreatment with phentolamine in dogs receiving intrathecal tetracaine with epinephrine abolished the prolongation of motor and sensory blockade. Similarly, pretreatment with yohimbine abolished the prolongation of motor and sensory blockade observed when epinephrine or phenylephrine were added to tetracaine spinal anaesthesia.

Discussion

The results indicate that epinephrine and phenylephrine when used as adjuncts in canine tetracaine spinal anaesthesia produce prolongation of sensory and motor blockade via stimulation of α_2 adrenoceptors. Although direct extrapolation to the clinical situation may not be entirely valid, specific α_2 adrenergic agonists merit a trial as adjuncts in prolonging clinical tetracaine spinal anaesthesia. Of particular clinical interest is clon-

idine (an α_2 adrenergic agonist) which has been shown to safely prolong the duration of canine tetracaine spinal anaesthesia¹ and provide prolonged pain relief in humans (up to 18 hours after a single intrathecal administration).²

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Perioperative critical incidents detected by pulse oximetry

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The Pulse Oximeter (POX) is a convenient, non-invasive, and accurate¹ clinical monitor of oxygen delivery. However, it is expensive. We used the Critical Incident Technique^{2,3} to study the value of a pulse oximeter in monitoring all patients receiving anaesthetics.

Methods

All members of the Anaesthesia Department were informed at a training session of a tick-off questionnaire stamped on every billing card. Three questions were posed: (1) Was the POX applied? (2) Was it the first warning of an unexpected problem? (3) Did false alarms occur? When items 2 and 3 were answered "yes," the chart was examined and the anaesthetist interviewed within a short time. A Critical Incident (CI) was recorded if an unexpected physiologic change occurred which was signalled first by the pulse oximeter and which might indicate danger to the patient. An unexpected false alarm was recorded as a False CI. A stamped billing card was provided for every anaesthetic given. Confidentiality was assured for both patients and anaesthetists.

Results

The Critical Incident Technique counts CI's (Table I), and

TABLE I Critical incidents detected first by Pulse Oximeter (POX)

	Inpatient	Outpatient	Obstetric	Total
Total cases	1126	476	54	1656
Cards marked	701	355	37	1093
Response rate	0.62	0.74	0.68	0.66
Pox applied	686	341	36	1063
Application rate	0.99	0.96	0.97	0.97
CI's	62	18	5	85
CI rate	0.09	0.05	0.13	0.07
False CI rate	0.04	0	0.05	0.03
"At least" CI rate	0.05	0.04	0.09	0.05

TABLE II Problem CI signalled

Desaturation	75
Hypoventilation	16
Bradycardia	13
Tachycardia	3
Temp decrease	3
BP increase	2
BP decrease	2
Apnoea	1

TABLE III Severity of desaturation

Problem	Saturation %		
	85-94	75-84	<75
Airway	8	4	
Narcosis	7	6	1
Lung disease	6	2	6
Obesity	6	3	2
Disconnect	1		
Ventilator off		1	
Other	3		

classifies them by type (Table II) and severity (Table III). The interview and chart were used to assign a cause.

CI's occurred in all groups. The length of case was not related to CI occurrence. More CI's happened during the maintenance phase of anaesthesia than during induction or emergence. We did not study how often other monitors warned before the POX, but this appeared to happen rarely. The "at least" CI rate is CI/total cases, and assumes no CI's in the presence of unmarked cards. We recommend that a POX be applied to every patient undergoing anaesthesia despite the cost.

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Accuracy of gastric volume measurement by blind gastric tube aspiration in obese patients during general anaesthesia
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Gastric volume has been recognized as an important determinant of risk for regurgitation and pulmonary aspiration in patients undergoing general anaesthesia.¹ Trials have utilized H₂ receptor blockers, anticholinergics and gastric emptying agents in order to reduce gastric volume and/or increase pH.^{2,3} Authors

FIGURE Blind aspiration (BASP) vs true total gastric volume (TTGV) $n = 10$.

classify patients "at risk" if the gastric pH is <2.5 and volume >25 ml. The most commonly used method of measuring gastric volumes in these studies has been blind gastric tube aspiration of stomach contents. Unfortunately the accuracy of this method is questionable and may underestimate true gastric volume.^{4,5} We thus evaluated the accuracy of this method using direct visualization of gastric contents with a gastroscope.

Methods

Ten obese patients, a group at high risk for aspiration, were studied. Informed consent was obtained. All patients underwent abdominal or gynaecological surgery using general anaesthesia. Immediately after a standard induction and tracheal intubation a multi-orificed 16 Fr Salem sump tube was passed orally into the stomach. Gastric volume was then aspirated using wall suction at 25-40 mmHg and an in-line collection container. The gastric tube was rotated in several planes and withdrawn slowly to maximize aspirate volume (Blind ASP). Once no further volume could be withdrawn the gastric tube was removed and a gastroscope was passed into the stomach by an experienced endoscopist who then aspirated any residual volume under direct visual guidance (Residual Vol). The blind aspirate and residual volumes were then measured and added to obtain true total gastric volume (TTGV). pH of the aspirate was also measured. Statistical analysis was done to evaluate the difference between blind aspirate and true total gastric volumes. Linear regression was used to quantify the relationship between these two volumes.

Results

See Table and Figure. There was a statistically significant difference between Blind ASP and TTGV ($p < 0.05$). Blind

TABLE Results (mean $\pm$ SD)

Blind ASP (ml)	24.7 $\pm$ 24.6
TTGV (ml)	39.4 $\pm$ 27.2
Residual (ml)	14.7 $\pm$ 5.8
(Residual Vol not = 0; $p < 0.05$)	
pH	2.1 $\pm$ 33;
(n = 7, 3 samples contaminated)	
Blind ASP/TTGV (%)	53.3 $\pm$ 21.2
Blind ASP not = TTGV; $p < 0.05$	

ASP underestimated TTGV by an average of 14.7 ± 5.8 ml. Blind ASP detected only 53.3 $\pm$ 21.2 per cent of TTGV. The sensitivity of Blind ASP in detecting patients with TTGV greater than 25 ml was only 3/7 (43 per cent). Residual Vol was at least 10 ml in nine of ten patients. Linear regression showed a high correlation between Blind ASP and TTGV over a wide range of gastric aspirate volumes.

Discussion

Blind gastric tube aspiration of stomach contents consistently underestimated true gastric volume in this group of patients. It had a poor sensitivity in the detection of obese patients at high risk for aspiration. Thus its use in clinical research should be reconsidered. If gastric volume is to be estimated a formula such as the one we derived would seem to be a more accurate method of estimating true gastric volume than blind aspirate volume alone.

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Effect of fentanyl on the coronary circulation in an isolated heart

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Fentanyl is the anaesthetic most often used for the anaesthesia of patients with coronary artery disease. Some of these patients anaesthetized with a large dose of fentanyl still have myocardial ischaemia during surgical stimulation.¹ These ischaemic epi-

LANGENDORFF ■ = 37°C WATER JACKET

FIGURE 1 Langendorff preparation. The heart is perfused through a canula fixed in the aorta above the coronary arteries. The perfusion pressure is constant (85 cm H₂O). The heart is paced at 200/min. There is no preload (no filling of left atrium) and no afterload (the heart does not produce an output). Oxygen consumption by the myocardium is constant. Agents are added directly to the perfusing solution by an automatic syringe. Coronary flow is determined by measuring the amount of solution flowing from the preparation.

sodes can certainly be explained by an increase of myocardial oxygen consumption due to a high level of catecholamine. However, fentanyl could interfere with myocardial oxygen supply and induce myocardial ischaemia. It was previously shown that fentanyl has a minimal effect on contractile response of isolated canine coronary artery rings stimulated by mediators of coronary spasm.² It was concluded that fentanyl does not interfere with coronary artery vasomotion. Fentanyl's effect on coronary arterioles is not known. Coronary arteriolar dilators can redistribute flow away from ischaemic myocardium and induce a "steal"; coronary arteriolar constrictors can reduce coronary reserve. Both groups of agents can certainly interfere with oxygen supply of an ischaemic myocardium. We therefore studied the effects of fentanyl on coronary arterioles (resistance vessels). For this purpose we measured the action of fentanyl on the coronary flow of an isolated heart as described first by Langendorff.³

Methods

Normal hearts from rats were isolated and the ascending aorta was cannulated. The other major vessels (vena cava, pulmonary

FIGURE 2 Effects of fentanyl and vasodilators on coronary flow. Baseline coronary flows were measured; then every 2 min for 10 min, the flow was measured after the addition of fentanyl (5 measurements); every 2 min for 10 min after fentanyl had been stopped. The effects of vasodilators (papaverine or adenosine) on coronary flow were measured every 2 min for 10 min. The five coronary flow measurements for each heart were averaged at each step. The mean and standard deviation ($n = 4$) for each step were computed. * $p < 0.05$ (paired t -test).

arteries and veins) were cut close to the heart. The isolated hearts were suspended to the Langendorff apparatus (Figure 1) and perfused with an oxygenated Krebs-Ringer bicarbonate solution at 37°C.

After stabilization of coronary flow, fentanyl was added to the perfusing solution (final concentration 100 ng ml⁻¹) and coronary flow was measured for ten minutes. Fentanyl was then discontinued and coronary flow was measured again. At the end of the experiment the effects of coronary vasodilators (adenosine or papaverine) were determined, to demonstrate that the coronary bed was still well reactive.

Results

Fentanyl had no effect on coronary flow (Figure 2). Adding or removing fentanyl from the perfusing solution did not change the flow. On the other hand, the vasodilators consistently increased coronary flow.

Discussion

It has been shown that fentanyl has no effect on coronary arterial vasomotion.² We have now shown that fentanyl has no effect on global coronary flow, suggesting that it has then no vasomotive effect on coronary arterioles (resistance vessels). These *in vitro* animal studies indicate that fentanyl has no effect on the coronary circulation and is a neutral drug if we consider its effects on regulation of coronary flow.

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Brain carbon dioxide response during isoflurane-induced hypotension

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Little information is available on how deep isoflurane anaesthesia for controlled hypotension affects both basal cerebral blood flow (CBF) and the cerebral vascular response to carbon dioxide (CO₂). In this study we investigated how regional CBF (rCBF) is affected during isoflurane-induced hypotension in the rat when the arterial CO₂ tension (PaCO₂) is either low (LC), normal (NC), or high (HC).

Methods

Male hooded rats were induced with ether, intubated and ventilated with 100 per cent O₂/isoflurane. Catheters were inserted into the tail and femoral arteries (FA) for continuous measurement of blood pressure (BP) and arterial blood gas sampling and via the right common carotid into the left ventricle (LV) for injection of radioactive microspheres. Four groups of six animals were studied, with 3 CBF determinations in each animal. For each group, the initial CBF was determined during normotension (mean BP 75-95 mmHg). For CBF 2 and 3, hypotension (mean BP 45-50 mmHg) was induced with isoflurane. To assess the CBF response to CO₂ for each group, the PaCO₂ was changed by altering the dead space to produce LC, NC or HC in the following manner: Group I (NC NC LC), Group II (LC LC NC), Group III (NC NC HC) and Group IV (HC HC NC). At least 20 minutes elapsed at each PaCO₂ before CBF measurement. rCBF was determined by LV injection of 500,000 microspheres of 15 μ m diameter of either ⁵¹Cr, ⁸⁵Sr or ¹⁴¹Ce. A reference sample of blood was withdrawn from the FA. Blood reference and brain samples from left frontal, parietal and occipital cortex were counted by gamma counter. Counts were converted to rCBF by computer program. Only left hemispheric flows were examined because of altered CO₂ response in the right hemisphere secondary to right carotid occlusion.¹ Within-group comparisons were by ANOVA for repeated measures with Duncan's test applied post-hoc; $p < 0.05$ was considered significant.

Results

See Table. During isoflurane-induced hypotension no brain region demonstrated any significant CBF response to CO₂ over the range of CO₂ examined (CBF 2 vs 3 for each group). During controlled hypotension with deep isoflurane anaesthesia, rCBF stabilized towards flows seen during the normocarbic normotensive state.

TABLE Results (mean $\pm$ SEM) $n = 6$

	PaCO_2	Mean BP	CBF ml g ⁻¹ ·min ⁻¹		
			Frontal	Parietal	Occipital
Group I					
CBF1	41.4 ± 1.1	80.3 ± 1.4	1.35 ± 0.11	1.37 ± 0.16	1.60 ± 0.16
CBF2	40.0 ± 1.2	46.8 ± 0.7†	1.51 ± 0.16	1.78 ± 0.13	1.98 ± 0.13
CBF3	22.5 ± 1.7†	46.0 ± 0.5†	1.59 ± 0.18	1.83 ± 0.26	2.06 ± 0.32
Group II					
CBF1	18.9 ± 1.3	88.7 ± 3.8	0.64 ± 0.05	0.66 ± 0.06	0.81 ± 0.06
CBF2	17.4 ± 1.1	46.0 ± 0.9†	1.22 ± 0.11†	1.26 ± 0.09†	1.42 ± 0.11†
CBF3	42.3 ± 2.9†	45.5 ± 0.3†	1.35 ± 0.13†	1.43 ± 0.13†	1.55 ± 0.15†
Group III					
CBF1	41.3 ± 2.1	85.5 ± 2.6	1.34 ± 0.14	1.49 ± 0.13	1.61 ± 0.23
CBF2	36.7 ± 2.3	48.0 ± 0.6†	1.81 ± 0.27	1.95 ± 0.29	2.13 ± 0.29
CBF3	57.7 ± 5.5†	47.7 ± 0.7†	2.01 ± 0.24†	2.15 ± 0.25†	2.43 ± 0.27†
Group IV					
CBF1	58.5 ± 2.4	81.7 ± 3.2	2.72 ± 0.28	2.61 ± 0.26	2.80 ± 0.27
CBF2	56.4 ± 1.8	47.7 ± 0.8†	1.83 ± 0.19†	1.91 ± 0.19†	2.03 ± 0.20†
CBF3	34.2 ± 2.5†	47.7 ± 0.6†	1.86 ± 0.16†	1.88 ± 0.16†	2.19 ± 0.27†

* $p < 0.05$ } vs CBF 1.
 $\dagger p < 0.01$

Discussion

These results demonstrate that during isoflurane-induced hypotension the CBF response to alterations in PaCO_2 was lost. With deep isoflurane anaesthesia, regardless of the initial CO_2 state, rCBF approached flows seen during the normocarbic normotensive state. In addition no region displayed ischaemic flows with deep isoflurane anaesthesia.

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Comparison of Doppler ultrasound, Allen's test and a postocclusive reactive circulation hyperaemia (PORCH) test for the assessment of ulnar collateral circulation: a double-blind study

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Allen's test (AT) is often used prior to radial artery cannulation but a systematic study of its usefulness in identifying patients with abnormal ulnar collateral circulation (UCC) has not been published.

This prospective double-blind study compared results of Doppler examination of the UCC (the "Gold standard") with AT and with a previously undescribed PORCH test.

Methods

One hundred and forty-four consecutive hospitalized patients (288 hands) were studied: 60 males (mean age 43.7 yr, range

21-100 yr), 84 females (mean age 34.6 yr; range 19-74 yr). Each was initially assessed by the principal investigator with a Doppler ultrasound velocity detector (Model 804, Parks Electronics). Superficial palmar arch flow was checked by the methods of Mozersky¹ and Kamienski.² Abnormal patients had flow assessed in the interdigital artery of the first interdigital cleft (between index and middle fingers) by Little's method.³ Only patients with the above criteria were classified as having an abnormal UCC.

Two trained medical student interns then performed a modified AT followed by the PORCH test. This test sequence was always used with 5 min allowed between tests. Patients and investigators were unaware of the results of the previous tests.

AT was performed exclusively by medical student A. Test reproducibility and reliability in 30 patients (25 normal; five abnormal) yielded a kappa value of 1.0. The PORCH test was performed exclusively by medical student B. Reactive hyperaemia was stimulated by a suprasystolic BP cuff on the upper arm for 2 min. Radial and ulnar arteries were then occluded at the wrist. A 15 sec period after cuff release restored blood flow down to the wrist; then ulnar artery compression was released and revascularization time (RT) was measured. Test reproducibility and reliability in 30 patients (25 normal; five abnormal) yielded a kappa value of 1.0. RT in excess of 15 sec was considered abnormal for both tests. Results were analyzed by Fisher's exact test.

Results

Seven males had an abnormal UCC by the Doppler method and all had RT in excess of 45 sec with AT and the PORCH test. One hundred and thirty-seven patients were normal; their mean RT with AT was 7.1 sec (SD $\pm$ 5.7 sec) and with PORCH test was 5.9 sec (SD $\pm$ 2.3 sec).

Table I summarizes results of 288 AT compared to the Doppler method. A positive predictive value (PPV) of 0.42 indicates that 58 per cent of patients with an abnormal AT will have a normal UCC. AT was not significantly affected by sex or smoking ($p > 0.1$), but there was a significant difference between patients >40 yr and those <40 yr ($p = 0.0013$). The false positive rate was 0.03 <40 yr and 0.2 >40 yr.

Table II summarizes results of 288 PORCH tests compared to the Doppler method. A PPV of 0.87 indicates that only 13 per cent of patients with an abnormal PORCH test will have a normal UCC. The PORCH test was not significantly affected by age, sex or smoking ($p > 0.1$).

Table III summarizes the change in performance of each test when three different RT are used as the "cut off" between patients with a normal UCC and those with an abnormal UCC.

Discussion

The use of Doppler ultrasound as the "Gold standard" was based upon previous clinical, anatomical and arteriographic studies. An abnormal AT will falsely indicate abnormality of the UCC in about 60 per cent of cases based on our prevalence of disease. AT is affected by age and its PPV decreases when RT less than 15 sec are used. The PORCH test performed better than AT at all RT and had the advantage of not being affected

TABLE I Allen's test versus Doppler for identifying an abnormal UCC

		Doppler result		Totals
		Abnormal	Normal	
Allen's test	Abnormal	14 (a)	19 (b)	33
	Normal	0 (c)	255 (d)	255
		14	274	288

Sensitivity = $a/a + c = 1.0$; specificity = $d/b + d = 0.93$; PPV = $a/a + b = 0.42$; negative predictive value = 1.0 ; prevalence = $a + c/a + b + c + d = 0.048$.

TABLE II Porch test versus Doppler for identifying an abnormal UCC

		Doppler result		Totals
		Abnormal	Normal	
Porch test	Abnormal	14 (a)	2 (b)	16
	Normal	0 (c)	272 (d)	272
		14	274	288

Sensitivity = 1.0 ; specificity = 0.99 ; PPV = 0.87 ; negative predictive value = 1.0 ; prevalence = 0.048 .

TABLE III Effect of changing revascularization time (RT) on test performance

RT (sec)	Allen's test			Porch test		
	11	15	19	11	15	19
Sensitivity	1.0	1.0	1.0	1.0	1.0	1.0
Specificity	0.85	0.93	0.94	0.97	0.99	1.0
PPV	0.25	0.42	0.46	0.63	0.87	1.0

by age, sex or smoking. With a RT >19 sec the PORCH test is perfectly predictive of an abnormal UCC.

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Pharmacokinetics of oral dantrolene prophylaxis in malignant hyperthermia-susceptible patients

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Preoperative oral dantrolene has been used as prophylaxis for malignant hyperthermia-susceptible (MHS) patients undergoing surgery. In MHS swine, a near-maximal twitch depressant intravenous dantrolene dose was both prophylactic and therapeutic for MH.¹ In humans, blood levels of dantrolene associated with equivalent twitch depression were 2.6 to 4.2 $\mu\text{g}\cdot\text{ml}^{-1}$.² The purpose of this study was to measure blood levels of dantrolene following a standard oral regimen³ to see if protective drug levels were achieved, and for how long they were maintained postoperatively.

Methods

Eight patients with known or suspected MH, but otherwise healthy, gave informed consent to participate in this institutionally approved study. Beginning 14 to 24 hours preoperatively, oral dantrolene was given in three to four divided doses every six hours, with the last dose four hours preoperatively. The total dose given was 5 $\text{mg}\cdot\text{kg}^{-1}$. A baseline blood sample was drawn prior to the first dose of dantrolene, then blood was drawn at induction of anaesthesia and every six hours thereafter for 48 hours. The plasma was separated and frozen for analysis. Dantrolene levels were determined using a reversed-phase high-performance liquid chromatographic method.⁴

Results

Dantrolene levels at induction were found to be 5.35 ± 2.20 $\mu\text{g}\cdot\text{ml}^{-1}$ (mean $\pm$ SD), with a range of 3.30-10.20 $\mu\text{g}\cdot\text{ml}^{-1}$. All patients had plasma levels of more than 2.6 $\mu\text{g}\cdot\text{ml}^{-1}$ for at least six hours, and up to 12 hours after induction, and four patients had levels over 2.6 $\mu\text{g}\cdot\text{ml}^{-1}$ for more than 18 hours. All eight patients complained of a subjective feeling of weakness, and one patient reported slight nausea. There were no other side effects.

Conclusion

A standard oral dantrolene regimen given preoperatively has been found to achieve protective blood levels in eight MHS patients coming for surgery. The blood levels of dantrolene remained in the protective range for at least six hours, and in some patients up to 18 hours after induction.

This study was generously supported by a grant from the Malignant Hyperthermia Association of Canada.

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A new technique to determine cumulative dose-response curves of vecuronium and atracurium

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Dose-response curves obtained by the cumulative dose (CD) technique¹ require fewer patients than the single dose (SD) method. However, the CD technique is valid only if little elimination and/or redistribution occurs during administration of incremental doses. For intermediate acting muscle relaxants CD might underestimate potency,² and it may be necessary to replace eliminated or redistributed drug by the addition of an infusion. The present study was designed to compare the potencies of vecuronium and atracurium obtained by SD, CD, and CD plus infusion (CDI).

Methods

The protocol was approved by the Hospital Ethics Committee. Sixty adult patients scheduled for elective surgical procedures were studied. Anaesthesia was induced with thiopentone 3-5 mg·kg⁻¹ and maintained with nitrous oxide 66 per cent in oxygen and supplemental doses of thiopentone 0.5-1.5 mg·kg⁻¹ and fentanyl 1-2 µg·kg⁻¹ as required. Ventilation was provided with a bag and mask. No volatile agent was given. Evoked force of contraction of the adductor pollicis muscle in response to train-of-four stimulation was measured and recorded. After stabilization of muscle twitch, patients received in a random fashion either SD (n = 36), CD (n = 12), or CD of vecuronium and atracurium with an infusion (CDI) to replace eliminated or redistributed drug (n = 12). Linear regressions were obtained between the logit transformation of neuromuscular blockade at the adductor pollicis and log dose. The slope of the curves and calculated doses expected to produce 50, 90 and 95 per cent first twitch depression (ED₅₀, ED₉₀, ED₉₅) obtained by the three methods were compared using analysis of variance. A p value <0.05 was considered significant.

Results

Time to complete cumulative dose-response curves (mean ± SEM) was 11.2 ± 0.9 min for vecuronium and 10.2 ± 0.8 min for atracurium following the initial dose. Similar potencies were obtained with all three methods (Figure). For vecuronium, ED₉₀ (mean ± SEM) was 0.034 ± 0.002 (SD), 0.037 ± 0.003 (CD), and 0.036 ± 0.003 mg·kg⁻¹ (CDI). For atracurium, the ED₉₀ was 0.175 ± 0.009 (SD), 0.206 ± 0.019 (CD) and 0.179 ± 0.015 mg·kg⁻¹ (CDI). The amount given by

FIGURE Dose-response curves for vecuronium and atracurium using single dose, cumulative dose, or cumulative dose plus infusion. Error bars represent SEM.

infusion with CDI was 17 and 22 per cent of the total dose of vecuronium and atracurium respectively.

Discussion

The potencies of vecuronium and atracurium obtained by the CD method were comparable to those estimated by SD. This is probably because the drug was given over a short period of time, during which elimination and/or redistribution was negligible. The CDI technique also yielded estimates similar to SD with the advantage of not being dependent on a short administration period. Therefore CDI appears to be the method of choice for construction of vecuronium and atracurium dose-response relationships.

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Atrial activity during bypass: is continuous oxygenated blood cardioplegia superior to intermittent crystalloid?

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Intermittent crystalloid cardioplegia (ICC) during cardiopulmonary bypass (CPB) should ideally lead to atrial cooling and quiescence. However, it is thought that prompt rewarming of the atria with its attendant return of electrical and mechanical

activity can result in atrial ischaemia, thus contributing to postoperative supraventricular arrhythmias.¹ Oxygenated blood cardioplegia delivered continuously (COBC) is said to provide oxygen and better right atrial (RA) cooling and complete quiescence. This study compares the efficacy of COBC and ICC in achieving RA cooling and quiescence, and examines the incidence of postoperative supraventricular arrhythmias in 30 patients.

Methods

Thirty elective coronary artery bypass patients were studied prospectively. Ten patients were assigned to each of three surgeons: COBC₁ (n = 10), COBC₂ (n = 10) and ICC (n = 10). Prognostic factors such as age, sex, angina classification, number of vessels bypassed etc. were similar in all groups. RA electrogram (RAEG) was recorded via low resistance pacing wires. RA and left ventricular (LV) temperatures were measured directly with probes and recorded every five minutes during bypass. The patients were followed postoperatively to determine the incidence of supraventricular arrhythmias.

Results

ICC resulted in significantly lower RA temperatures compared to COBC₂ (16.7 ± 7.8 vs $23.1 \pm 4.5^\circ\text{C}$). The initial cardioplegia bolus arrested the atria in all ten ICC patients compared to atrial arrest in only 5/10 patients in the COBC₁ group ($p < 0.05$) and 9/10 patients in the COBC₂ group. The RA in all groups rewarmed rapidly towards similar systemic temperatures ($28\text{--}32^\circ\text{C}$). ICC and COBC provided equivalent LV cooling. LV temperatures in all groups were significantly lower than simultaneous RA temperatures.

Four RAEG patterns were observed: (a) Atrial spikes (s) associated with mechanical activity: COBC₁ = $56.3 \pm 66.1 \text{ s} \cdot \text{min}^{-1}$; COBC₂ = $54.8 \pm 72.2 \text{ s} \cdot \text{min}^{-1}$; and ICC = $43.5 \pm 36.4 \text{ s} \cdot \text{min}^{-1}$ (differences not significant). (b) 1–2 mV low amplitude electrical activity (LEA).² Total duration of LEA and LEA per min of cross-clamp time was similar in all groups. LEA preceded atrial arrest and spikes in most patients. (c) Atrial spikes in combination with LEA. (d) Atrial quiescence: ICC provided significantly longer atrial quiescence ($15.3 \pm 8.4 \text{ min}$) than COBC₁ ($5.7 \pm 7.1 \text{ min}$) or COBC₂ ($5.7 \pm 5.5 \text{ min}$) ($p < 0.05$).

The incidence of postoperative supraventricular arrhythmias ranged from 30–42 per cent in the three groups (no significant differences).

Discussion

Our data suggest that (i) initial temperature with ICC is at least as low as with COBC. Although COBC provides continuous ventricular cooling with oxygen delivery, neither provided consistent atrial cooling. Factors responsible for RA rewarming include (a) thin atrial wall, (b) exposure to warmer systemic blood ($28\text{--}32^\circ\text{C}$) with single right atrial cannulation technique, (c) exposure to warmer atmospheric temperature, and (d) non-coronary collateral flow. (ii) ICC and COBC provided equivalent ventricular cooling. (iii) COBC did not decrease the incidence of postoperative supraventricular arrhythmias (SVA). There was no relationship between intraoperative atrial activity

(spike and LEA) and postoperative SVA. (iv) ICC provided significantly longer RA quiescence and more initial RA arrest than did COBC. No superiority of COBC over ICC was demonstrated in our study.

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Correlation between integrated evoked EMG and respiratory function following atracurium administration

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Residual neuromuscular blockade at the end of a surgical procedure may lead to inadequate ventilation and/or upper airway obstruction and is not an infrequent complication observed in the recovery room. With the advent of the integrated evoked electromyogram (IEEMG), it is now possible to quantify the degree of neuromuscular blockade accurately. The purpose of the study was to assess the correlation between IEEMG with variables of respiratory function and peripheral motor strength in healthy volunteers following administration of subparalytic doses of atracurium.

Methods

With approval from the institutional Ethics Committee on Human Research, five healthy male volunteers, aged 30–47 were studied. Using the Datex NMT monitor, IEEMG was recorded with surface electrodes over the hypothenar muscles in response to train-of-four supramaximal stimuli delivered to the ulnar nerve via surface electrodes at a frequency of 2 Hz. Following recording of stable control EMG, and allowing the subjects to be conditioned to the nose clip and the mouthpiece, the following respiratory variables were measured using a Collins spirometer: (1) tidal volume, (2) forced vital capacity (FVC), (3) forced expired volume in 1 second (FEV₁), and (4) maximum negative inspiratory pressure (NIP) (with a pressure gauge). In addition, peripheral muscle strength was measured using a modified hand-grip dynamometer (HG). All variables were measured in duplicate. After administration of atropine 0.3–0.4 mg to reduce secretions, atracurium 0.03 mg·kg⁻¹ was given followed with a continuous infusion (0.2 mg·ml⁻¹) titrated to achieve the desired level of neuromuscular blockade. All variables were measured again at (1) T₄/T₁ of 0.6 and (2) maximum depression (Max Dep) defined as the point when the subject felt he could no longer continue. All attempts were made to ensure as near steady state conditions as possible

TABLE Results. Per cent of control. Mean $\pm$ SEM

	FVC (Litre)	FEV ₁ (Litre)	NIP (mmHg)	HG (mmHg)
T ₄ /T ₁ = 0.6 (n = 4)	91 $\pm$ 3	93 $\pm$ 4	80 $\pm$ 6*	79 $\pm$ 18
Max dep (n = 5)	75 $\pm$ 6*	77 $\pm$ 6*	56 $\pm$ 6*	35 $\pm$ 8*

* $p < 0.05$ vs control (ANOVA and Dunnett's based on $n = 4$).

during the time of measurement by careful adjustment of the infusion rate. For statistical analysis, all measurements were expressed as percentages of control and comparison with control were made using ANOVA for repeated measures and Dunnett's test.

Results

Throughout the study, there was no change in tidal volume in any subject. At the point of maximum depression, all subjects experienced difficulty with swallowing and phonation, and none were able to perform any head-lift. This occurred at a T₄/T₁ of 16 ± 4.39 (mean $\pm$ SEM). The rest of the results are summarized in the Table.

Discussion

Using mechanical twitch as a monitor of neuromuscular function, Ali *et al.*¹ previously reported no significant respiratory impairment exists when T₄/T₁ exceeds 0.7. Our current findings are consistent with these observations, demonstrating the relative resilience of the respiratory muscles at T₄/T₁ of 0.6. The maximum negative inspiratory pressure, however, was significantly depressed. At the point of maximum depression, all measured variables were significantly reduced, despite the presence of a normal tidal volume. The early and significant reduction of NIP suggests that upper airway obstruction may have been an important contributing factor to changes in other respiratory variables. This is consistent with the early onset of subjective feeling of inability to swallow. In this study we confirm that: (1) EMG T₄/T₁ > 0.6 is consistent with normal respiratory function. (2) Significant respiratory impairment can exist without reduction in tidal volume. (3) Upper airway obstruction may be an important factor in patients with residual neuromuscular blockade.

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Yohimbine-precipitated clonidine withdrawal: an experimental model for the antihypertensive drug withdrawal syndrome

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Increases in blood pressure (BP) and heart rate (HR) have been observed following antihypertensive drug withdrawal.¹ The mechanisms underlying the antihypertensive drug withdrawal syndrome (AHDWS) are not known. The objective of this study was to develop an experimental model of precipitated antihypertensive drug withdrawal in order to investigate these mechanisms. Since the antihypertensive drug clonidine (Catapres), an α_2 -receptor agonist has frequently been implicated in the AHDWS, this agent was chosen to develop the experimental model.

Methods

Male Sprague Dawley rats (280–320 g) were anaesthetized with halothane and an osmotic mini-pump filled with saline or clonidine HCL solution ($400 \mu\text{g} \cdot \text{kg}^{-1}$) was implanted subcutaneously in the neck. Measurements of BP and body weight were made in conscious animals immediately before the implant and at six days post-implant. On the seventh day the animals were anaesthetized with α -chloralose ($70 \text{ mg} \cdot \text{kg}^{-1}$), tracheotomized and artificially ventilated. The HR and BP were recorded through a carotid artery catheter using a Statham transducer. The jugular vein was catheterized for drug injections. To block the peripheral muscarinic receptors and vagal reflexes, methyl atropine ($1.0 \text{ mg} \cdot \text{kg}^{-1}$), was administered. Baseline values of HR and BP were recorded. To precipitate clonidine withdrawal, the animals were challenged with yohimbine (a specific α_2 -receptor antagonist) in doses of 0.25, 0.50 and $1.0 \text{ mg} \cdot \text{kg}^{-1}$ at 30-minute intervals. The HR and BP were recorded over this period.

Results

Clonidine-treated animals showed a significant decrease in body weight but no change in blood pressure over the six-day period (data not shown, $p < 0.02$). Yohimbine administration in the saline group did not produce a significant change in the HR or BP. In contrast, yohimbine administration in the clonidine group produced an immediate increase in the HR and BP. The changes observed were statistically significant (Table).

TABLE Results: mean $\pm$ SD ($n = 5$ or 6)

	Group	Pre-yohimbine†	Post-yohimbine†	% Change
BP (mmHg)	Saline	124 $\pm$ 9	115 $\pm$ 9	-7
	Clonidine	89 $\pm$ 19	130 $\pm$ 12*	48
HR (beats $\cdot$ min ⁻¹)	Saline	447 $\pm$ 37	471 $\pm$ 31	6
	Clonidine	370 $\pm$ 40	512 $\pm$ 22*	39

*Significantly different from pre-yohimbine value $p < 0.002$.

†Yohimbine $0.50 \text{ mg} \cdot \text{kg}^{-1}$.

Discussion

The results of this study show that yohimbine can abruptly precipitate cardiovascular signs of withdrawal when administered to animals chronically treated with clonidine. The yohimbine-precipitated changes in HR and BP resemble those that have been observed in spontaneous clonidine withdrawal.² This model of yohimbine-precipitated withdrawal can be used to explore the sites and mechanisms of the AHDWS in future studies.

(Supported by the Medical Research Council of Canada.)

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Influence of prior succinylcholine on action of atracurium - an electromyographic study

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Despite the availability of intermediate-acting non-depolarizing muscle relaxants, succinylcholine remains the relaxant of choice for intubating purposes. Stirt *et al.*¹ previously reported that the prior use of succinylcholine potentiates the action of atracurium without prolonging its action. The purpose of this study was to reassess this interaction using each subject as his own control by isolating the circulation in one arm with a tourniquet.

Methods

The study was approved by the institutional Human Ethics Committee and eleven ASA physical status I and II patients aged 27 to 73 yr (mean 48) undergoing elective orthopaedic or gynaecologic procedures were studied. In all patients, anaesthesia was induced in a standardized manner with sufentanil 1-2 µg·kg⁻¹, thiopentone 3-5 mg·kg⁻¹ and intubated without the aid of a muscle relaxant. Patients were then maintained on nitrous-oxide/oxygen anaesthesia with intravenous narcotic or barbiturate supplementation as required. Inhalational agents were not used. Integrated evoked electromyogram (EMG) was monitored bilaterally with surface electrodes placed over the hypothenar muscles in response to supramaximal stimulation of the ulnar nerve (Datex NMT 221 monitor). A tourniquet was placed on one arm and following establishment of stable control readings with both arms abducted and immobilized to minimize artifact, the tourniquet was inflated to 100 mmHg above systolic pressure, and succinylcholine 1.0 mg·kg⁻¹ was then injected intravenously. Two groups of patients were studied; in Group I (n = 6) the time interval between succinylcholine and subsequent 0.15 mg·kg⁻¹ of atracurium was 30 minutes (tourniquet on for 25 minutes and off for five minutes for recovery),

allowing for full EMG recovery prior to injection of atracurium. In Group II (n = 5), the time interval was ten minutes (tourniquet on for five minutes, and off for five minutes) to reflect more closely the clinical usage of these agents. Both single twitch suppression expressed as a percentage of control (T₁/T_C), and train-of-four ratio (T₄/T₁) were recorded during onset of neuromuscular blockade and recovery. A paired t test was used for bilateral comparison of maximum blockade, time of onset of maximum blockade, 25 to 75 per cent recovery time, and total recovery time. In addition, to compare the characteristics of the blockade, the T₄/T₁ ratio was measured at three specific points during recovery in each patient.

Results

TABLE Mean ± SEM

	Group I (30 min)		Group II (10 min)	
Maximum blockade (%)	93 ± 1	96 ± 1*	88 ± 3	91 ± 3*
Time of onset (min)	7.7 ± 0.4	5.6 ± 0.6*	7.6 ± 0.8	6.1 ± 0.9*
Rec ₂₅₋₇₅ (min)†	9.7 ± 1.7	10.7 ± 1.7	14.5 ± 1.2	16.5 ± 2.5
Tot Rec (min)†	43.5 ± 2.8	45.1 ± 4.0	46.0 ± 7.0	56.0 ± 10.0*
Pooled T ₄ /T ₁	27 ± 5	17 ± 3*	43 ± 8	29 ± 6*

*p < 0.05 between ATC (atracurium) and the corresponding S + ATC (succinylcholine + atracurium).

†n = 5 for Group I.

Discussion

Succinylcholine caused a slight potentiation and accelerated the onset of subsequent atracurium block but had no influence on the 25 to 75 per cent recovery time. The total recovery time, however, was significantly prolonged in the ten-minute group, suggesting that the administration of atracurium before recovery from succinylcholine prolongs the duration of neuromuscular blockade. Our results are qualitatively similar to previously reported observations¹ but the magnitude of potentiation is less. The consistently reduced T₄/T₁ ratios during recovery in the S + ATC groups suggest that the mechanism of potentiation is the development of phase II block with succinylcholine, even when administered at normal doses.

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Propofol versus thiopentone for induction and maintenance of general anaesthesia for brief surgical procedures

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Propofol, a new intravenous anaesthetic, was compared with thiopentone for induction and maintenance of general anaesthesia for brief surgical procedures. The randomized trial was

TABLE I Dosage requirements for induction and maintenance of anaesthesia

	Propofol		Thiopentone	
Induction				
Dose ($\text{mg} \cdot \text{kg}^{-1}$)	2.5	2.4–2.6	4.0	3.8–4.1
Total dose (mg)	198	160–250	331	220–400
Onset time (sec)	30	18–38	29	18–39
Induction and maintenance				
Rate of administration ($\text{mg} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$)	0.07	0.04–0.12	0.12	0.08–0.16
Total dose (mg)	310	170–490	494	340–700
Anaesthesia time* (min)	64	20–104	53	30–75

*Time from injection of induction dose until nitrous oxide was discontinued.

TABLE II Postoperative recovery times

Time from discontinuation of nitrous oxide to:	Propofol		Thiopentone		p value
	Mean	Range	Mean	Range	
Awakening (min)	10	0–25	18	2–31	<0.01
Response (min)	11	0–25	18	6–30	<0.01
Orientation (min)	13	0–35	23	7–40	<0.001

conducted in 30 adult patients premedicated with atropine and fentanyl. Anaesthesia was induced with propofol $2.5 \text{ mg} \cdot \text{kg}^{-1}$ IV or thiopentone $4.0 \text{ mg} \cdot \text{kg}^{-1}$ IV and maintained with repeated bolus injections of 25 per cent of the initial dose supplemented by nitrous oxide and, if necessary, enflurane. Both agents induced anaesthesia within 30 seconds (Table I). The mean duration of anaesthesia was about one hour in each group. The mean rate of administration was $0.07 \text{ mg} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ for propofol and $0.12 \text{ mg} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ for thiopentone. The two agents did not differ significantly with regard to cardiovascular and respiratory effects. However, recovery was faster after propofol than after thiopentone (Table II). Patients receiving propofol were awake, responding to verbal commands and fully oriented within 13 minutes after discontinuation of all anaesthesia, compared to 23 minutes for patients receiving thiopentone ($p < 0.001$). As shown by a double-blind postsurgery questionnaire, patients felt more energetic and correspondingly less tired and sleepy after propofol than after thiopentone. It was concluded that propofol may be especially useful for outpatient surgery.

Partition coefficients for sevoflurane in human blood, saline, and olive oil

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Sevoflurane is a rapid-acting, potent, inhaled anaesthetic¹ whose rapid uptake and elimination are due to a low blood/gas partition coefficient. Although the blood/gas partition coefficient was previously reported to be 0.60,¹ the methods by which this

value for the coefficient was determined were not described. The purpose of the present study is to verify the previous estimates of partition coefficients for sevoflurane in blood, saline, and oil. We also determined the effect of age and haemoglobin concentration on the blood/gas partition coefficient.

Methods

With approval from our Committee on Human Research and consent from each patient, we obtained 30 ml of venous blood from each of 19 ASA physical status I–III patients ranging in age from 21 to 77 yr. The method of Lerman *et al.*² was used to determine the blood/gas and saline/gas partition coefficients of sevoflurane. Fifteen ml samples of blood or 0.9 per cent saline were placed in a 30 ml syringe and were equilibrated with an equal volume of two per cent sevoflurane for two hours at 37°C . The concentration of sevoflurane in the gas phase over each sample was determined by gas chromatography. An aliquot of the equilibrated blood or saline was transferred anaerobically to a 581 ml flask which had been evacuated. Each flask was placed in a 37°C water bath for two hours. The sevoflurane concentration in the gas phase of the flask was then determined by gas chromatography. The blood/gas partition coefficient (λ) was determined using the following equation:

$$\lambda = \frac{C_s(V_f/V_g)}{C_f - C_s}$$

where C_s is the concentration of sevoflurane in the gas phase in the 30 ml syringe used for tonometry; C_f is the concentration of sevoflurane in the gas phase of the flask; V_f is the volume of the flask; and V_g is the volume of the blood or saline.

We sought dual determinations of the partition coefficient for each patient. Data for one patient were deleted because the difference between the paired observations exceeded 16 per cent of the mean value. The remaining values were averaged for each patient and this value assumed to represent the partition coefficient for that patient's blood. This produced 18 values for the partition coefficient which were regressed against patient age and haemoglobin concentration. We obtained five unpaired determinations of the saline/gas partition coefficient.

We made five unpaired determinations of the oil/gas partition coefficient for sevoflurane using the method described by Tanifuji *et al.*³ Liquid sevoflurane (0.3 ml) was added to 100 ml of olive oil and thoroughly mixed. Ten ml of this mixture was equilibrated with 20 ml of air for two hours in a 30 ml syringe placed in a 37°C waterbath. The concentration of sevoflurane in the gas phase over the olive oil was then determined by gas chromatography. An aliquot of the equilibrated mixture was placed in a 581 ml flask and the flask sealed. The flask was placed in a waterbath at 37°C . After two hours, the concentration of sevoflurane in the gas above the mixture in the flask was determined by gas chromatography. The equation used to calculate the oil/gas partition coefficient was that described earlier for blood and saline.

Results

Patients ages averaged 53.5 ± 17.9 (mean $\pm$ SD) years. Haemoglobin concentrations averaged $13.4 \pm 1.8 \text{ g} \cdot \text{dl}^{-1}$. The

blood/gas partition coefficient equalled 0.686 ± 0.047 . The saline/gas partition coefficient averaged 0.370 ± 0.016 . The oil/gas partition coefficient was 47.2 ± 2.7 . There was no significant correlation ($p > 0.05$) between patient age or haemoglobin concentration and the blood/gas partition coefficient.

Discussion

Our value of 0.686 ± 0.047 for the blood/gas partition coefficient for sevoflurane appears to be slightly higher than the value of 0.60 ± 0.07 published by Wallin.¹ However, this difference is unlikely to have clinical significance because either value for the partition coefficient is consistent with an agent which provides a rapid induction of and recovery from anaesthesia. Neither patient age nor haemoglobin concentration appeared to correlate with the blood/gas partition coefficient for sevoflurane. We speculate that our failure to find a correlation relates to the low solubility of sevoflurane in blood and the limited range of age and haemoglobin values. Our saline/gas partition coefficient of 0.370 ± 0.016 is similar to the water/gas partition coefficient of 0.36 ± 0.01 reported by Wallin.¹ However, a water/gas partition coefficient usually is only 94.4 per cent of the saline/gas partition coefficient.² Applying this correction to Wallin's data gives a saline/gas partition coefficient of 0.34 ± 0.009 . The difference between this value and our value is significant. Our oil/gas partition coefficient of 47.2 ± 2.7 is modestly lower than the value of 53.4 ± 1.2 given by Wallin.¹ Either value for the oil/gas partition coefficient suggests a MAC for sevoflurane larger than the 2.5 per cent observed for rats.

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Anaesthetic requirements (MAC) and the circulatory responses to sevoflurane in newborn swine

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Sevoflurane is a new non-inflammable halogenated ether. Its attributes include a low blood/gas solubility (0.60), a pleasant odour, and minimal cardiovascular depression in adults. The present study was undertaken to determine the anaesthetic requirements (MAC) and the circulatory responses to sevoflurane in newborn swine.

Methods

With approval from the Animal Care Committee, six fasting,

TABLE Circulatory responses (mean $\pm$ SD)

Sevoflurane	HR min ⁻¹	SBP mmHg	CI L·min ⁻¹ ·kg ⁻¹
0.5 MAC	137 $\pm$ 17	98 $\pm$ 12	0.24 $\pm$ 0.03
1.0 MAC	137 $\pm$ 19	91 $\pm$ 11	0.22 $\pm$ 0.03
1.5 MAC	136 $\pm$ 16	90 $\pm$ 12	0.20 $\pm$ 0.03

unpremedicated Yorkshire swine aged four to ten days and 1.5–3.0 kg in weight were studied. Each swine was given an inhalational induction with sevoflurane in 100 per cent oxygen, the trachea was intubated and ventilation adjusted to maintain normocapnoea using a Bain circuit and a Puritan Bennett respirator. End-tidal gas was sampled from the distal end of the endotracheal tube through a #17 angiocath catheter and analyzed in a Beckman LB2 analyzer. The electrocardiogram and rectal temperature were monitored continuously. Temperature was maintained with an overhead radiant heater. Intravenous fluids D5/0.2 per cent S were administered at a rate of 4 ml·kg⁻¹·hr⁻¹. Each animal was administered an end-tidal concentration of sevoflurane approximating MAC.¹ Following 15 minutes of equilibration, one hoof was clamped for 60 seconds and the end-tidal concentration was increased or decreased depending on the response (move or no-move respectively). This was repeated until concentrations bracketing move/no-move responses were obtained. MAC was determined as described previously.² The internal carotid artery and external jugular vein were then cannulated with 5 Fr polyethylene catheters under direct vision. Three end-tidal concentrations of sevoflurane corresponding to 0.5, 1.0, and 1.5 MAC were administered to each swine in random sequence. After 15 minutes equilibration at each MAC multiple, heart rate (HR), systolic blood pressure (SBP), and cardiac output (CO) were determined. CO was measured in duplicate using a cardiogreen dye dilution technique and a Waters densitometer, and the cardiac index (CI) (the ratio of cardiac output and weight) was estimated. Statistical significance ($p < 0.05$) was determined using ANOVA, Newman-Keuls and the t test.

Results

The mean ($\pm$ SD) age and weight of the six pigs were 5.8 ± 1.3 days and 2.06 ± 0.7 kg respectively. We found that MAC (mean $\pm$ SD) for sevoflurane was 1.97 ± 0.18 per cent. HR, SBP, and CI did not change significantly (Table).

Discussion

MAC for sevoflurane in newborn swine is comparable to that reported in other species. In the present study, sevoflurane did not depress the cardiovascular system significantly. Similar responses have been reported in human adult studies.³ Although sevoflurane appears to have many features of the ideal anaesthetic for inhalational induction in paediatrics, further studies are required to identify its role in clinical practice.

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Stability of sevoflurane in soda lime

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Physical stability of a volatile halogenated anaesthetic is an important quality because instability may result in toxic products. Sevoflurane is a new, potent inhaled anaesthetic whose low solubility and ability to produce a rapid induction of and recovery from anaesthesia recommend its application.^{1,2} Initial tests of the stability of sevoflurane in soda lime suggested that although it was less stable than currently available agents, the degree of instability was minor.¹ After seven hours of recirculation of five per cent sevoflurane in a closed system with soda lime at a maximum temperature of 50°C, the condensate of the remaining vapour contained 99.8 per cent sevoflurane and 0.18 per cent of $\text{CF}_2=\text{C}(\text{CF}_3)-\text{O}-\text{CFH}_2$. Similarly, when liquid sevoflurane was sealed in a glass vial with soda lime, and heated to 70°C for three hours, only 2.7 per cent of the remaining liquid was identified as breakdown products, sevoflurane constituting the other 97.3 per cent. Because neither of the above experiments accounted for the net loss of sevoflurane, we have reexamined this issue. Also, because sevoflurane supposedly decomposes slowly in water,¹ we studied the stability of sevoflurane in a buffered aqueous solution.

Methods

Three groups of five 581 ml flasks were filled with fresh soda lime. Ten ml of distilled water were added to each flask and the flask sealed. The flasks were evacuated and 100 ml of a mixture of 1.9 per cent sevoflurane, 1.3 per cent isoflurane, and 0.7 per cent halothane were added to each flask. At each sampling point, 10 ml of gas was taken and the concentration of each anaesthetic determined by gas chromatography. The first group of five flasks was maintained at 22°C and the gas in the flasks serially sampled at 75, 150, 250, 550, and 1440 min. The second group was maintained in a water bath at 37°C, and gas serially sampled at 75, 120, 240, 480, and 1440 min. The third group was maintained in a waterbath at 54°C, and gas serially sampled at 75, 150, 250, 550, and 1440 min. The concentrations for each anaesthetic at each temperature were plotted against time for each group of flasks. A regression analysis was performed for the data for individual anaesthetics at each tem-

TABLE Results. Anaesthetic degraded by soda lime (% per hour)

Temperature	Sevoflurane	Isoflurane	Halothane
22°C	6.46*	0.04	0.83
37°C	31.04*	0.06	0.52
54°C	57.36*	0.30	2.21*

*Statistically different from 0 with $p < 0.05$.

perature, assuming a logarithmic decay. We performed a *t* test on the deviation of the slope of each regression equation from zero. Finally, we examined the rate of degradation of sevoflurane in water at a pH of 7.0. Fifteen hundred and forty ml of distilled water were buffered to a pH of 7.0 with a 25 mM phosphate buffer and sealed in a 2,100 ml glass flask. Fifty ml of air were evacuated from the flask and 100 ml of 2.0 per cent sevoflurane added. Half a ml of nitrous oxide also was added to the flask as a marker with which to detect leakage. The flask was shaken vigorously and placed in a water bath at 37°C. An initial 20 ml sample of gas was taken after 85 minutes. Additional samples were taken after 540, 1,740, 2,640, 4,260, and 5,820 min. Each sample was taken after the flask was shaken vigorously. Samples were analyzed for sevoflurane by gas chromatography as above. The nitrous oxide also was analyzed by gas chromatography.

Results

Isoflurane did not undergo significant degradation at any temperature (Table). Similarly, halothane did not undergo significant degradation at 22°C or 37°C but did degrade slowly at 54°C. By contrast, sevoflurane underwent significant degradation at all temperatures. The rate of degradation was linearly related to the temperature, increasing by 1.6 per cent per hour per degree increase in temperature. At 54°C the rate of degradation of sevoflurane was 26 times more rapid than that of halothane. No detectable loss of sevoflurane or nitrous oxide occurred over a four-day period in the flask containing sevoflurane in a solution of buffered water.

Discussion

We found a rate of sevoflurane degradation that was higher than that obtained in previous studies.¹ We suggest that this difference arose because previous studies measured the degradation products found dissolved in the remaining sevoflurane and did not account for degradation products retained by soda lime. Our experiment took a different approach, examining the disappearance of the parent compound rather than the partial appearance of degradation products. The degradation of sevoflurane we found was substantial and raises questions relative to the potential toxicity of this compound. Wallin identified two likely breakdown products.¹ One was a condensation product and the other an olefin ($\text{CF}_2=\text{C}(\text{CF}_3)-\text{O}-\text{CFH}_2$). The double bond of the olefin makes this a potentially toxic compound. Further studies of the breakdown products are indicated to (1) characterize their structure; (2) determine whether they are able to escape from the soda lime; (3) determine their

toxicity; and (4) evaluate whether they may be produced *in vivo*.

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Anaesthetic requirements and circulatory responses in newborn swine: halothane and isoflurane

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Profound circulatory depression during general anaesthesia in the newborn may be attributed in part to an overestimation of the minimal alveolar concentration (MAC).^{1,2} In order to compare the degree of circulatory depression at equipotent concentrations, we measured both the MAC and the circulatory responses to equipotent concentrations of halothane and isoflurane in two groups of newborn swine.

Methods

With approval from the Animal Care Committee, 12 fasting, unpremedicated newborn Yorkshire swine, aged four to ten days and 1.5-3 kg in weight were studied. Each swine was randomly assigned to receive either halothane or isoflurane in 100 per cent O₂. After an inhalational induction and tracheal intubation, ventilation was adjusted to maintain normocapnia, using a Bain circuit and a Puritan-Bennett respirometer. End-tidal gas was sampled from the distal end of the endotracheal tube through a #17 angiocath catheter and analyzed in a Beckman LB2 infra-red analyzer. Each swine was administered the assigned anaesthetic agent at a concentration approximating MAC. End-tidal concentrations were corrected for water vapour pressure and barometric pressure. Intravenous fluids (D5/0.2 per cent S) were administered at a rate of 4 ml·kg⁻¹·hr⁻¹. The electrocardiogram and rectal temperature were monitored continuously. After 15 minutes of equilibration, both the tail and the coronary ligaments of the hooves were clamped for 60 seconds and MAC was determined as described previously.³ The internal carotid artery and the external jugular vein were cannulated with a #5 polyethylene umbilical line catheter under direct vision. The swine were then extubated and allowed to recover.

Forty-eight hours after recovering, each swine was carefully suspended in a stockinette sling. Awake measurements of heart rate (HR), systolic blood pressure (SBP) and cardiac output were recorded. Cardiac output was measured in duplicate using a cardiogreen dye dilution technique and a Waters densitometer and cardiac index (CI) (cardiac output/weight) was determined. Each swine was then anaesthetized with the same anaesthetic

that was used previously in 100 per cent O₂, intubated and ventilated to maintain normocapnoea. Each swine was then administered 0.5, 1.0 and 1.5 × MAC in a random sequence. After 15 minutes of equilibration at each MAC multiple, HR, SBP and CI were determined. Statistical significance ($p < 0.05$) was determined using paired and unpaired *t* tests with the Bonferroni correction.

Results

We found that the MAC ($\pm$ SD) for halothane was 0.95 ± 0.02 per cent and that for isoflurane was 1.54 ± 0.02 per cent. Heart rate, systolic blood pressure and cardiac index at 1.0 and 1.5 MAC halothane decreased significantly compared to awake values. SBP decreased at 1.0 and 1.5 MAC isoflurane and CI at 1.5 MAC isoflurane. HR was unchanged (Table).

TABLE Circulatory responses (mean $\pm$ SD)

	Halothane			Isoflurane		
	HR	SBP	CI	HR	SBP	CI
Awake	175 ± 18	101 ± 8.6	0.4 ± 0.07	172 ± 15	104 ± 8	0.44 ± 0.24
0.5 MAC	124 ± 30	82 ± 13.3	0.28 ± 0.11	155 ± 33	90 ± 11	0.34 ± 0.17
1.0 MAC	121* ± 25	60* ± 3	0.22* ± 0.06	148 ± 11	69* ± 9	0.28 ± 0.10
1.5 MAC	112* ± 23	56* ± 6.7	0.19* ± 0.04	148 ± 13	68* ± 10	0.23* ± 0.02

* $p < 0.05$ compared to awake measurements.

Discussion

MAC for halothane and isoflurane in newborn swine is consistent with previous published reports and is comparable to that in human newborns.^{2,4} Systolic blood pressure and cardiac index were significantly depressed in the newborn swine anaesthetized with both halothane and isoflurane. We conclude that at equipotent concentrations, halothane and isoflurane depress the cardiovascular system in the newborn swine to a similar extent.

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Multicentre clinical trial: sufentanil for major surgery

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With the initial release of sufentanil into clinical practice in October 1985, 141 anaesthetists across Canada were recruited into a prospective clinical trial assessing the efficacy of sufentanil in anaesthesia for major surgery. In addition to recording patient demographics, intraoperative haemodynamics and adverse reactions occurring either intraoperatively or postoperatively, an assessment of the technique was also elicited.

Methods

Patients undergoing elective major surgery, less than 70 years of age, ASA physical class I, II or III, and not experiencing any type of arrhythmia were included in the study. All concurrent medications were administered as necessary on the day of surgery. Anaesthesia premedication included diazepam 5–10 mg and droperidol 0.625–1.25 mg. Following pre-oxygenation, 0.05 mg·kg⁻¹ of d-tubocurarine, 1–3 µg·kg⁻¹ sufentanil, 0–2 mg·kg⁻¹ thiopentone and 1.5 mg·kg⁻¹ succinylcholine were administered followed by tracheal intubation. Anaesthesia was maintained with N₂O/O₂ (70:30) and pancuronium 0.07–0.1 mg·kg⁻¹, given in 2 mg increments. Additional 25 µg increments of sufentanil and supplementation with low concentrations of volatile inhalational agent were administered as necessary. Heart rate (HR) and systolic, diastolic and mean arterial pressures (SAP, DAP, MAP) were recorded on entry into the OR, and one minute following sufentanil administration, post-intubation, and post-incision, and five minutes post-incision and thereafter at ten-minute intervals until the end of the procedure. Chi-square, or analysis of variance was used for statistical comparisons. Data are reported as mean ± SEM.

Results

A total of 616 patients (mean age 46 ± 0.59 years) of whom 313 (57.6 per cent) were ASA physical status I, 196 (36.1 per cent) were ASA II, and 34 (6.3 per cent) were ASA III, were reported. Procedures were classified as gastro-intestinal in 184 (29.8 per cent), genito-urinary in 176 (28.6 per cent), general orthopaedic in 120 (19.5 per cent), orthopaedic-spinal in 43 (7.0 per cent), neurological in 34 (5.5 per cent), cosmetic in 20 (3.2 per cent) and cataract or other in 39 (6.3 per cent) patients. The mean duration of anaesthesia was 2.12 ± 0.05 hours (range 0.33 to 9.92 hours) and the mean total dose of sufentanil was 2.1 ± 0.04 µg·kg⁻¹ (range 0.43 to 8.3 µg·kg⁻¹). Two hundred and sixty-six patients (43 per cent) received an inhalational supplement. Maximal change in haemodynamics occurred 1 min post-intubation vs control with mean reductions of HR of 4.9 per cent, SAP of 24.6 per cent, DAP of 15.2 per cent and MAP of 19.2 per cent. A total of 129 disturbing and possibly drug-related incidences were reported including chest wall rigidity (2.92 per cent), bradycardia (3.41 per cent), hypotension (6.01

per cent) and tachycardia (1.3 per cent). One patient had intraoperative awareness. Mean time to extubation was 0.27 ± 0.01 hours. A total of 86 (13.9 per cent) patients received naloxone postoperatively. Of these, 17 (19.7 per cent) received sufentanil 1.0 µg·kg⁻¹·hr⁻¹ or less, while 51 (59.3 per cent) had exceeded 1.25 µg·kg⁻¹·hr⁻¹. The induction was rated as good or satisfactory in 573 (94 per cent), maintenance in 561 (92.1 per cent) and recovery in 556 (92.8 per cent) of cases.

Conclusion

This large, multicentre clinical trial, by virtue of its size and design, is representative of clinical utilization of sufentanil for major surgery. The relatively high incidence of respiratory depression was in most cases attributable to a relative dosage excess and highlights the need for vigilance during the recovery period.

Dezocine – anaesthetic efficacy and myocardial depression in the dog

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Narcotic agonist-antagonist analgesics associated with stable haemodynamics after IV injection may be useful in the production of general anaesthesia. Dezocine (Dez) is an agonist-antagonist analgesic currently undergoing clinical evaluation. A measure of anaesthetic efficacy in animals is the degree to which the agent in question can reduce enflurane MAC (EMAC).¹ The ability of Dez to reduce EMAC and the haemodynamic changes produced by intravenous bolus doses of Dez were studied in dogs.

Methods

Mongrel dogs (n = 20) weighing 17 ± 1 kg (mean ± SEM) were each given succinylcholine 0.1 mg·kg⁻¹ and atropine 0.1 mg·kg⁻¹. Anaesthesia was immediately induced with enflurane five per cent. Following insertion of an endotracheal tube, controlled ventilation maintained arterial blood gases in the normal range. Monitoring included an ECG, urinary output by a catheter, temperature probe with temperature maintained by a warming blanket, and blood gases and pressures via a femoral arterial catheter. End-tidal enflurane was measured with a Beckman LB-2 infrared analyser utilizing a calibrated enflurane vapourizer. Two separate studies were performed.

Study 1 – EMAC reduction

Eight dogs received no further muscular relaxant and EMAC was measured as previously described utilizing the tail-clamp method.¹ Following determination of each animal's control EMAC, Dez was administered in incremental IV doses. Six animals received Dez 0.2, 0.5, 1.5, 5, and 20 mg·kg⁻¹ while two animals received Dez 5, 20, and 80 mg·kg⁻¹. EMAC was determined five and 60 min after each dose. The EMAC produced by the first dose of Dez was compared to control EMAC

*Complete list of participants to be published elsewhere.

using Student's *t* test. Further changes in EMAC produced by subsequent doses were analysed by a one-way analysis of variance.

Study 2 - Haemodynamics

Anaesthesia was maintained with enflurane (one per cent in end-tidal gas) and vecuronium $0.1 \text{ mg} \cdot \text{kg}^{-1}$. A pulmonary artery catheter with the proximal port at 15 cm was inserted via the right external jugular vein. Haemodynamic variables measured prior to injection of Dez or placebo and again at 0, 30, 60, 90 and 120 seconds after each injection were: mean pressures including aortic (MAP), pulmonary artery (PAP), pulmonary capillary wedge (PCWP), and central venous (CVP); heart rate (HR), cardiac output (CO), stroke volume (SV), systemic vascular (SVR) and pulmonary vascular resistance (PVR). Two groups of animals were studied. Group I - Dezocine ($n = 7$) received Dez in incremental doses of 0.2, 1.5, 5.0, and $20 \text{ mg} \cdot \text{kg}^{-1}$. A one-hour period elapsed between each injection. Group 2 - Placebo ($n = 5$) were studied in exactly the same fashion except that instead of Dez each animal received an equivalent volume of the drug carrier solution containing propylene glycol $0.2 \text{ ml} \cdot \text{ml}^{-1}$. Statistical comparisons between drug and placebo groups at any dose level were made using a *t* test (analysis of variance and co-variance program - BMPD).

Results

Study 1

Dez produced a dose-dependent reduction of EMAC (Table). Maximum EMAC reduction (58 ± 3 per cent) occurred following the $20 \text{ mg} \cdot \text{kg}^{-1}$ dose. Three animals receiving $20 \text{ mg} \cdot \text{kg}^{-1}$ required bolus doses of intravenous phenylephrine to support MAP. Death due to cardiac depression followed the $80 \text{ mg} \cdot \text{kg}^{-1}$ dose.

Study 2

Haemodynamic variables differed statistically only for Dez $20 \text{ mg} \cdot \text{kg}^{-1}$ vs placebo. This dose level of Dez reduced MAP to 39 ± 5 per cent of control ($p = 0.0002$), CO to 60 ± 9 per cent of control ($p = 0.004$), and SV to 69 ± 9 per cent of control ($p = 0.002$). There was a concomitant fall in HR and elevations of PCWP and CVP.

TABLE Reduction of enflurane MAC by dezocine (mean $\pm$ SEM)

Dez ($\text{mg} \cdot \text{kg}^{-1}$)	n	EMAC	% Reduction
Control	8	2.17 ± 0.07	—
0.2	6	1.84 ± 0.09	$13 \pm 3^*$
0.5	6	1.72 ± 0.08	$18 \pm 4^*$
1.5	6	1.65 ± 0.11	$21 \pm 5^*$
5.0	8	1.46 ± 0.08	$33 \pm 4^*, \dagger$
20.0	8	0.89 ± 0.08	$58 \pm 38\dagger$

n = Number of dogs studied.

* $p < 0.05$ vs control.

† $p = 0.02$ vs $0.2 \text{ mg} \cdot \text{kg}^{-1}$.

‡ $p = 0.0004$ vs $5.0 \text{ mg} \cdot \text{kg}^{-1}$.

Discussion

The maximum EMAC reduction by Dez approached that produced by narcotic agonists.¹ Greater reductions or the demonstration of a ceiling effect were precluded by the cardiovascular toxicity of doses above $20 \text{ mg} \cdot \text{kg}^{-1}$ in the presence of enflurane. The haemodynamic data are indicative of direct myocardial depression by Dez at very high doses.

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Effects of self-retaining surgical retractors on oxygenation in obese patients

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Obese patients are at risk for hypoxaemia during the perioperative period. Previous studies have demonstrated hypoxaemia in patients due to the presence of intraabdominal packing used to facilitate surgical exposure.¹ It was our clinical impression that the self-retaining retractor, utilized in gallbladder surgery, may lead to significant hypoxaemia, particularly in obese patients. This study evaluated the effects on oxygenation during elective cholecystectomy of normal, overweight and obese patients in whom the self-retaining retractor was used.

Methods

Twenty-one patients were divided into three groups using body mass index. BMI = weight (kg)/height (m^2). Group I (non-obese $n = 8$) were patients with BMI 26 or less. Group II (overweight $n = 4$) had a BMI 27-29 and in Group III (obese $n = 9$) BMI was greater than 30. All patients were anaesthetized with isoflurane, succinylcholine for intubation, pancuronium, and 50 per cent N_2O . The FiO_2 was maintained at 0.5. Mechanical ventilation was instituted with a tidal volume of $10 \text{ ml} \cdot \text{kg}^{-1}$ and rate of 8/min. Oxygenation was evaluated via an indwelling arterial cannula. Control (C) arterial blood gases were obtained after the patient was stable on the ventilator for 15 minutes. Subsequent measurements were made 5 (R5) and 10 (R10) minutes after the retractor was inserted and 5 (P5) and 15 (P15) minutes after removal of the retractor. Results were analyzed using analysis of variance and Tukey's HSD test for pair-wise comparison of the means.

Results

The results are summarized in the Figure. The mean values for PaO_2 for Group III were significantly different from Group I for control ($p < 0.01$), R5 ($p < 0.05$), R10 ($p < 0.01$), and P5 ($p < 0.05$). Within the obese group P15 was significantly different from R5 ($p < 0.05$) and from R10 ($p < 0.01$). Although the mean PaO_2 of the obese group was $> 130 \text{ mmHg}$, three of these subjects had PaO_2 values of 80-90 mmHg through-

FIGURE Effects of self-retaining retractors on oxygenation.

out the study period. There were no significant differences within Group II. In Group I, the mean for C was significantly different from R10 ($p < 0.05$).

Discussion

Previous studies have demonstrated an inability to maintain adequate oxygenation in otherwise healthy obese patients in whom an FiO_2 of 0.4 was used.¹ Our obese patients exhibited significantly lower mean PaO_2 values than non-obese at all points measured except for P15. None of the obese subjects were noted to be hypoxaemic with an FiO_2 of 0.5; however, three obese patients demonstrated consistent PaO_2 values in the 80–90 mmHg range. While non-obese patients exhibited a statistically significant fall in PaO_2 values from C to R10; this was not clinically significant. This study indicates that the self-retaining retractor, unlike subdiaphragmatic packing, did not acutely impair oxygenation in these obese patients, and surprisingly, a significant increase mean PaO_2 was found following removal of the retractor in the obese group. Because of the large variations in PaO_2 among the obese group, we feel that close monitoring of arterial oxygenation is warranted.

Reference

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Arterial oxygen saturation in adults during transport from the Operating Room to the Recovery Room

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The pulse oximeter, a non-invasive portable monitor, has facilitated the investigation of arterial oxygen saturation in the postoperative period. Hypoxaemia during transport has been

just recently reported with obesity.¹ However, the effects of age and the duration of transport on the incidence of hypoxaemia remain less clear. Therefore, we determined the extent of arterial oxygen desaturation in adult patients breathing room air during transport between the Operating Room and the Recovery Room.

Methods

After approval from the Human Research Review Committee, 104 ASA physical status I or II adult patients, aged 15–95 years, scheduled for surgery requiring tracheal intubation were studied. The patients were all fasting and premedicated. Patients were excluded if oral, thoracic, neurosurgical or upper abdominal surgery was involved. Patients were arbitrarily divided into two groups by the attending anaesthetist: those receiving oxygen and those not receiving oxygen during transfer to the Recovery Room. Distances between four Operating Rooms (pre-selected) and the Recovery Room were determined. Each patient was anaesthetized with the same balanced anaesthetic technique. At the end of anaesthesia, each patient was ventilated with 100 per cent oxygen and extubated when considered appropriate by the attending anaesthetist.

Arterial oxygen saturation was determined using a rapid-response, battery powered pulse oximeter (Nellcor Pulse Oximeter Model N-100, Hayward, CA). Oxygen saturations were recorded during the preoperative visit as control, prior to anaesthesia and at the completion of the surgery when the patient was receiving 100 per cent oxygen. Thereafter, arterial oxygen saturation was continuously recorded from the first air breath in the Operating Room until arrival in the Recovery Room. The duration of the transportation was recorded using a Seiko chronometer. After arrival in the Recovery Room each patient was given oxygen by mask. The oxygen saturation was then determined for five minutes. An oxygen saturation < 90 per cent was considered hypoxaemia and < 85 per cent was considered severe hypoxaemia.

Student's t test was used to analyse continuous variables and the Chi square test with the Yates correction for continuity was used for discrete variables. P values < 0.05 were considered statistically significant.

Results

The shortest and the farthest transportation distances were 100 feet and 265 feet. The mean ($\pm$ SD) ages (yr) were 38.9 ± 17.0 and 50.25 ± 17.60 and the mean times for transport (sec) were 169.42 ± 66.88 and 218.38 ± 40.62 for the distances. Nine of the 48 patients who were transported for more than 218 seconds desaturated to < 90 per cent. Of these, three desaturated to < 85 per cent and all three required ventilatory assistance before reaching the Recovery Room. All nine patients who desaturated were > 65 years of age ($p < 0.05$). The arterial oxygen desaturation resolved immediately after the administration of oxygen in the Recovery Room.

Discussion

Postoperative hypoxaemia has been demonstrated even after minor procedures under general anaesthesia. The effect of the

duration of transportation while breathing room air is significant only for patients >65 years of age. Although transient decreases in the arterial oxygen saturation may be tolerated in young adult patients, this may not be true for patients with impaired coronary or cerebral perfusion. The authors encourage oxygen administration to patients >65 years of age during transport to the Recovery Room.

Reference

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Supplemental oxygen and maternal oxygenation during epidural anaesthesia for Caesarean section

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Supplemental oxygenation during epidural anaesthesia for Caesarean section is recommended from the beginning of the operation until delivery of the fetus in order to improve fetal oxygenation.¹ It is common practice to remove the oxygen mask from the mother as soon as the fetus is delivered. The purpose of this study was to determine the effect of discontinuation of supplemental oxygen after delivery on maternal arterial oxygen saturation (MAOS).

Methods

Twenty healthy parturients requesting epidural anaesthesia for elective Caesarean section were studied. With left uterine displacement, continuous lumbar epidural anaesthesia was induced, using two per cent carbonated lidocaine with $5 \mu\text{g} \cdot \text{ml}^{-1}$ epinephrine. Following a 3 ml test dose 5 ml increments of local anaesthetic were administered every three minutes until T_4 analgesia to pinprick was present. Supplemental oxygen at the rate of $8 \text{ L} \cdot \text{min}^{-1}$ was administered by mask from the time of the test dose until delivery. Monitors included ECG and automatic blood pressure cuff. MAOS was measured continuously with a Biox 3700 pulse oximeter using a finger probe. After delivery, discomfort was treated with small doses of fentanyl and anxiety with diazepam at the discretion of the anaesthetist. Maternal height, weight, the height of the block, fluids administered, and blood loss were recorded. The dose of fentanyl and diazepam and their time of administration were noted. The lowest preanaesthetic MAOS, measured in the left lateral position in room air, and the lowest post delivery saturation that persisted for more than 60 seconds were compared. Persistent desaturation (MAOS of 90 per cent or less for longer than one minute) was considered clinically significant hypoxaemia and was treated with supplemental oxygen. Preoperative and post-operative oxygen saturations were compared using the paired Student's *t* test. A *p* value of <0.05 was considered statistically significant.

TABLE Results - maternal oxygen saturation (mean $\pm$ SD)

		Pre-delivery O_2 saturation (%)	Post-delivery O_2 saturation (%)	<i>p</i>	O_2 saturation $\leq 90\%$
	<i>n</i>				
No sedation	9	97 ± 1.4	94 ± 0.8	<0.05	(0) 0
Fentanyl	9	98 ± 1.5	94 ± 3.5	<0.05	(2) 22%
Fentanyl and diazepam	2	97 ± 1.4	85 ± 0.7	<0.05	(2) 100%

Results

Eleven patients required sedation post-delivery and nine did not. Sedation consisted of fentanyl ($n = 9$, mean dose $98 \mu\text{g}$, range 50-200 μg) or fentanyl and diazepam ($n = 2$, dose 100 μg and 150 μg fentanyl, 3.5 and 5 mg diazepam). There was no difference between sedated and unsedated patients in height, weight, gestational age, weight gain during the pregnancy, height of the block, blood loss or fluids administered. Vital signs remained stable in all patients throughout the procedure. The lowest MAOS pre- and post-delivery are shown in the Table. Oxygen saturation normalized with supplemental oxygen in all patients.

Discussion

The pulse oximeter (Biox 3700) has been shown to accurately monitor arterial oxygen saturation.² Using the oximeter, maternal desaturation was found to occur after delivery, particularly in sedated patients. Ventilation to perfusion mismatch may be anticipated in abdominal procedures because of reduced functional residual capacity and impingement of tidal volume on closing capacity from restriction of diaphragmatic excursion by packs, and possibly because of decreased intercostal muscle strength. Pregnant patients may be at higher risk for developing hypoxaemia because of their increased oxygen consumption.³ Clinically significant desaturation, as defined by a saturation of 90 per cent or less, persisting for more than 60 seconds, occurred in four sedated patients during the surgery but did not occur in unsedated patients. Fentanyl may have caused reduced respiratory drive with hypoventilation; diazepam may have potentiated this depressant effect. In summary, parturients receiving sedation following delivery at Caesarean section under epidural anaesthesia are at increased risk of hypoxaemia. If an oximeter is not available, supplemental oxygen should be administered.

References

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Augmentation of morphine-induced respiratory depression by a subanaesthetic dose of isoflurane

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A major hazard of the immediate postanaesthetic period is hypoventilation. Of the many causative factors, persisting subanaesthetic levels of inhalational agents, narcotics or their combination may play an important role. Subanaesthetic concentrations of the inhalational agents do not affect ventilation ($\dot{V}$) or the hypercapnic ventilatory response (HCVR) but selectively reduce the isocapnic hypoxaemic ventilatory response (HVR). Narcotics lower $\dot{V}$ and reduce both HCVR and HVR. The effects of a combination of subanaesthetic doses of inhalational agent and narcotic on ventilation have not been reported. This study investigates such a combination and compares its effects with those of the individual drugs alone. We also examine the potential modifying influence of the level of consciousness.

Methods

We studied six healthy, male volunteers, aged 23–43 in four separate steady states – awake control; sedated with inhaled isoflurane (0.15 MAC); narcotized with IV morphine 0.15 mg·kg⁻¹ and finally exposed to a combination of these doses of isoflurane and morphine. In all states we measured ventilation ($\dot{V}_T$) with a pneumotachograph and RespiTrace, PaCO₂ and the HVR and HCVR by the methods of Weil and Read. We monitored oxygenation with an ear oximeter and end tidal gases with a mass spectrometer. Level of consciousness was assessed using an electroencephalogram and an electrooculogram. The results were subjected to analyses of variance and a *p* value of 0.05 was accepted as significant.

Results

Isoflurane at 0.15 MAC alone reduced only the response to hypoxaemia. Morphine significantly depressed $\dot{V}_T$, elevated the arterial PCO₂ and diminished both HVR and HCVR. The combination of drugs elevated the PaCO₂ more than morphine alone and produced a marked reduction in HVR, almost abolishing it in three volunteers. In addition, with isoflurane and morphine together, four volunteers demonstrated occasional

short episodes of sleep, during which marked hypoventilation bordering on apnoea was noted.

Discussion

We conclude that a subanaesthetic level of isoflurane potentiates the ventilatory depressant effect of morphine and that the combination predisposes to severe hypopnoea with loss of consciousness. This drug interaction may account for some cases of profound hypoventilation seen in the postoperative recovery room.

Effect of aminophylline on morphine-induced respiratory depression in the conscious rabbit

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Aminophylline may be useful in antagonizing some of the actions of opiates including respiratory depression. The objective of this study was to determine the effect of aminophylline on morphine-induced respiratory depression in the conscious rabbit.

Methods

Male, New Zealand rabbits (2.5–3.5 kg), with cannulae in an ear artery and vein were studied. To select a morphine dose for antagonism with aminophylline, the effects of 1.0 (*n* = 8), 2.5 (*n* = 6) and 4.0 (*n* = 5) mg·kg⁻¹ of morphine IV on respiratory rate (RR), arterial blood gases (ABG's), heart rate and blood pressure were determined every 5 min for 60 min. To determine the effects of aminophylline on morphine-induced respiratory depression, each of five rabbits was treated randomly with morphine (1.0 mg·kg⁻¹ IV) followed 17.5 min later by aminophylline (20 mg·kg⁻¹ IV plus infusion 2.0 mg·kg⁻¹·hr⁻¹) or morphine followed by normal saline. ABG's, RR, blood pressure and heart rate were determined every 5 min for 60 min. Naloxone (0.7 mg·kg⁻¹) was injected IV at 61 min. Comparison of morphine dose response data, and within group data in the aminophylline antagonism experiments was by one-way ANOVA, followed by Newman-Keuls test for significant *F* ratio. Comparison of saline- and aminophylline-treated groups at individual time points was conducted using a paired Student's *t* test. Significance was assessed at *p* < 0.05.

Results

All doses of morphine significantly decreased PaO₂ and RR and increased PaCO₂. Following morphine 1.0, 2.5 and 4.0 mg·kg⁻¹, maximum PaO₂ values were 78.1 ± 6.2, 65.9 ± 9.2 and 65.4 ± 6.6 per cent of control (0 min), and maximum PaCO₂ values were 114.9 ± 8.4, 122.0 ± 13.4 and 137.4 ± 14.6 per cent of control, respectively. The time courses of PaO₂ and PaCO₂ in morphine-treated rabbits followed by aminophylline or saline are shown in the Table. Morphine significantly decreased RR and PaO₂ and increased PaCO₂ at 5, 10 and 15 min in both saline and aminophylline groups. There was no significant dif-

TABLE Results. Mean ± SEM. *n* = 6

	Awake control	Isoflurane alone	Morphine alone	Isoflurane and morphine
$\dot{V}_T$ (L·min ⁻¹)	5.5 ± 0.6	5.7 ± 0.3	4.7 ± 0.2†	4.6 ± 0.4†
PaCO ₂ (mmHg)	42 ± 1	41 ± 2	45 ± 2*†	48 ± 1*†‡
HVR slope (L·min ⁻¹ ·SaO ₂ ⁻¹)	0.53 ± 0.14	0.31 ± 0.11*	0.33 ± 0.10*	0.16 ± 0.08*‡
HCVR slope (L·min ⁻¹ ·mmHg ⁻¹)	2.1 ± 0.3	2.1 ± 0.2	1.1 ± 0.2*†	1.1 ± 0.2*†

* Different from control.

† Different from isoflurane alone.

‡ Different from morphine alone.

TABLE Results

	Time (min)													
	0	5	10	15	20	25	30	35	40	45	50	55	60	65
PaO ₂ saline	82.1	65.3	65.7	66.1	69.1	70.9	70.1	71.2	71.0	71.8	73.3	73.7	68.8	89.9
±	1.0	3.3	2.3	2.3	2.7	2.3	1.8	1.6	2.5	0.5	1.5	1.6	2.4	4.1
PaO ₂ aminophylline	84.5	61.8	61.1	60.3	52.3	50.0	53.6	54.2	55.0	61.2	61.0	65.0	58.6	81.3
±	2.1	3.6	5.5	3.3	7.4	5.9*	5.4*	5.6*	5.9*	2.5*	2.6*	5.8	4.2*	1.9*
PaCO ₂ saline	34.0	36.2	39.7	42.2	40.2	40.4	40.9	40.4	39.3	39.6	40.8	39.3	40.4	33.6
±	0.9	1.3	1.0	1.2	1.3	2.0	0.9	0.7	1.6	0.8	1.0	0.9	0.7	0.7
PaCO ₂ aminophylline	34.2	38.8	41.3	39.1	44.5	46.3	44.8	46.0	45.1	46.1	45.8	42.3	45.0	35.8
±	2.7	2.7	1.6	1.6	1.7	1.8	1.2	0.6*	1.5*	1.0*	0.8*	1.2	1.6*	1.2*

*Significant difference from saline.

ferences in ABG's and RR between the two groups at 5, 10 and 15 min after morphine. IV saline did not affect the depressed RR or the status of ABG's up to 60 min. Aminophylline produced a transient increase in RR compared to saline, but there was no improvement in PaO₂ and PaCO₂. ABG's were significantly worse during aminophylline treatment as compared with saline. Naloxone reversed the respiratory depressant and sedative effects of morphine in saline and aminophylline treated rabbits. A significant decrease in blood pressure and transient cardiac arrhythmias lasting less than 5 min occurred during the initial aminophylline injection in two of five animals.

Discussion

If morphine-induced respiratory depression is mediated by release of adenosine in the brain stem, aminophylline, at sufficient concentrations should antagonize this effect. Aminophylline could act as a pharmacological antagonist to interfere with binding of adenosine to central adenosine receptors or as a physiologic antagonist to stimulate respiration. Recently, aminophylline has been used to antagonize the CNS and respiratory depressant effect of morphine, and the residual effects of fentanyl in the postoperative period.^{1,2} Aminophylline had no beneficial effect on morphine-induced respiratory depression in this model. Although aminophylline produced a transient increase in RR, ABG's were significantly worse as compared to saline. The increase in respiratory rate may have been accompanied by a decrease in depth of respiration or alternatively aminophylline may have induced changes in ventilation-perfusion by affecting hypoxic pulmonary vasoconstriction.

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Respiratory pattern components after epidural morphine in post-thoracotomy patients

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Epidural morphine producing effective pain relief after thoracotomy¹ is associated with respiratory depression as demonstrated by Respiratory Inductive Plethysmography (RIP).² This study investigated the long-term accuracy of RIP in measuring breathing pattern components after thoracotomy and the effect of epidural morphine induced pain relief on these components.

Methods

The study involved eight ASA physical status II and III patients undergoing thoracotomy. Premedication consisted of 10 mg diazepam PO. Before surgery, calibration factors were determined for the RIP² and preoperative respiratory variables recorded (Table I). A lumbar epidural catheter was then placed and tested for position with two per cent lidocaine. The patients received a non-narcotic general anaesthetic with N₂O/isoflurane or halothane and pancuronium. Epidural morphine 5-7.5 mg in 20 ml normal saline was given intraoperatively 2-3 hr prior to closure. The study began (T₀) when the patients requested analgesia in the recovery room (PAR). Repeated doses of epidural morphine (2.5-5 mg) were given on request with a minimum interval of 30 min between doses. Pain score (PS) arterial blood gases (ABG) and vital signs were measured pre-dose and 30, 60, 120 and 180 min post-dose. RIP was measured continuously upon entry into the PAR using the calibration factors determined preoperatively. Upon achieving a PS of 75+ (0 = max pain, 100 = no pain), RIP accuracy was assessed by comparing spirometric tidal volumes to RIP transducer tidal volume using the RespiTrace 300SC validation program.² Results were expressed as %error (%ERR). The validation procedure was repeated at 3 hr intervals for the following 9 hr period. Data were analysed using paired t tests comparing preoperative to postoperative data.

TABLE I Results (n = 6). Mean $\pm$ SD.

Time	%ERR	PS	RR ·min ⁻¹	V _T ml	V _{MIN} L·min ⁻¹	T _I sec	T _I /T	V _T /T _I	RC/V _T %
Preop	5	100	18	397	6.8	1.4	0.37	318	51
	± 3	± 4	± 8	± 1.8	± 0.3	± 0.03	± 0.03	± 49	± 12
T _{0.5}	—	15	20	344	6.9	1.2	0.37	334	28
	—	± 17	± 5	± 131	± 3.0	± 0.3	± 0.05	± 178	$\pm 17^*$
T ₁	5	82	21	347	7.1	1.3	0.37	324	50
	± 5	± 12	± 7	± 81	± 3.1	± 0.3	± 0.04	± 113	± 12
T ₂	5	90	17	361	5.8	1.4	0.34	290	41
	± 3	± 9	± 7	± 72	± 2.3	± 0.4	± 0.06	± 78	± 16
T ₃	9	87	18	345	6.0	1.3	0.33	302	42
	± 4	± 10	± 8	± 66	± 2.3	± 0.4	± 0.04	± 95	± 13
T ₄	7	90	17	378	6.2	1.3	0.33	311	34
	± 5	± 7	± 7	± 29	± 3.3	± 0.3	± 0.07	± 74	$\pm 18^*$

*p < 0.05 postoperative to preoperative value.

Results

All results are mean $\pm$ SD. Six of the eight patients were found to have less than ten per cent error at the validation times. Mean age, height, and weight were 57 ± 8 yr, 165 ± 11 cm, and 70 ± 12 kg. Respiratory variables measured or calculated by RIP include respiratory frequency (RR), tidal volume (V_T), minute ventilation (V_{MIN}), inspiratory time (T_I), fractional inspiratory time (T_I/T), mean inspiratory flow (V_T/T_I), and per cent rib cage contribution (RC/V_T). Mean time from T₀ to first validation (T₁) was 3 ± 0.9 hr. T₂, T₃, T₄ were 3, 6, 9 hr post T₁. T_{0.5} was 30 min post T₀ (unvalidated due to low PS). All data are shown in Table I and Table II. Cumulative morphine dose to T_{0.5} was 10 ± 0 mg and to T₁ was 15 ± 2 mg. No further dose was necessary from T₁ to T₄. There were no significant differences between the preoperative and postoperative respiratory variables at the measurement times except for RC/V_T which was decreased at T_{0.5} and T₄ (Table I). Significant CO₂ retention occurred postoperatively up to T₄ (Table II). Apnoeic episodes occurred in four patients.

Discussion

RIP monitoring was accurate to within ten per cent of spirometric values in six of eight patients for approximately 12 hr post-thoracotomy. Early reduction in RC/V_T tends to return to normal with good pain relief although there were no demonstrable changes in the other respiratory variables.

TABLE II Results (n = 6). Mean $\pm$ SD.

Time	pH	PCO ₂	HCO ₃	Cum. dose
Preop	7.41 ± 0.03	39 ± 5	26 ± 3	—
T _{0.5}	$7.34 \pm 0.03^*$	$45 \pm 5^*$	25 ± 2	10 ± 0
T ₁	$7.34 \pm 0.03^*$	$48 \pm 5^*$	26 ± 2	15 ± 2
T ₂	$7.34 \pm 0.03^*$	$49 \pm 6^*$	27 ± 3	—
T ₃	$7.36 \pm 0.05^*$	$44 \pm 6^*$	25 ± 2	—
T ₄	$7.38 \pm 0.02^*$	$44 \pm 4^*$	27 ± 2	—

*p < 0.05 postoperative to preoperative value.

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Increased resistance to breathing: a potentially lethal hazard across a coaxial circuit–connector coupling

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Both the Bain and C-PRAM circuits are commonly used coaxial circuits (Modified Mapleson-D). The only difference between the two circuits other than the length and the colour of the inner tubing is that the end of the inner tubing (fresh gas inflow) in the Bain circuit is recessed from the end of the circuit, whereas in the C-PRAM circuit it ends flush with the end of the circuit in a jet. This jet, designed to minimize deadspace, when coupled with metal connectors with solid shoulders, may create excessive airflow resistance. We have recently encountered such an anaesthetic misadventure in a dental patient managed with a 5 mm internal diameter (ID) Dupaco connector coupled to a C-PRAM circuit. There was total inability to ventilate the patient, leading to an initial erroneous diagnosis of status asthmaticus. This potentially lethal hazard prompted us to examine airflow resistance across the two types of coaxial circuits and connectors.

Methods

An experimental investigation was carried out to study four combinations of coaxials circuit-metal connector couplings: (1) C-PRAM with Dupaco connector (with shoulders), (2) Bain with Dupaco connector, (3) C-PRAM with Rusch connector (without shoulders), (4) Bain with Rusch connector. Metal connectors from 5 mm to 9 mm ID were used. For each combination, a static as well as a dynamic study was carried out. In the static study, medical air was allowed to flow through the outer lumen of the coaxial circuit at a rate of $25 \text{ L} \cdot \text{min}^{-1}$ while oxygen was allowed to flow through the inner tubing (fresh gas flow) at $7 \text{ L} \cdot \text{min}^{-1}$. A tracheal tube of the same ID as the connector was attached distally and left open to air. Pressure was measured at specifically constructed side ports, proximal and distal to the circuit–connector coupling and the difference calculated as the pressure drop. In the dynamic study a test lung was used into which a fixed tidal volume of 700 ml was delivered via the circuit–connector coupling using a volume ventilator at a rate of 12/min with an I:E ratio of 1:2. Peak pressures were measured at the same side ports. All flow rates and ventilating parameters were chosen to imitate actual clinical situations. Each measurement was made in duplicate and the results averaged.

FIGURE. Pressure drop across circuit-connector couplings.

Results and Discussion

The change in airflow resistance as reflected by pressure drop across the circuit-connector coupling with the various sizes of the connectors for all four combinations in the static study are summarized in the Figure. Results obtained in the dynamic study were similar. With each circuit-connector coupling airflow resistance rises with decreasing connector ID, but while there is little or no difference among three of the four combinations studied (Bain with either connector and C-PRAM with Rusch connector), the C-PRAM-Dupaco coupling results in a significantly greater rate of increase in resistance (log-log plot, $p < 0.05$). Moreover, the resistance is unacceptably high with connectors less than 6 mm ID. This not only creates a situation where the patient cannot be ventilated, but any delay in diagnosis will allow the continuous inflow of fresh gas with little outflow. The resultant barotrauma is potentially lethal. Based on our experimental study, we advise that Dupaco connectors or other similar metal connectors with solid shoulders not be used with the C-PRAM circuit and this information be communicated to the respective manufacturers.

Craniosynostosis: an assessment of blood loss and transfusion practices

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The assessment and accurate replacement of blood loss during primary craniosynostosis repair is difficult due to the small size of the patient and the surgical technique. Previously published estimates of blood loss vary widely depending on surgical and anaesthetic practice and few include assessment of adequacy of blood transfusion.¹⁻⁴ We reviewed charts of all patients undergoing operations for primary craniosynostosis during a 15-year-period to determine both the blood loss and the appropriateness of transfusion practices at our institution.

Methods

Charts of 73 patients undergoing 76 operations for primary craniosynostosis were reviewed. Variables examined were: patient's age and weight, associated anomalies, cranial sutures involved, duration of surgery, all haemoglobin and haematocrit (Hct) results recorded, type, quantity and timing of blood products transfused, and surgical procedure performed. Blood loss was calculated on the basis of estimated red cell mass (ERCM) with Hcts of blood products valued as follows: packed RBC 75 per cent, reconstituted RBC with plasma 40 per cent, whole blood 40 per cent. Various anaesthetic techniques were used but in no case was controlled hypotension utilized. Surgical technique did not include the use of scalp infiltration with epinephrine-containing local anaesthetic solutions. Management with respect to blood transfusion was considered appropriate if the post-transfusion ERCM was within 15 per cent of the preoperative value.

Results

The majority of procedures were performed for isolated sagittal synostosis (60 per cent) or single or both coronal suture synostosis (25 per cent). The mean weight and age of patients at operation was 6.5 kg (range 2.7-11.7 kg) and 19.2 weeks (range 2-118 weeks). Preoperative Hcts varied from 25.4-60.7 per cent. The mean blood loss for sagittal craniectomies was 24 per cent of the estimated preoperative blood value (EPBV). For metopic craniectomies, the loss was 42 per cent of EPBV, despite similar mean surgical duration (70 min vs 78 min) (Table).

TABLE Blood loss and surgical duration by type of surgery performed

Suture	# of patients	Blood loss (% of volume) mean (range)	Surgical duration (min) mean (range)
Sagittal	46	24 (3-51)	70 (30-145)
Unicoronal	13	21 (6-44)	110 (65-145)
Metopic	5	42 (28-58)	78 (55-95)
Bicoronal	7	62 (11-99)	137 (115-180)
Others	5	18 (3-34)	78 (40-105)

For coronal craniectomy blood loss was increased over that for sagittal craniectomies only if surgery on both coronal sutures was performed. Analysis of preoperative transfusion revealed that 70 per cent of patients were appropriately managed (whether transfused or not). In the postoperative period, 21 of 76 patients were transfused with no indication for transfusion in 7 patients (33 per cent); only 6 of 21 (29 per cent) were transfused appropriately.

Discussion

Blood loss during craniectomy for primary craniosynostosis in infants is significant (18–62 per cent of EPBV) and varies with the suture operated upon. Perioperative transfusion is often performed empirically or to maintain stability of vital signs intraoperatively; despite a lack of accurate blood loss measurement it is carried out reasonably appropriately. Postoperative transfusion, as judged by ERCM pre- and postoperatively, is more often performed inappropriately. We recommend that more attention be paid to the postoperative Hct as it relates to the preoperative Hct and to the child's age, preoperative physical condition, and presence of cardiorespiratory disease before postoperative transfusion is considered.

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Minimal effective concentration of bupivacaine for caudal blocks in paediatrics

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The effectiveness of caudal blocks for postoperative analgesia in children following lower abdominal surgery has been established. However, cardiovascular collapse has been described following administration of a toxic dose of local anaesthetic in the caudal space.¹ Although it has been our practice to administer less than toxic doses of bupivacaine ($<2.5 \text{ mg} \cdot \text{kg}^{-1}$) for caudal blocks, the minimal effective dose for this block has not been determined. Therefore, we undertook this study to determine the minimal effective bupivacaine concentration for caudal blocks in children.

Methods

With approval from the local Ethics Committee, a randomized double-blind study was undertaken. Written informed consent was obtained from the parents of 45 infants and children scheduled for lower abdominal surgery. All patients were six months to ten years of age, fasting, unpremedicated, and ASA physical status I or II. Surgery included hypospadias repair,

circumcision (non-plastibell type), inguinal hernia repair and orchidopexy. All children were anaesthetized with an intravenous technique and maintained with a volatile anaesthetic with or without a muscle relaxant. Narcotics were not administered to these patients at any time.

Each patient was randomly assigned to receive one of three caudal solutions containing epinephrine 1:200,000: 0.0625 per cent, 0.125 per cent, or 0.25 per cent bupivacaine. The volume of solution given to each patient was $0.75 \text{ ml} \cdot \text{kg}^{-1}$. The caudal block was administered by one of the authors, at the completion of surgery. After the block was administered, anaesthesia was discontinued and the patient was allowed to recover.

The postoperative course was recorded hourly for six hours and then again at 12 hours. Postoperative pain, motor strength and urinary retention were assessed by a blinded observer at one hour, and by blinded nurses on the ward hourly thereafter for five hours and at 12 hours. Postoperative pain was assessed after Hannallah.² The nurses were instructed to administer intramuscular codeine ($1 \text{ mg} \cdot \text{kg}^{-1}$) if the child could localize the pain or had a pain score ≥ 4 . Motor strength was assessed according to a four-point scale, ranging from paralyzed (1) to forced movement against gravity (4). A mixture of a belladonna alkaloid and an opiate was administered if bladder spasm occurred.

Statistical significance ($p < 0.05$) was determined using Chi-square analysis with the Yates correction, and the Kruskal-Wallis test for non-parametric data and one-way ANOVA with the Student-Newman-Keuls test for parametric data.

Results

Forty-five infants and children were studied: 14 received the 0.0625 per cent solution, 15 received the 0.125 per cent solution, and 16 received the 0.25 per cent solution. The mean age and weight for the three groups of patients did not differ significantly (Table). The number of hours of analgesia and the number of patients who required codeine did not differ significantly among the three groups. Motor strength during the first four hours after surgery was significantly reduced in the 0.25 per cent group compared to the 0.0625 per cent and 0.125 per cent groups. There was no significant difference in the incidence of bladder spasm among the three groups. Because of a dural puncture, one child was excluded from the study.

TABLE. Results.

	Bupivacaine concentration‡		
	0.0625%	0.125%	0.25%
Number of patients	14	15	16
Weight (kg) (mean $\pm$ SD)	18.8 $\pm$ 6.7	17.2 $\pm$ 4.6	18.7 $\pm$ 6.6
Per cent of patients given codeine†	50%	27%	19%
Median strength score†	4	4	3*

* $p < 0.05$ compared to other two groups.

†Within first four hours.

‡Containing epinephrine 1:200,000.

Discussion

The preliminary results of this study indicate that the 0.125 per cent bupivacaine solution provides adequate analgesia with minimal motor blockade for postoperative analgesia in infants and children undergoing lower abdominal surgery.

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Caudal anaesthesia for paediatric outpatient surgery – effects of volume and concentration on bupivacaine blood levels

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With increasing interest in the use of regional anaesthesia in children, the focus has recently been on pharmacokinetics. In this study, we attempted to correlate the effects of increasing dose ($\text{mg} \cdot \text{kg}^{-1}$) and increasing volume ($\text{ml} \cdot \text{kg}^{-1}$) on peak levels of bupivacaine HCl attained during caudal block for paediatric outpatient surgery.

Methods

This study was approved by the University Committee for Medical Bioethics and the hospital Research Committee. All parents gave informed consent for inclusion of their children. Forty-six patients scheduled for outpatient minor surgical procedures were studied. All caudal blocks were performed in patients induced either with thiopentone or by mask, with halothane, and maintained with an inhalation technique with $\text{N}_2\text{O}/\text{O}_2$. While being monitored with a precordial stethoscope, BP cuff, and ECG, the patients were turned on their left side and a caudal block was placed using a 23-gauge needle. Bupivacaine 0.25 to 0.5 per cent with epinephrine 1:200,000 was administered in a volume of 0.5–1.2 $\text{ml} \cdot \text{kg}^{-1}$. Blood samples were taken from a separate indwelling intravenous catheter at

FIGURE 1 Dose ($\text{mg} \cdot \text{kg}^{-1}$) effect on peak levels (variable concentrations and volumes).

control, 2, 5, 10, 15, 20, 30, 45, and 60 minutes after injection. Samples were centrifuged and stored at -20°C until assayed. Serum concentrations were measured using HPLC.¹ Peak blood levels were determined and correlated with dose in $\text{ml} \cdot \text{kg}^{-1}$ and $\text{mg} \cdot \text{kg}^{-1}$ and with concentration of drug administered. Least squares coefficients for a single variable regression were calculated for linear, exponential, logarithmic and power law functions for each variable.

Results

Prior to statistical analysis, seven patients were excluded because sampling abnormalities resulted in aberrant initial sample results. The results are shown in the Table and the accompanying Figures. Increasing dose of bupivacaine from 1.2 to 4.1 $\text{mg} \cdot \text{kg}^{-1}$ correlates in a linear fashion with increasing peak blood levels, having a Pearson product-moment correlation of 0.69. Increasing concentration results in a corresponding increase in peak blood levels, with a Ppm linear correlation of 0.41. The relationship between drug volume and peak blood levels is not linear in the range 0.5–1.5 $\text{ml} \cdot \text{kg}^{-1}$ and correlates with the function $Y = A \times X^B$ at the level 0.38.

TABLE Peak values ($\mu\text{g} \cdot \text{ml}^{-1}$), bupivacaine concentration administered, and corresponding variables for each patient

Peak	0.46	0.41	0.59	0.60	0.32	0.36	0.52	0.23	0.40	0.72	0.70	0.64	0.79	1.01	0.75	0.60	0.96	0.72
Conc.	0.17	0.18	1.19	0.19	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.30	0.31	0.72
$\text{mg} \cdot \text{kg}^{-1}$	2.50	2.50	2.50	2.50	1.25	1.26	1.28	1.28	1.32	2.50	2.50	2.50	2.50	2.50	2.55	2.29	3.71	3.73
$\text{ml} \cdot \text{kg}^{-1}$	1.50	1.40	1.33	1.29	0.50	0.50	0.51	0.51	0.53	1.00	1.00	1.00	1.00	1.00	1.02	0.75	1.21	1.21

Peak	0.21	0.40	0.63	0.71	0.06	0.54	0.31	0.42	1.25	1.46	1.53	0.80	0.54	0.69	0.82	1.07	1.08	1.32	1.30
Conc.	0.375	0.375	0.375	0.375	0.375	0.375	0.375	0.375	0.375	0.375	0.375	0.38	0.43	0.50	0.50	0.50	0.50	0.50	0.50
$\text{mg} \cdot \text{kg}^{-1}$	1.85	1.88	1.88	1.90	1.93	1.93	1.94	1.97	2.81	3.38	3.57	3.63	3.76	2.48	2.50	3.57	3.75	3.79	4.09
$\text{ml} \cdot \text{kg}^{-1}$	0.49	0.50	0.50	0.51	0.51	0.52	0.52	0.52	0.75	0.90	0.95	0.96	0.87	0.50	0.50	0.71	0.75	0.76	0.82

FIGURE 2 Dose ($\text{ml} \cdot \text{kg}^{-1}$) effect on peak levels (variable concentrations).

Conclusions

An increase in total $\text{mg} \cdot \text{kg}^{-1}$ of bupivacaine and, to a lesser extent, an increase in concentration of the drug correlates with an increase in peak blood levels of the drug following absorption from the caudal epidural space. Increasing volume of drug in the range $0.5\text{--}1.5 \text{ ml} \cdot \text{kg}^{-1}$ does not appear to increase peak blood levels in a corresponding fashion. This may have implications in determining the maximum recommended dose of drug for administration into the caudal epidural space.

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Post-strabismus vomiting in paediatric outpatients: spontaneous versus controlled ventilation

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Vomiting is a distressing and possibly hazardous symptom occurring frequently in children after strabismus surgery.¹ Droperidol has been shown to reduce postanaesthetic vomiting in these patients during controlled² but not spontaneous³ ventilation (SV). Controlled ventilation (IPPV) with relaxants decreases volatile agent requirements and may decrease the incidence of vomiting in adults.⁴ Consequently, this study was designed to compare the frequency and severity of vomiting in children receiving IPPV or SV.

Methods

Institutional approval and informed consent from the parents were obtained. One hundred and twenty-seven children (ages

TABLE Characteristics of children undergoing elective strabismus surgery (mean $\pm$ SEM)

	Spontaneous ventilation	Controlled ventilation	p value
Male/female	37/23	27/33	>0.1
Age (yr)	5.45 ± 0.36	5.73 ± 0.37	>0.5
No. muscles repaired	1.95 ± 0.09	2.20 ± 0.10	>0.08
Length of surgery (hr)	1.34 ± 0.06	1.35 ± 0.06	>0.5
Time to discharge (hr)	3.49 ± 0.17	3.19 ± 0.13	>0.25
Incidence of vomiting	50%	40%	>0.25

2–12 yr) scheduled for elective strabismus repair as outpatients were randomly assigned to receive SV ($n = 62$) or IPPV ($n = 65$). No premedication was given. Anaesthesia was induced with thiopentone, $5\text{--}7 \text{ mg} \cdot \text{kg}^{-1}$ followed by atropine $0.02 \text{ mg} \cdot \text{kg}^{-1}$. After tracheal intubation with succinylcholine $1.5 \text{ mg} \cdot \text{kg}^{-1}$, patients breathed halothane $1\text{--}1.5$ per cent and N_2O 66 per cent spontaneously (SV), or received IPPV, halothane $0.5\text{--}1$ per cent, N_2O and pancuronium $0.05 \text{ mg} \cdot \text{kg}^{-1}$, which was reversed with neostigmine $0.06 \text{ mg} \cdot \text{kg}^{-1}$ and atropine $0.02 \text{ mg} \cdot \text{kg}^{-1}$. Patients were extubated after return of pharyngeal reflexes. Frequency and severity of vomiting were evaluated by the method of Abramowitz.¹ Patients were discharged home when fully awake and able to tolerate oral fluids. Results were analyzed by Chi-square, unpaired Student's *t* test, linear regression, and Spearman rank correlation.

Results

The incidence of vomiting with SV was 50 per cent (95 per cent confidence limits: 34.5–65.5 per cent) compared with 40 per cent (24.5–55.5 per cent) with IPPV ($p > 0.25$) (Table). Patients receiving SV and experiencing emesis had longer operations than those not vomiting (1.5 ± 0.09 vs 1.19 ± 0.06 hours, $p < 0.005$). This was not the case with IPPV. There was no correlation between age, sex, duration of surgery, or number of extraocular muscles repaired, and frequency or severity of vomiting or time to discharge.

Discussion

This study could not demonstrate any significant reduction in frequency or severity of vomiting with IPPV compared with SV. However, vomiting in spontaneously breathing patients was associated with longer more complex procedures (e.g., 4 muscle repairs) which was not the case with IPPV. This may be partially explained by the following:⁴ (a) lighter levels of anaesthesia could be used during IPPV which might decrease postoperative emesis; (b) when respiration is controlled and relaxant techniques are used, duration of anaesthesia up to three hours has little effect on vomiting; and (c) reversal agents such as neostigmine/atropine may act as antiemetics. In conclusion, pretreatment with an antiemetic such as droperidol utilizing IPPV may be the preferred technique for reducing post-anaesthetic vomiting in children following strabismus repair.

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Oxygen consumption in infants in the early postoperative period: effect of analgesic therapy and subsequent activity

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There are no published studies of oxygen consumption ($\dot{V}O_2$) in infants during the early postoperative period. Such information is important to determine the optimal management of patients at a time when oxygen delivery may be compromised by pre-existing conditions (e.g., physiologic anaemia) and by postoperative cardiopulmonary dysfunction. We measured $\dot{V}O_2$ in a group of infants less than one year of age under routine postoperative conditions and related the results to the analgesic regimen used and the activity of the child.

Methods and Results

This study was approved by the Human Investigation Committee and appropriate informed consent obtained. Sixty-four ASA physical status I and II patients aged from 1-58 weeks (mean age 25 weeks) and weighing 2.38-10.7 kg were studied. Patients who had cardiovascular, thoracic, or neurosurgical procedures and those who required continued postoperative oxygen therapy were excluded. The site of surgery was head and neck 12; abdomen 12; inguinal 12; perineal 10; orthopaedic 12 and endoscopic 6. Sixty per cent were Day Care operations and only six patients were premedicated. Sixty-five per cent of patients had an IV induction with thiopentone. The remainder had inhalational induction with halothane and nitrous oxide. General anaesthesia was maintained with nitrous oxide and halothane or isoflurane. The mean duration of operation was 45 minutes (range 15-120 minutes). Postoperative analgesia by means of regional nerve block or intramuscular codeine was ordered and administered at the discretion of the anaesthetist and PAR nurses.

$\dot{V}O_2$ was measured by the open circuit flow-through method using the Waters Instruments Inc. MRM-2 device with a paediatric hood in the 20-250 ml·min⁻¹ fast response mode. This device measures $\dot{V}O_2$ using a servo-controlled variable gas flow system with a polarographic oxygen sensor. $\dot{V}O_2$ was measured at least 15 minutes after all anaesthetic agents and oxygen were discontinued. Lowest stable $\dot{V}O_2$ over a two-

FIGURE Postoperative oxygen consumption in infants.

minute test period was recorded. Simultaneously, patient activity was graded as quiet, active or crying. Age, postnatal and conceptional, weight, length, skin and core temperature and analgesic therapy were also recorded. $\dot{V}O_2$ was calculated in ml·kg⁻¹·min⁻¹ and ml·m⁻²·min⁻¹. The quiet group: (n = 35) $\dot{V}O_2 = 7.72$ ml·kg⁻¹·min⁻¹ (134 ml·m⁻²·min⁻¹) differs significantly from the active patients (n = 14) $\dot{V}O_2 = 11.4$ ml·kg⁻¹·min⁻¹ (188 ml·m⁻²·min⁻¹) and the crying group (n = 15) $\dot{V}O_2 = 13.3$ ml·kg⁻¹·min⁻¹ (225 ml·m⁻²·min⁻¹). The Figure displays $\dot{V}O_2$ stratified for activity status.

No postoperative analgesia had been given to 32 patients ($\dot{V}O_2 = 10.8 \pm 3.1$ ml·kg⁻¹·min⁻¹); IM codeine had been given to 18 ($\dot{V}O_2 = 9.1 \pm 2.6$ ml·kg⁻¹·min⁻¹); regional analgesia to 8 ($\dot{V}O_2 = 9.2 \pm 5.1$ ml·kg⁻¹·min⁻¹); and regional block and codeine IM to 6 ($\dot{V}O_2 = 7.9 \pm 1.9$ ml·kg⁻¹·min⁻¹). There was a significant difference in $\dot{V}O_2$ between those having no analgesia and those having regional analgesia plus IM codeine. There was a trend to a higher percentage of quiet infants and lower $\dot{V}O_2$ when codeine or regional analgesia techniques were used (Figure).

Discussion

The range of $\dot{V}O_2$ values for postoperative infants is consistent with the comparable age groups of sedated cardiac catheterization patients reported by Fixler.¹ The practicality of the simple flow-through technique used in this study outweighs the minor errors due to unmeasured RQ. Avoidance of immediate postoperative measurements limits the error due to residual volatile agents.²

Our findings clearly indicate that a quiet status achieved by judicious use of effective regional analgesia, codeine sedation and sympathetic PAR nursing was associated with a lower level

of oxygen consumption. Such a reduction in $\dot{V}O_2$ may have a significant therapeutic advantage in the sick neonate.

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Intraoperative subarachnoid morphine for postoperative pain control following Harrington rod instrumentation in children

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Corrective scoliosis surgery with Harrington Rod instrumentation is associated with severe postoperative pain. Pain relief has been traditionally achieved with intermittent parenteral narcotic administration.

The purpose of this study was to examine, in a prospective controlled manner, whether subarachnoid morphine can be safely used in children following Harrington Rod instrumentation to produce effective postoperative analgesia.

Methods

The study was approved by the Institutional Review Board, and informed consent was obtained in every case. Ten ASA physical status I and II paediatric patients aged 13 to 19 years, who were undergoing Harrington Rod instrumentation for scoliosis were studied. The selection of the anaesthetic agents and techniques was left to the discretion of the anaesthetist except for the avoidance of both preoperative and intraoperative narcotics. At the completion of surgery but just prior to closing the incision 0.01 mg·kg⁻¹ of preservative-free morphine was injected via a 26 gauge spinal needle into the lumbar subarachnoid space under direct vision by the surgeon. Postoperatively, patients were monitored for at least 18 hours in the intensive care unit (ICU). The intensity of pain was assessed every two hours using a 0-10 linear analogue pain scale. Pain was considered to be zero if the child was asleep, and the analgesia produced by the spinal narcotics had resolved when the pain score was greater than six points. The time of this resolution was noted and additional analgesia was provided with either intermittent parenteral narcotics or patient controlled analgesia. Possible side effects such as nausea, vomiting, pruritus and respiratory depression were monitored, and treatment, if indicated, was administered. Urinary retention was not evaluated since all patients had indwelling urinary catheters.

Results

Nine patients had profound postoperative analgesia which lasted from 11 to 25 (mean 16.3) hours (Table). One child required supplemental intravenous morphine 0.01 mg·kg⁻¹ immediately

TABLE Duration of analgesia and associated side effects following subarachnoid morphine (0.01 mg·kg⁻¹) administration

Age (years)	Level of surgery	Total dose (mg)	Duration (hr)	Side effects
13	T ₄ -L ₂	0.4	23	N/V Rx prochlorperazine
13	T ₄ -L ₂	0.5	13	none
13	T ₄ -L ₂	0.6	22	none
14	T ₄ -L ₃	0.5	21	none
14	T ₄ -L ₃	0.6	25	V × 1, no Rx
14	T ₄ -L ₂	0.4	18	V × 1, no Rx
14	T ₅ -L ₂	0.5	0*	none
15	T ₅ -L ₄	0.6	13	mild N/V Rx diphenhydramine
16	T ₅ -L ₅	0.6	17	none
16	T ₅ -L ₃	0.6	11	none

*No analgesia. Required morphine 0.01 mg·kg⁻¹ IV Q 2 H × 18 hr; then 0.1 mg Q 2 H.

N = nausea, V = vomiting.

following emergence from anaesthesia and intermittently for 18 hours thereafter. After 18 hours his narcotic requirements increased ten-fold. All patients were either extubated in the operating room or upon arrival in the ICU except for one child with spinal muscular dystrophy in whom overnight ventilatory support was planned preoperatively. No patients required ventilatory support or narcotic antagonist to reverse respiratory depression. None of the patients were troubled by pruritus. Nausea, and/or vomiting were noted in four patients (40 per cent), two of whom required treatment, one with Benadryl (diphenhydramine), the other with Compazine (prochlorperazine).

Discussion

The duration of analgesia obtained following the intrathecal administration of morphine 0.015 to 0.03 mg·kg⁻¹ in adults is frequently longer than 24 hours; however, this dose is occasionally associated with severe respiratory depression that requires either prolonged ventilation or antagonism with naloxone. In this study, a smaller dose of morphine (0.01 mg·kg⁻¹) was selected in an attempt to minimize these complications, and was found to provide safe, profound, and prolonged postoperative analgesia. Only minor adverse side effects such as nausea and vomiting were encountered, and these were easily corrected. Respiratory depression was not noted in this study; however, we continue to monitor these patients in the ICU for at least 18 hours following surgery.

Effect of subcutaneous nalbuphine on intrathecal morphine-induced analgesia in the rat

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Systemically administered nalbuphine has been shown to reverse epidural morphine-induced respiratory depression and

TABLE Drugs/doses

	IT dose (ug)	SC drug
<i>Experiment 1</i>		
Group A, n = 7	4	Nalbuphine 10 mg·kg ⁻¹
Group B, n = 7	4	Naloxone 1 mg·kg ⁻¹
Group C, n = 7	4	Saline
<i>Experiment 2</i>		
Group A, n = 7	4	Nalbuphine 0.5 mg·kg ⁻¹
Group B, n = 7	4	Saline
<i>Experiment 3</i>		
Group A, n = 9	1.5	Nalbuphine 0.5 mg·kg ⁻¹
Group B, n = 6	1.5	Saline
<i>Experiment 4</i>		
Group A, n = 7	—	Nalbuphine 10 mg·kg ⁻¹
Group B, n = 7	—	Nalbuphine 0.5 mg·kg ⁻¹
Group C, n = 7	—	Saline

pruritus while maintaining analgesia.¹ The purpose of our study was to further evaluate the effect of systemic nalbuphine upon analgesia induced by intrathecal (IT) morphine in the rat.

Methods

Male Sprague-Dawley rats, weighing 275–450 g were implanted with chronic intrathecal catheters according to the method of Yaksh and Rudy.² Four randomized, blinded experiments were performed. Rats in experiments 1, 2 and 3 received intrathecal (IT) morphine followed in 30 minutes by subcutaneous (SC) injection of nalbuphine or control. Rats in experiment 4 received only SC injections. The dosage regimens are outlined in the Table. Response latencies for both the tail-flick and paw-pressure withdrawal tests were determined before IT injection, then every 15 min for one hour, followed by every 30 min for three hours in experiment 1 and two hours in experiments 2, 3 and 4. Statistical analysis of the data was done using randomized one-way analysis of variance for experiments 1 and 4 and unpaired Student's *t* test for experiments 2 and 3 (*p* < 0.05 considered statistically significant).

Results

Figures 1 and 2 illustrate the results of experiment 1. Before SC drug administration there was no statistical difference between the three groups in either analgesia test. In the tail-flick test, after nalbuphine and naloxone administration both groups returned to baseline while the saline group remained elevated at 370 per cent above the control at *t* = 45 min (*p* < 0.001). In the paw-pressure test, only the naloxone group returned to baseline value. After *t* = 60 min the nalbuphine group maintained a higher level of analgesia than the saline group. This difference became statistically significant at *t* = 180 min and beyond (*p* < 0.01). In experiments 2 and 3 the difference between the mean response latencies of the saline and nalbuphine groups were not statistically significant at any point in either the tail-flick or

FIGURE 1 Tail-flick.

FIGURE 2 Paw-pressure.

FIGURE 3 Paw-pressure.

paw-pressure tests. In experiment 4 no groups demonstrated any analgesic activity in the tail-flick test. Figure 3 illustrates the mean paw-pressure threshold for the three groups in experiment 4. The differences between the means of the 10 mg·kg⁻¹ nalbuphine and saline groups were statistically significant from $t = 15$ min until $t = 150$ min.

Discussion

Systemic nalbuphine antagonizes the analgesic effect of IT morphine in the tail-flick test but appears to prolong analgesia in the paw-pressure test. This is explained by analgesia in the tail-flick test being primarily dependent upon morphine's activity at the mu opioid receptor, whereas in the paw-pressure test the kappa opioid receptor plays a greater role. Nalbuphine then acts as an antagonist at the mu receptor, but its agonist property at the kappa receptor results in prolongation of analgesia in the paw-pressure test. In summary, the analgesic interaction between IT morphine and systemic nalbuphine depends on the type of nociceptive stimulus and the concentration of both morphine and nalbuphine at the various opioid receptors.

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A comparison of epidural morphine 3 mg and 5 mg with and without bupivacaine for postoperative analgesia

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Hanson *et al.* reported that the addition of bupivacaine to epidural morphine enhanced its efficacy in the treatment of post-Caesarean section pain and decreased its incidence of side effects.¹ In that trial a morphine dose of 3 mg was used, lower than that commonly used in this country. A double-blind, randomized trial was undertaken to compare the efficacy and incidence of side-effects of 3 mg epidural morphine and 5 mg epidural morphine with and without 0.125 per cent bupivacaine.

Methods

Following approval from the Clinical Screening Committee for Research Involving Human Subjects of the University of British Columbia, 100 ASA physical status I and II patients for elective Caesarean section under epidural anaesthesia were enrolled. Informed consent was obtained and the patients were randomized to receive either 3 mg or 5 mg of preservative-free morphine diluted in 0.9 per cent saline or in 0.125 per cent bupivacaine (to a total volume of 10 ml) for postoperative analgesia. All patients received carbonated lidocaine with 1:400,000 epinephrine for surgical anaesthesia, in a volume sufficient to produce a block to T₄. After the birth of the baby, each patient

TABLE Results

	5 mg morphine + saline	5 mg morphine + bupiv.	3 mg morphine - saline	3 mg morphine + bupiv.
No. of patients	25	25	25	25
Duration block (hours) (mean $\pm$ SEM)	22 $\pm$ 1.7*	27.4 $\pm$ 2.0	23.3 $\pm$ 2.2	24.4 $\pm$ 2.1
Nausea alone (no. of patients)	2	5	2	2
Vomiting (no. of patients)	9	13	9	9
Itch treated	7	6	5	9

* $p < 0.05$.

received the epidural morphine solution. The patients were asked to complete a visual, linear analogue scale (0-10 cm) for pain and itching at 3, 7 and 24 hours post-epidural morphine. After 24 hours, the patient and chart were consulted to elicit the lowest respiratory rate, incidence of nausea, vomiting and urinary retention, time of first analgesic medication and for any other medications given. The data were analyzed using Student's t test, Chi square analysis and one-way analysis of variance.

Results

The time to first request for analgesia was 27.4 hours for morphine 5 mg in 0.125 per cent bupivacaine, 22 hours for 5 mg in saline, 24.4 hours for 3 mg in 0.125 per cent bupivacaine and 23.3 hours for 3 mg in saline (Table). The difference between the 5 mg doses was statistically significant ($p < 0.05$) but there was no significant difference between the 5 mg and 3 mg doses with or without bupivacaine. There were no statistically significant differences between the groups with respect to nausea, vomiting, pruritus, need for re-catheterization, additional medications or respiratory rate.

Discussion

The difference between the 5 mg doses with and without bupivacaine may simply reflect inadequate numbers as there was no significant difference between the 3 and 5 mg doses. Our study did not show a significant difference in the incidence of side effects. The interesting feature of this study is the duration of action of 3 mg of morphine (with or without bupivacaine). None of our patients required supplemental parenteral narcotics and this seems to indicate that a lower dose of epidural morphine can be used in the Caesarean section patient. Many of the earlier studies using epidural morphine involved a non-epinephrine containing local anaesthetic for anaesthesia. The duration of action demonstrated by this study may reflect the benefit derived from the addition of epinephrine to the local anaesthetic used for surgical anaesthesia. It has been shown that such addition does have an effect on the incidence and intensity of epidural morphine-induced pruritus.²

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Epidural bupivacaine at wound closure is a useful adjuvant to epidural morphine in the prevention of early post-thoracotomy pain

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Epidural morphine for post-thoracotomy pain is effective whether given by the lumbar or thoracic route.¹ Utilizing prophylactic epidural morphine $0.1 \text{ mg} \cdot \text{kg}^{-1}$, given within 30 minutes of induction, we have consistently noted a period of sub-optimal analgesia and restlessness in the first one to two hours after surgery, before the epidural morphine becomes fully effective.²

The combination of epidural morphine with epidural bupivacaine has been shown to be effective in the prophylaxis of postsurgical pain, including Caesarean section.³ With the goal of optimizing analgesia in the early postoperative period in patients receiving prophylactic lumbar epidural morphine during thoracotomies, we report our experience using bupivacaine at the time of wound closure.

Methods

Twelve patients scheduled for thoracotomy as a result of pulmonary disease took part in the study. At the time of preanaesthetic visit, each subject was instructed in the completion of the visual scale (VAS) pain score. Those who required mechanical ventilation for more than four hours after surgery were excluded.

At the time of surgery epidural catheters were inserted in the lumbar spine and placement confirmed. Preservative-free morphine sulphate in a dose of $0.1 \text{ mg} \cdot \text{kg}^{-1}$ was administered with the patient supine, after induction. Anaesthesia was with O_2 , N_2O , relaxant with isoflurane and incremental doses of fentanyl (maximum dose $5 \mu\text{g} \cdot \text{kg}^{-1}$). At the commencement of wound closure all 12 patients received a 25 ml bolus of 0.125 per cent epidural bupivacaine over ten minutes, the first 3-5 ml containing 1:200,000 epinephrine as a test dose.

Treatment of pain in the Recovery Room (RR) was with intravenous morphine sulphate in 1 mg increments given as required. Pain assessments (VAS), on a scale of 0 (no pain) to 100 (worst pain), were made at the time of admission to the RR and repeated at half-hourly intervals for the first four hours. Efficacy variables were (1) the total amount of morphine given, (2) the time to request of first analgesia, and (3) the VAS.

Results

The mean ($\pm$ SD) age of our 12 patients was 61.6 years (± 9.4). Six were males and six were females, and their mean weight was 68.3 kg (± 15.7). All but two of the procedures lasted 150 minutes or less. Three patients required mechanical ventilation postoperatively. Two of these patients were extubated within

TABLE Analgesia efficacy variables for the first four postoperative hours (mean $\pm$ SD)

Time interval	0	$\frac{1}{2}$ hr	1 hr	$1\frac{1}{2}$ hr
VAS*	14.4 ± 33.7	25.7 ± 39.2	34.6 ± 43.0	19.1 ± 34.4

Time interval	2 hr	$2\frac{1}{2}$ hr	3 hr	$3\frac{1}{2}$ hr	4 hr
VAS*	28.6 ± 32.0	17.0 ± 23.5	17.6 ± 21.3	17.1 ± 22.9	10.8 ± 13.0

Mean IV morphine requirements in 4 hr: $3.6 \pm 5.2 \text{ mg}$

Mean time to first request for analgesia: 8 hr 12 min ± 9 hr 22 min

*VAS score for the 12 patients at each time interval after arriving in the RR.

an hour of arrival in the RR; the third patient, who required postoperative mechanical ventilation for two hours, was obese (weight 81.1 kg) and received 14 mg of pancuronium two hours before arriving in the RR.

Pain assessment, as measured by patients' VAS scores, revealed satisfactory analgesia overall (Table). Five patients had almost complete absence of postoperative pain. An additional five patients had two or less scores greater than 50 mm on the VAS. The remaining two patients required considerable intravenous narcotic supplementation to achieve acceptable analgesia.

No significant hypotension (defined as a 20 per cent fall in systolic blood pressure) was seen in any of the 12 patients.

Discussion

This study confirms the efficacy of using a combination of epidural morphine and local anaesthetic in achieving a smooth, pain-free emergence from anaesthesia for thoracic surgery. It is recognized that many of these patients will be in the older age group and may have evidence of atherosclerosis, both of which may decrease local anaesthetic requirements and result in significant sympathetic blockade. This was not a problem with our patients. To achieve a sensory block to the upper thoracic region (20 dermatomes), we used 25 ml of solution, which resulted in the administration of 31.25 mg of bupivacaine. It is our impression that the combination of epidural morphine and bupivacaine at wound closure is a useful technique in the prophylaxis of early pain following thoracotomy.

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The cardiovascular effects of epidural bupivacaine 0.75 per cent with epinephrine for femoral popliteal bypass surgery

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It has been suggested that epidural anaesthesia (EA) is associated with greater cardiovascular stability than general anaesthesia in patients undergoing femoral-popliteal bypass surgery (FPB).¹ Furthermore, the cardiovascular effects of EA itself are dependent on the type and dose of anaesthetic, the addition of epinephrine and the patient's condition.² This study describes the cardiovascular effects of bupivacaine (B) 0.75 per cent with epinephrine in patients with cardiac disease undergoing FPB – observations which have not been previously published.

Methods

Ten patients requiring FPB were studied (Table I). All had coronary artery disease and/or cardiac failure for which they received medication (Table II). Patients were premedicated with diazepam 5–10 mg PO as required together with their usual cardiac medication. On arrival in the operating room, a modified V₅ ECG was applied and a pulmonary artery catheter inserted. Systemic blood pressure was obtained throughout surgery by a non-invasive blood pressure monitor. After control measurements were obtained, the patient sat up and B 0.75 per cent 11 ml (range 10–12 ml) with 5 µg·ml⁻¹ epinephrine was injected over 5 min into the epidural space at L₃₋₄. The patient was subsequently placed supine and a urinary catheter inserted. Pulmonary wedge pressure (PWP) and central venous pressure (CVP) were maintained at control values by an infusion of Ringer's lactate. Forty-five minutes after the injection of B, the upper level of anaesthesia was measured by pinprick and haemodynamic measurements were obtained. At the end of surgery patients were monitored in the recovery room until they were haemodynamically stable and motor function had returned. Data are reported as mean ± SEM and compared using a paired Student's *t* test.

Results

The haemodynamic observations at control and 45 min are

TABLE I Demographic data

Ht	176 ± 3 cm
Wt	70 ± 2 kg
BSA	1.87 ± 0.03 m ²
Age	67 ± 2 yr
M:F	8:2

TABLE II Cardiac medication/No. of patients

Digoxin	5
Diuretics	3
Beta adrenergic antagonists	4
Calcium channel blockers	3
NTG	2

TABLE III Haemodynamic data

	Control	45 Minutes	<i>p</i> value
MBP mmHg	105 ± 3.2	91 ± 3.6	<0.01
CO L·min ⁻¹	5.3 ± 0.3	6.2 ± 0.3	<0.01
SVR dyne·s·cm ⁻⁵	1568 ± 152	1170 ± 124	<0.01
HR bpm	67 ± 2.9	65 ± 1.9	NS
CVP mmHg	5 ± 1.4	3 ± 0.8	NS
PWP mmHg	12 ± 2.1	10 ± 1.3	NS

presented in Table III. Systemic vascular resistance (SVR) and mean blood pressure (MBP) decreased. Cardiac output (CO) increased, but there was no change in heart rate (HR), PWP and CVP. The upper level of anaesthesia was T₆₋₈ (range T₄–T₈). The time from the induction of EA to the end of surgery was 2.575 ± 0.2 hr, throughout which lactated Ringer's solution 3500 ± 535 ml was administered. Estimated blood loss was 319 ± 71 ml and urine output was 905 ± 381 ml.

Discussion

Despite preoperative cardiac compromise, this elderly group of patients were able to respond to EA by increasing CO by 17 per cent. The magnitude of the changes in SVR, CO and MBP suggest that these were due to beta adrenergic stimulation by epinephrine,² although in contrast to previous reports no change in HR was observed. The continued bradycardia may be explained by the concurrent administration of cardiac medication. No adverse effects of B 0.75 per cent were observed due to the low total dose of B, the slow rate of injection (approximately 2 ml·min⁻¹) and the continuous monitoring during injection. Substantial quantities of crystalloid solution were required to maintain PWP at control value. Circulatory overload was not detected intraoperatively nor in the immediate postoperative period. The study demonstrates that elderly patients with compromised cardiac function undergoing FPB respond to EA induced by B 0.75 per cent with epinephrine by increasing CO when PWP is maintained.

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Morphine produces a profound disruption of nocturnal sleep in humans

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In previous studies we have documented the marked changes in sleep architecture which occur in the first week after abdominal surgery¹ and have shown that isoflurane anaesthesia alone plays a minor role in the overall sleep disturbance.² The pur-

TABLE Results (mean $\pm$ SD)

	Night		
	Placebo	Morphine	Recovery
Total sleep time (min)	395 $\pm$ 45	348 $\pm$ 91	407 $\pm$ 70
Stage 1 (%)	10 $\pm$ 3	25 $\pm$ 12*	9 $\pm$ 4
Stage 2 (%)	51 $\pm$ 5	62 $\pm$ 10*	46 $\pm$ 7
Slow wave (%)	15 $\pm$ 6	9 $\pm$ 6*	22 $\pm$ 7*
REM (%)	22 $\pm$ 5	4 $\pm$ 3*	23 $\pm$ 3
Awakenings (number)	9 $\pm$ 4	28 $\pm$ 12*	5 $\pm$ 2

*Statistically different from placebo.

pose of this study was to examine the effects of morphine on sleep and determine its contribution to the disruption of postoperative sleep.

Methods

Polysonnographic recordings were obtained from seven healthy volunteers who were studied from 2300 hrs to 0700 hrs on four consecutive nights. Night one allowed subject adaptation to the sleep laboratory. On night two, subjects received placebo, normal saline IM, at 2200 and 0200 hrs. On night three, subjects received morphine 0.2 mg $\cdot$ kg⁻¹ IM also at 2200 and 0200 hrs. On night four subjects slept undisturbed. Sleep stages were scored according to standard criteria. Total sleep time (TST), sleep stages as a per cent of TST and number of awakenings were calculated. Statistical assessment was by analyses of variance. A *p* value of 0.05 was considered significant.

Results

Morphine produced a marked reduction in both REM and slow wave sleep with a reciprocal increase in lighter sleep (stages 1 and 2) and a dramatic increase in nocturnal awakenings (Table). On night four sleep parameters had essentially recovered.

Discussion

We conclude that morphine produces profound disruption of nocturnal sleep. Standard analgesic doses of morphine are more disruptive to sleep than three hours of isoflurane anaesthesia.² Changes in sleep architecture produced by morphine are very similar to the sleep pattern observed after abdominal surgery.¹ These data suggest that narcotics play a very important role in postoperative sleep disruption. Bedtime administration of narcotics may impair rather than improve the quality of sleep.

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Morphine-induced ventilatory depression is potentiated by non-REM sleep

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Analgesic doses of narcotics can produce marked hypopnoea or apnoea in susceptible patients,¹ often in association with loss of consciousness or "sleep." Narcotics also reduce the ventilatory response to added CO₂ and this particular effect appears enhanced during a brief period of sleep.² To see if narcotics affect resting breathing differently during physiological sleep and its individual stages, we studied ventilation, PCO₂ and SaO₂ throughout a night of sleep in which morphine was administered.

Methods

Seven healthy young adults were studied throughout two nights. On night one, placebo (saline 2 ml) was given IM at 2200 and at 0200 hours, and on night two, morphine 0.2 mg $\cdot$ kg⁻¹ IM at the same times. At 2300 hours, the subject retired to sleep for the night, during which we recorded transcutaneous PCO₂ (Radiometer TCM 20), SaO₂ (Biox II oximeter), respiratory rate (Respirator), and bioclectric variables used to stage sleep (EEG, EOG and EMG). The average PCO₂, SaO₂ and respiratory rate of each 30 sec epoch of the night was computed and analyzed in relation to the stage of sleep, i.e., nonREM sleep – partitioned into stage 2 and slow wave sleep (SWS) – or REM sleep. Transcutaneous PCO₂ values of sleep were converted to arterial PCO₂ equivalents on the basis of the transcutaneous-arterial differences determined in the awake state. Results were assessed by analyses of variance. A *p* value of 0.05 was considered significant.

Results

Morphine increased PaCO₂ during wakefulness and sleep (Table). The increments in awake and REM states were similar but the increments in nonREM sleep were significantly greater. Morphine also reduced SaO₂ in nonREM sleep and decreased respiratory rate in both wakefulness and nonREM sleep.

Discussion

We conclude that morphine is most depressant to breathing in

TABLE Results (mean $\pm$ SD)

		nonREM			
		Awake	Stage 2	SWS	REM
PaCO ₂ (mmHg)	Placebo	40 $\pm$ 4	43 $\pm$ 5†	42 $\pm$ 4†	43 $\pm$ 5†
	Morphine	42 $\pm$ 4*	49 $\pm$ 6*†	49 $\pm$ 6*†	45 $\pm$ 8*†
SaO ₂ (%)	Placebo	97 $\pm$ 1	96 $\pm$ 1	96 $\pm$ 2	97 $\pm$ 1
	Morphine	96 $\pm$ 1	94 $\pm$ 1*†	94 $\pm$ 1*†	95 $\pm$ 1*
Respiratory rate	Placebo	17 $\pm$ 3	16 $\pm$ 2	16 $\pm$ 2	16 $\pm$ 3
	Morphine	13 $\pm$ 2*	12 $\pm$ 2*	13 $\pm$ 2*	15 $\pm$ 3

*Different from placebo same state.

†Different from awake.

nonREM sleep. Patients sensitive to the ventilatory effects of narcotics may be particularly so in this state. Since breathing in nonREM sleep is completely dependent on chemical mechanisms of ventilatory control, whereas in awake and REM states it is only partially so,³ the results are consistent with morphine acting primarily on chemical control.

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Psychomotor performance following laparoscopic surgery with and without methohexitone induction

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Serial four-choice reaction time (4CRT) has been shown to be a practical method of assessing postoperative psychomotor performance.¹ In clinical studies two models for comparing IV induction agents have been used. A normal induction dose of the test drug may be followed by the same inhalation anaesthetic in both study groups. Secondly the test drug may be used for both induction and maintenance, resulting in a higher total dosage. To elucidate the relative contribution of inhalation and IV anaesthetic components in the first model, two to six hours after surgery, we have compared postoperative 4CRT in patients after N₂O/enflurane anaesthesia with or without the use of 1.5 mg·kg⁻¹ methohexitone.

Methods

With the approval of a hospital ethics committee, informed consent was obtained from 30 patients scheduled for laparoscopic tubal ligation, randomly assigned to two groups. Patients received droperidol 1.0 mg, glycopyrrolate 0.2 mg and gallamine 20 mg prior to induction. Group I inhaled five per cent enflurane in oxygen from a Mapleson "D" circuit at a flow of 8 L·min⁻¹. Following loss of the lash reflex ventilation was assisted and succinylcholine administered. Group II inhaled O₂ while methohexitone 1.5 mg·kg⁻¹ was given IV. In both groups the trachea was intubated and ventilation was controlled, with a gas flow of 75 ml·kg⁻¹. Anaesthesia was maintained with O₂ (40 per cent), N₂O, enflurane five per cent until BP was ten per cent below preinduction and then reduced to 1.3 per cent until the end of surgery. 4CRT tests lasted eight minutes. Preoperatively, patients completed one practice 4CRT, a control 4CRT and three 10 cm visual analog scales (VAS) to assess pain, nausea and drowsiness. Postoperatively 4CRT and VAS's were completed 2, 4, and 6 hr after the cessation of anaesthesia and after an overnight stay in hospital. Differences between treatments were sought using ANOVA, repeated measures ANOVA with one covariance factor. A tail probability of <0.05 was considered significant.

FIGURE Serial reaction times of all subjects.

Results

Six subjects failed to complete the full protocol. Their treatments were reassigned to new subjects. No significant differences were found between the two groups in age, percentage body fat, operation time or time to respond to commands. There were no significant differences between anaesthetic treatment groups for median 4CRT or pain, nausea or sleepiness VAS's. Therefore data from both groups have been pooled. Values are the mean difference from preop score $\pm$ 99 per cent confidence limits of the change. Pain VAS was significantly increased postoperatively (20.1 ± 3.5 mm) but did not vary between 2 hr and discharge. Nausea VAS was increased slightly (6.9 ± 5.0 mm) 6 hr postop. Sleepiness VAS increased 35.8 ± 5.9 mm at 2 hr. It declined significantly at 4 and 6 hr respectively. Median 4CRT results are shown in the Figure. Median 4CRT increased 55 ± 9.9 msec 2 hr postoperatively. 4CRT remained significantly higher than preoperatively at 4 and 6 hr postop and immediately prior to discharge.

Discussion

The mean increase in 4CRT following N₂O/enflurane anaesthesia was very small but persisted for at least six hours postoperatively. This small change was not increased by the addition of methohexitone 1.5 mg·kg⁻¹ for induction. Comparison between anaesthetic techniques was not affected by differences in subjects' feelings of pain, nausea or sleepiness measured using VAS's.

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Mental function after neuroleptic anaesthesia for cataract surgery

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An increasing bed shortage has made it popular to do cataract operations on a day-bed basis. There is concern that delayed mental recovery of these patients makes it unsafe to discharge them the same day as their operation. A study assessing the mental recovery of elderly patients after cataract operations under local anaesthesia and sedation found that a significant number (37.7 per cent) of these patients had impaired cognitive function perioperatively, and at six and 24 hours postoperatively.¹ This study was done to assess the mental recovery of a younger age group following cataract operations under local anaesthesia and sedation.

Methods

This study was approved by the Human Experiments Committee of the University of Toronto. Thirty-two alert and oriented patients (mean age 58 yr, SD $\pm$ 12) scheduled to undergo cataract operation under local anaesthesia and sedation, were included in the study. Informed consent was obtained. Mental function was assessed preoperatively, and at six and 24 hours postoperatively. Mini-Mental State (MMS) was used.² MMS evaluates the cognitive aspects of mental function such as orientation, registration, attention and calculation, recall and language. The test is simple and takes less than five minutes. A retrobulbar block and intravenous sedation with fentanyl, droperidol and diazepam were given as required. The preoperative score was the control and this was compared with the scores at six and 24 hours postoperatively. Comparison between groups was made by Student's *t* test for the total score and for each MMS subdivision.

Results

Our results showed a statistically significant difference between mean total scores preoperatively and at six hours postoperatively (Figure 1, $p < 0.001$), and no difference 24 hours later.

FIGURE 1 Total MMS scores.

FIGURE 2 Divided MMS scores.

There was a significant difference at six hours for attention and calculation ($p < 0.01$), recall ($p < 0.01$) and language ($p < 0.01$), while no difference found for orientation or registration. Scores at 24 hours showed no difference in any aspect of mental function (Figure 2).

The range for normal cognitive function is between 24 and 30. None of the patients studied were impaired preoperatively, six were impaired at six hours (18.75 per cent) and none were impaired at 24 hours.

Discussion

Cataract operations are done in our institution under local anaesthesia plus intravenous sedation. Assessment of mental function in middle-aged patients showed that 18.75 per cent had impaired cognitive function six hours postoperatively. It seems that a simple screening test such as MMS should be encouraged to identify those day-bed patients with impaired cognitive function to ensure their safety after discharge.

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Gastric fluid volume and pH: correlations with independent variables

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Over the past decade it has been demonstrated that overnight fasting in elective surgical patients does not guarantee an empty stomach. Indeed, nearly half of the patients prepared in this

way have significant volumes of highly acidic gastric contents.¹ Manchikanti *et al.* suggested that gastric acidity may increase with the duration of fast.² Our study further examined the correlation of preoperative oral fluid, ranitidine, and demographic data on gastric volume and pH.

Methods

Institutional approval was obtained and all patients gave informed consent. Three hundred healthy, nonpregnant inpatients between 18 and 60 yr were randomly allocated to one of four groups. Details of age, sex, weight, duration of overnight fast, and history of smoking and heartburn were recorded. Patients receiving drugs known to affect gastric secretion or motility, including opiate or belladonna alkaloid premedication, were excluded; oral diazepam premedication was permitted. Between two and three hours before the scheduled time of surgery patients received: coffee or orange juice 150 ml with oral ranitidine 150 mg (Group I), or placebo (Group II), ranitidine alone (Group III), or placebo alone (Control). Following induction of anaesthesia a #18 Salem sump tube was passed into the stomach and gastric contents aspirated for measurement of volume and pH.

Results

Patients who received ranitidine had significantly lower gastric fluid volumes and higher pH than those who did not (Table). In those patients who received ranitidine there was no correlation between gastric volume or pH and age, weight, sex, history of heartburn or smoking, duration of fast, diazepam premedication, or the ingestion of oral fluids. Those patients who received oral fluid with placebo (Group II) had very similar gastric volume and pH to the control group. In the control group there was a positive correlation between the duration of fast and the gastric fluid volume. The only other correlation was in Group II; a lower mean volume was found in the coffee subgroup who received diazepam premedication.

Discussion

Using forward multifactorial analysis, it appears that prolonged fasting may increase gastric volume. In patients receiving oral fluid and placebo, age, sex, weight, fast duration, ingestion-surgery interval, smoking and heartburn appear unimportant.

The potent effect of ranitidine on gastric volume and pH appears to override all other variables investigated. Prolonged fasting has been shown to be of no benefit in the elective surgical inpatient.

TABLE Results (mean $\pm$ SD)

	Group I	Group II	Group III	Control
n (m/f)	100 (50/50)	100 (50/50)	50 (25/25)	50 (25/25)
Age (yr)	35.7 $\pm$ 11.4	38.6 $\pm$ 11.7	35.5 $\pm$ 11.3	38.4 $\pm$ 12.8
Weight (kg)	72.0 $\pm$ 15.2	73.6 $\pm$ 15.6	71.3 $\pm$ 15.2	72.3 $\pm$ 13.9
Fast (hr)	12.0 $\pm$ 2.5	11.9 $\pm$ 2.2	12.2 $\pm$ 2.9	12.1 $\pm$ 2.5
No. of smokers	40	48	14	16
No. with heartburn	15	19	12	10
Volume (ml)	14.6 $\pm$ 16.2	24.1 $\pm$ 20.0	9.7 $\pm$ 12.6	23.2 $\pm$ 17.3
pH	5.54 $\pm$ 2.10	2.07 $\pm$ 1.43	6.21 $\pm$ 1.51	1.95 $\pm$ 1.26

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Evaluation of oesophageal contractility as an indicator of depth under balanced general anaesthesia

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Assessing depth of anaesthesia is difficult when multiple agents are used; thus anaesthetists rely on cardiovascular stress responses as indications for therapeutic interventions. Since such stress responses may be associated with significant morbidity, the development of monitors which afford an earlier warning is desirable. Evans *et al.* have shown that spontaneous lower oesophageal contractility (SLEC) correlates well with MAC under inhalational anaesthetics alone.¹ We examined the utility of SLEC as a measure of depth under "balanced" general anaesthesia in comparison to heart rate (HR), systolic blood pressure (SBP), and EEG.

Methods

In 14 patients undergoing routine general anaesthesia, spontaneous (tertiary) contractions in the smooth muscle portion of the oesophagus were recorded with Lectron 301 oesophageal contractility monitor using a balloon pressure transducer. The Neurometrics' Lifescan monitor was used for online aperiodic analysis of a five-lead EEG. An average of the Lifescan edge frequencies (EF) for each hemisphere was recorded for each sampling epoch. HR and SBP were monitored via ECG and automated sphygmomanometer. We evaluated these cases for episodes of lightening of anaesthesia, marked by either therapeutic intervention by the anaesthetist or clinical assessment of awakening, and evaluated each one for recognizable changes in HR (increase to >120 per cent of baseline or >100 beats $\cdot$ min⁻¹), SBP (increase to >120 per cent of baseline or >140 mmHg), EEG (EF ≥ 10), and SLEC (≥ 1 min⁻¹).

Results

We identified 27 episodes: eight episodes were of awakening at the end of the case (in six cases, one of the monitors had been removed or was malfunctioning); 19 episodes were marked by the administration of additional anaesthetic drugs. Twenty-five episodes were preceded or occurred concomitantly with a recognizable change of at least one of the four monitored parameters. One episode of awakening and one episode of additional drug dosage were not accompanied by a recognizable change of either HR, SBP, EEG, or SLEC. SBP and EEG showed recognizable changes in 15 episodes each, SLEC in 14, and HR in four episodes. Either HR and/or SBP marked 17 episodes (= 62 per cent). The combination HR, SBP and EEG detected

22 episodes (= 81 per cent). The combination HR, SBP and SLEC detected 23 episodes (85 per cent). Advance warning (≥ 1 min) was afforded by HR in one episode with a warning time of 2 min. The values for the other variables are SBP: seven episodes/median warning time of 4 min; EEG: 12 episodes/5.5 min; SLEC: 12 episodes/5.5 min. There were ten falsely positive SLEC warnings. In one case SLEC was uninterpretable due to variable transmissions of intrathoracic ventilation pressures to the oesophagus.

Discussion

Measuring oesophageal contractility may be a valuable adjunct to the traditional methods of gauging anaesthetic depth. Used by itself, the monitor is not superior to either the combined cardiovascular parameters or EEG. Its lower cost and the already existing combination with the oesophageal stethoscope and future combination with thermometers, ECG probes, echocardiography make this monitoring modality very promising.

Reference

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The anaesthetists' preoperative visit - when is it most effective?

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Outpatient surgery is increasingly popular. The preoperative anaesthetic visit may be done in the outpatient clinic, the day-bed unit or outside the operating room. The optimal timing of the anaesthetic visit to alleviate anxiety has never been studied. The purpose of this study was to assess the value of the anaesthetic preoperative visit in reducing outpatient anxiety, and to determine the optimal timing of the anaesthetic visit.

Methods

Institutional approval was obtained. Following informed consent, 63 female ASA physical status I or II patients undergoing elective outpatient therapeutic abortions were studied. Anxiety was assessed by the State-Trait Anxiety Inventory (STAI)¹ and a Visual Analogue Scale (VAS).² The Trait portion of the STAI was administered at the first assessment. All tests for anxiety were administered by an independent investigator. The preoperative anaesthetic assessments were completed by one of two staff anaesthetists.

Patients were divided randomly into three groups. In Group I ($n = 20$), the anaesthetic preoperative visit was completed in an outpatient clinic one week prior to surgery. The STAI and VAS was administered before and after the anaesthetist's preoperative assessment. They were repeated on admission to the Day Bed Unit (DBU) and immediately prior to transfer into the operating room (OR).

In Group II ($n = 23$), anaesthetic preoperative assessment

FIGURE Mean anxiety scores (STAI) in the three patient groups showing locations of assessment and effect of anaesthetist's visit.

was done in the DBU on the day of surgery. The STAI and VAS was administered before and after the anaesthetist's visit and immediately prior to transfer into the OR. In Group III ($n = 20$), the anaesthetic preoperative assessment was done outside the OR. STAI and VAS were done in the DBU, and before and after the anaesthetic visit outside the OR.

Results

The results of the STAI scores for the three groups are summarized in the Figure. The initial STAI among the three groups showed no significant difference. There was no long-term benefit of the preoperative anaesthetic visit in the outpatient clinic (Group I) or in the Day Bed Unit patient groups (Group II) in alleviating anxiety. Only in Group III did the anaesthetist's visit reduce anxiety scores significantly ($p < 0.05$). STAI and VAS scores correlated well ($r = 0.68$).

Discussion

Previous studies in inpatients have shown that the anaesthetist's preoperative visit may alleviate patient anxiety.³ In a group of outpatients undergoing therapeutic abortions, there appears to be no long-term reduction of anxiety in those patients seen by the anaesthetist in the outpatient clinic one week prior to operation or in the Day Bed Unit on the day of surgery. This study suggests that the anaesthetist's preoperative visit outside the operating room is the most effective in allaying anxiety.

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Occupational exposure to nitrous oxide during paediatric anaesthesia

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Occupational exposure to nitrous oxide may cause bone marrow toxicity and polyneuropathy; prolonged exposure has produced leukopenia and death. Nitrous oxide is known to depress the activity of methionine synthetase, an enzyme important in DNA formation. In addition, waste anaesthetic gases may interfere with the mental performance of operating room personnel. Despite these hazards, there is no accepted paediatric standard of waste anaesthetic gas concentrations. Paediatric anaesthesia has increased potential for pollution: gas inductions are frequently used; provision is made for a leak around endotracheal tubes. We are thus attempting to establish a standard in paediatric operating rooms for nitrous oxide and halothane exposure, expressed as a Time Weighted Average (TWA). A TWA denotes an average exposure of x parts per million (ppm) for a period of one hour. A known, achievable standard for TWA would assist in determining realistic goals for operating room pollution and could help to determine if operating room exposure to nitrous oxide induces toxicity in operating room personnel.

Methods

As a pilot study, Landauer's Nitrox Dosimeters¹ were worn by operating room personnel. An additional dosimeter was placed at a room air exhaust outlet for comparison.² Collections were made on separate days in the same operating room. For example, Day 1 consisted of tonsillectomies and myringotomies, with passive waste gas scavenging present; cases on Day 2 were similar but scavenging was not used. Day 3 consisted of head and neck surgery, with intubation of all cases and scavenging employed. Anaesthesia fresh gas flow rates were standardized. Room air was exchanged 30 times/hour on each day.

Results

On Days 1 and 3, equal room concentrations were found, in comparison to Day 2 (Table). For the anaesthetist and circulating nurse, lower concentrations were found when the mask was consistently held close to the child's face (e.g., Day 2), in comparison to values found on Day 1. On Day 3, the surgeon and scrub nurse experienced the highest exposures.

TABLE Summary of nitrous oxide exposures

	Day 1	Day 2	Day 3
Exhaust outlet	30	109	31
Anaesthetist	378	149	44
Circulating nurse	750	92	52
Scrub nurse	50	87	96
Surgeon	44	116	143

Time weighted averages (TWA) in ppm/hour for operating room exhaust air outlet and personnel on three typical days.

Discussion

Initially, attempts were made to collect data for halothane, as well as nitrous oxide. However, technical difficulties were encountered in collecting and analyzing halothane data and results are presented only for nitrous oxide. Scavenging reduced ambient air concentrations, regardless of anaesthetic technique. However, this does not guarantee reduced personal exposure as seen by high personnel TWA on Day 1 and for surgeon and scrub nurse on Day 3.

References

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Effects of haemorrhage and phenylephrine on cerebral blood flow in rats during isoflurane anaesthesia

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Neuroanaesthesia is being conducted increasingly with isoflurane. There is little information available describing either the effects of haemorrhage or phenylephrine (PE) administration on regional cerebral blood flow (rCBF) during isoflurane anaesthesia. In this study we investigated how rCBF in the rat was altered following haemorrhage and subsequent support of the blood pressure (BP) with a PE infusion during stable isoflurane anaesthesia.

Methods

Male hooded rats were induced with ether, intubated and ventilated with 100 per cent O₂/isoflurane with normocarbina maintained throughout. Catheters were inserted into a femoral vein, tail (TA) and femoral arteries (FA) for PE infusion, continuous measurement of BP and arterial blood gas sampling respectively. Another catheter was advanced via the right common carotid artery into the left ventricle (LV) for injection of radioactive microspheres. Seven animals were studied with three CBF determinations in each. The initial CBF (CBF1) followed a stable 30-minute period of 1.5 per cent isoflurane. The animal was then bled from the TA until a stable mean blood pressure of about 50 mmHg was obtained for ten minutes; CBF2 followed. A continuous infusion of PE was started to return the mean BP to within 10 mmHg of the control BP. Following a stable period of ten minutes, CBF3 was done. rCBF measurements were determined by LV injection of 500,000 microspheres of 15 μ m diameter of either ⁴⁶Sc, ⁸⁵Sr or ¹⁴¹Ce. A reference sample of blood was withdrawn from the FA. Blood reference and brain samples from left and right parietal cortex, cerebellum and basal ganglia were counted by gamma counter. Counts were converted to rCBF by computer program. Within and between group comparisons were by ANOVA for repeated

TABLE Cerebral blood flow (mean $\pm$ SEM) ($n = 7$)

	CBF1	CBF2	CBF3
Left parietal	1.71 $\pm$ 0.23	1.07 $\pm$ 0.09*	1.87 $\pm$ 0.25‡
Right parietal	1.34 $\pm$ 0.22	0.94 $\pm$ 0.08	1.59 $\pm$ 0.18‡
Left cerebellum	3.67 $\pm$ 0.59	2.43 $\pm$ 0.14*	4.29 $\pm$ 0.43‡
Right cerebellum	3.96 $\pm$ 0.77	2.40 $\pm$ 0.19*	4.42 $\pm$ 0.44‡
Left basal ganglia	1.93 $\pm$ 0.36	1.23 $\pm$ 0.11	1.94 $\pm$ 0.36
Right basal ganglia	1.75 $\pm$ 0.31	1.12 $\pm$ 0.10	2.20 $\pm$ 0.30‡
PaCO ₂	46.0 $\pm$ 1.5	39.5 $\pm$ 1.1*	43.4 $\pm$ 1.5
Mean blood pressure	91.9 $\pm$ 3.7	50.0 $\pm$ 1.2†	92.7 $\pm$ 4.4§

CBF ml·g⁻¹·min⁻¹; * $p < 0.05$; † $p < 0.01$ vs CBF1; ‡ $p < 0.05$; § $p < 0.01$ vs CBF2.

measures with Duncan's test applied post-hoc; $p < 0.05$ was considered significant.

Results

See Table. In the rat, during stable isoflurane anaesthesia with normotension and normocarbida maintained, rCBF was significantly higher in the cerebellar cortex than in cerebral cortex or basal ganglia. During haemorrhagic hypotension there was a decrease in rCBF in all regions examined but this reached statistical significance in only three of the six regions. The maximal decrease in rCBF to 60 per cent of control flow was unlikely to be within the ischaemic range. Following PE infusion rCBF was returned to control levels.

Discussion

These results indicate that in the rat rCBF is higher in the posterior circulation as evidenced by high cerebellar flows;¹ rCBF decreases when haemorrhagic hypotension ensues, but flows appear adequately maintained; PE significantly increased rCBF following haemorrhagic hypotension indicating pressure-passive flow. If these results are referable to man, during stable isoflurane anaesthesia, in the face of haemorrhagic hypotension rCBF can be well maintained by supporting the blood pressure with a phenylephrine infusion.

Reference

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Perioperative electrocardiographic monitoring of patients with cerebral aneurysms

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Patients with subarachnoid haemorrhage (SAH) presenting for surgery frequently have an abnormal preoperative (preop) electrocardiogram (ECG).¹ The purpose of this study was to investigate the intraoperative (intraop) and postoperative (postop)

TABLE I ECG results

	Group		
	A ($n = 49$)	B ($n = 42$)	C ($n = 31$)
Bottrell grade	0	I	II–V
Mean age $\pm$ SD	53 $\pm$ 10	49 $\pm$ 12	53 $\pm$ 12
Sex M:F	12:37	15:27	9:22
Preop ECG			
– Normal	28	23	6
– Abnormal	21*	19	25
% Abnormal	43%	45%	81%
Holter			
– Normal	11	11	7
– Abnormal	4	8	4
% Abnormal	27%	42%	36%
Postop ECG			
– Normal	14	16	12
– Changed†	35	26	19
% Changed†	71%	62%	61%

*See Table II.

†Changed = changed from preop.

effects of anaesthesia and surgery on these ECG abnormalities, and to assess the relationship of the Bottrell grade, size, and location of the cerebral aneurysm to the ECG abnormality.

Methods

The study was approved by the Institutional Ethics Committee. One hundred and twenty-two patients with cerebral aneurysms presenting for surgery were studied. All patients had a standard 12-lead ECG preop and postop in the Recovery Room and/or on postop day one. Intraop Holter monitoring of leads V₁ and V₅ was conducted on 45 patients. Anaesthetic technique, including the use of induced hypotension, was left to the discretion of the anaesthetist. Aneurysm size was classified as giant (>2.5 cm diameter), large (2.5–1.5 cm) and small (<1.5 cm).

Results

Seventy-three patients had had a SAH prior to surgery (Groups B and C), of these 60 per cent had an abnormal preop ECG (Table I). These abnormalities consisted mostly of nonspecific ST-T wave changes. Twenty-one patients with an intact aneurysm (Group A) had an abnormal preop ECG, and of these patients 16 had a giant aneurysm (Table II). The presence of cardiac disease in Group A is shown in Table II. Intraop, 35 per cent of all patients developed an abnormality on Holter monitoring, mostly ST or T wave changes. Postop, 65 per cent of all patients had a definite change from their preop ECG (Table I). The frequency of intraop and postop ECG changes was independent of the preop frequency. Size of the aneurysm was important, but the location of the aneurysm did not influence the occurrence of ECG abnormalities. Patients with a higher Bottrell grade (Group C) had a greater incidence of preop ECG abnormalities.

TABLE II Group A. Intact aneurysm (grade = 0)

	Size		
	Small	Large	Giant
Normal preop ECG			
- Number of patients	16	5	7
- Hypertension	10	3	2
- CAD	—	—	—
Abnormal preop ECG			
- Number of patients	3	2	16
- Hypertension	1	1	12
- CAD	2	1	—

CAD = Coronary Artery Disease.

Discussion

The occurrence of ECG abnormalities following SAH is well known.¹ This may present a dilemma to the anaesthetist as one must rule out myocardial disease preop. In our study, we found a significant number of patients who developed new ECG abnormalities intraop and postop. An interesting group were patients with an intact giant aneurysm as they have similar ECG changes without a SAH. These changes are not the typical ECG changes seen with myocardial infarction. The exact aetiology of these abnormalities is not known. Breslow *et al.* documented postop ECG changes in approximately 19 per cent of non-neurosurgical patients.² Our results show a greater incidence occurring in patients undergoing neurosurgery.

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Preoperative cardiac medication - does it matter?

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Slogoff *et al.* recently demonstrated that in patients undergoing coronary artery bypass grafting (CABG) a significant relationship exists between tachycardia, myocardial ischaemia, and perioperative myocardial infarction.¹ Their study did not show if the incidence of myocardial ischaemia is related to preoperative cardiac medications. The aim of this study was to detect the difference in incidence of pre-bypass ischaemia by electrocardiogram (ECG) criteria in patients taking beta adrenergic blockers (Group I), Ca channels blockers (Group II), or combined beta adrenergic and Ca channel blockers (Group III).

Methods

Institution approval was obtained. Patients with stable angina

scheduled for routine coronary artery bypass grafts from January 1986 to June 1986 were included in the study. All cardiac medication was continued until the time of premedication. Calibrated ECG tracings of Lead II and V₅ and haemodynamic profiles were recorded during the pre-bypass period and at the following intervals: before induction (baseline) and one minute after induction, intubation, skin incision, sternotomy, and aortic dissection. A high-dose fentanyl anaesthetic protocol was used. Heart rate (HR) and blood pressure (BP) were maintained within 20 per cent of the average ward value (control). For elevated BP, infusion of nitroglycerine with or without the addition of an inhalational anaesthetic up to 0.5 per cent was used. For lowered BP, volume, and when necessary infusion of phenylephrine was given. For increased HR, intravenous doses of propranolol were used. ECG was examined retrospectively by an independent investigator for evidence of ischaemia. Ischaemia was defined as 1 mm or more of downsloping or horizontal ST segment depression, greater than 2 mm of upsloping ST segment depression measured 0.08 seconds from the J-point, or ST elevation greater than 1 mm. Ischaemia, as evidenced by ECG changes, and haemodynamic data were analysed according to the three groups of patients by chi square and analysis of variances with $p < 0.05$ considered statistically significant.

Results

Fifty patients were studied: seven in Group I (β -adrenergic blockers), ten in Group II (Ca channel blockers), and 33 in Group III (β -blockers and Ca blockers). There was no difference in age, weight, ASA physical status class, severity of angina, LV score, ejection fraction, time of bypass, or cross-clamp time among the three groups. Baseline heart rate in Group II was significantly higher than Group III (67.89 ± 3.59 vs 56.94 ± 1.87 , ($p < 0.01$)). There was no difference in HR among the three groups at induction, intubation, incision, sternotomy or aortic dissection. There was no difference in mean arterial pressure (MAP), pulmonary capillary wedge pressure (PCWP), peripheral vascular resistance (PVR), or cardiac output (CO), among the three groups at various stages pre-bypass. However, the rate pressure product was significantly higher in Group II than Group III at incision, sternotomy, and aortic dissection ($p < 0.01$). The incidence of ischaemia at sternotomy was significantly higher ($p < 0.03$) in Group II (50 per cent) as compared with Group III (24.24 per cent) (Table).

TABLE Incidence of ischaemia

Event	Ischaemic ECG		
	Group I β blockers $n = 7$	Group II Ca blockers $n = 10$	Group III Combined β and Ca $n = 33$
ECG-C	0%	30%	15.15%
ECG-IND	14.28%	20%	18.18%
ECG-INT	0%	20%	21.21%
ECG-INC	14.28%	20%	15.15%
ECG-STERN	28.57%	60%*	24.24%

* $p < 0.03$.

Discussion

There was no difference in HR, MAP, PCWP, PVR, or CO, at incision, sternotomy, and aortic dissection among the three groups of patients. However, in spite of IV nitroglycerine infusion and IV propranolol, rate pressure product at incision, sternotomy, aortic dissection, and the incidence of ischaemia at sternotomy were significantly higher ($p < 0.03$) in Group II versus Group III patients. Thus the incidence of myocardial ischaemia appeared to correlate with the type of preoperative cardiac medication in patients undergoing CABG.

Reference

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Is alfentanil a complete anaesthetic in humans?

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Ausems *et al.* were able to define arterial plasma alfentanil concentrations [ALF] necessary for satisfactory anaesthesia in the presence of nitrous oxide.¹ This study was undertaken to determine the relationship of alfentanil concentration [ALF] to response (i.e., adequacy of anaesthesia) in patients undergoing CABG.

Methods

Two studies were performed in 19 patients with good ventricular function undergoing CABG. After institutional approval, informed consent was obtained from each patient.

Study 1

($n = 6$) Patients received lorazepam $0.08 \text{ mg} \cdot \text{kg}^{-1}$ PO as premedication and alfentanil $4.5 \mu\text{g} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ as a maintenance infusion.

Study 2

($n = 13$) Patients received lorazepam $0.04 \text{ mg} \cdot \text{kg}^{-1}$ PO and were randomly assigned to receive one of three alfentanil maintenance infusion rates (5.4 ($n = 4$), 6.6 ($n = 5$), or 7.8 ($n = 4$) $\mu\text{g} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$). Patients in the two studies were similar in age, body weight and surface area, with a comparable representation of gender and chronic drug therapy. Patients were monitored by ECG leads II and V₃, radial, central venous, and pulmonary artery pressures. An alfentanil priming infusion was delivered over 10 min followed by the alfentanil maintenance infusion. Observations of haemodynamic, sympathetic and somatic responses to stimulation¹ and blood sampling for [ALF] were performed at loss of consciousness (LOC), tracheal intubation (ETT), sternotomy (SS), and during multiple episodes of electrocauterization (Bovie). The use of muscle relaxants prior to cardiopulmonary bypass was limited to succinylcholine for intubation ($n = 13$), cardioversion ($n = 3$), and for sternotomy ($n = 12$). Return of muscular function after each dose of

succinylcholine was confirmed using a peripheral nerve stimulator. The response to any stimulus was classified as minor or major. A minor response consisted of any of the following: systolic blood pressure (SBP) rise of 15–25 mmHg, heart rate (HR) increase of 15 beats $\cdot \text{min}^{-1}$ (bpm), facial grimacing without eye opening to command. Major responses were greater increases in SBP or HR, gross movement, or eye opening. Minor responses were treated with IV bolus doses of alfentanil $14\text{--}20 \mu\text{g} \cdot \text{kg}^{-1}$ and major responses with $28\text{--}40 \mu\text{g} \cdot \text{kg}^{-1}$.

Results

Study 1

No response whatsoever occurred in 3/6 (50 per cent) patients at the measurement points. Mean [ALF] for these three patients was $1090 \pm 80 \text{ ng} \cdot \text{ml}^{-1}$ (mean $\pm$ SEM) and for the group as a whole was $1178 \pm 54 \text{ ng} \cdot \text{ml}^{-1}$. In one patient a rise in MAP not controlled by alfentanil boluses responded to NTG. Motor responses (2/6 patients) were easily controlled with alfentanil boluses and an increased infusion rate ($8.7 \mu\text{g} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$).

Study 2

Responses occurred in 13/13 patients (100 per cent). Elevations of MAP ($n = 4$) and ST changes in the ECG ($n = 1$) were not controlled by alfentanil boluses in four patients even at [ALF] of $2270\text{--}4600 \text{ ng} \cdot \text{ml}^{-1}$. Somatic responses occurred in 9/13 patients and were controlled by very frequent alfentanil boluses. The mean infusion rate for Study 2 was $6.8 \mu\text{g} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ producing an average [ALF] = $2185 \pm 62 \text{ ng} \cdot \text{ml}^{-1}$. The highest [ALF] at which no response occurred was statistically different between the groups for all stimuli, both discrete and repetitive (Table).

Discussion

Anaesthetic conditions were satisfactory when a large premedicant dose of lorazepam ($0.08 \text{ mg} \cdot \text{kg}^{-1}$) was used in combination with [ALF] in the range of $1000\text{--}1400 \text{ ng} \cdot \text{ml}^{-1}$. These observations are consistent with those of de Lange and de Bruijn.² After a lower lorazepam dose ($0.04 \text{ mg} \cdot \text{kg}^{-1}$), [ALF] up to $4600 \text{ ng} \cdot \text{ml}^{-1}$ failed to prevent haemodynamic and somatic responses to noxious stimulation. It seems likely that in the absence of substantial premedication, alfentanil alone (or in

TABLE Highest [ALF] associated with no response to stimulation (mean $\pm$ SEM)

Event/stimulus	Study 1		Study 2	
	n	[ALF]	n	[ALF]
LOC	6	1194 ± 257	13	$2481 \pm 197^*$
Intubation	6	$1803 \pm 484^\dagger$	11‡	$2782 \pm 182^*$
SS	5‡	1064 ± 130	4‡	$2208 \pm 181^*$
Bovie	6	1130 ± 140	13	$1846 \pm 87^*$

* $p < 0.05$ vs Study 1.

† $p > 0.2$ vs any other [ALF] in Study 1.

‡Responses were observed in one patient after SS in Study 1 and in two patients after intubation and seven patients after SS in Study 2.

combination with muscle relaxants) would be insufficient to maintain general anaesthesia in human patients. This conclusion is supported by the observation in dogs that narcotics are capable of reducing MAC for enflurane by only 70 per cent.³

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Sufentanil for coronary artery bypass graft surgery: the Canadian experience

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It has been suggested that the increased potency of the newer synthetic opioids results in increased haemodynamic stability and decreased side-effects.¹ Sufentanil is a new thienyl derivative of fentanyl that has approximately five to ten times its analgesic potency. Recent evidence indicates that it provides greater haemodynamic stability than high-dose fentanyl during coronary artery bypass surgery.^{2,3} This is the report of a multi-centre study to evaluate the safety and efficacy of sufentanil (Phase 4 Canadian Clinical Trial) used in patients undergoing coronary artery bypass graft surgery (CABG).

Methods

Patients scheduled for CABG surgery were entered into the study where each participating anaesthetist was asked to perform five anaesthetic procedures. Preoperative administration of cardiac medications and premedication was according to the custom of the institution. After insertion of routine monitoring lines, baseline haemodynamic values were recorded. Anaesthesia was induced with sufentanil ($10 \mu\text{g} \cdot \text{kg}^{-1}$) administered over four minutes and pancuronium ($0.1 \text{ mg} \cdot \text{kg}^{-1}$) for muscle relaxation. Additional doses of $5-10 \mu\text{g} \cdot \text{kg}^{-1}$ of sufentanil were given immediately prior to skin incision (2nd dose), and sternotomy (3rd dose). During maintenance of anaesthesia further supplemental doses of sufentanil ($50 \mu\text{g}$) or a volatile agent were given to treat an adverse reaction to surgical stimulus. Heart rate (HR), systolic, diastolic and mean arterial blood pressures (SBP, DBP and MAP) were recorded at specific intervals during the prebypass period. Duration of anaesthesia and surgery, time to arousal, response to verbal commands and extubation were recorded. All adverse reactions were documented and classified as either disturbing, non-disturbing, drug-related or non-drug-related. Each anaesthetic was rated by the anaes-

thetist as either good, satisfactory or bad. Measures of cardiovascular haemodynamics were analysed using ANOVA and Student's *t* test with the Bonferroni correction for multiple comparison. The anaesthetists' ratings were tested for quality of proportion using the goodness-of-fit test and Chi-square analysis. After analysis of the recorded data as a total, population group patients were placed into two groups: Group I those who had not received any additional volatile anaesthetics and Group II those who had. These two groups were compared using the same statistical analysis as above. The null hypothesis was rejected when $p < 0.05$.

Results

In this study 177 patients were included by 56 anaesthetists in 19 centres. The mean initial dose of sufentanil was $10.2 \mu\text{g} \cdot \text{kg}^{-1}$ with a mean total dose of $24.2 \mu\text{g} \cdot \text{kg}^{-1}$. HR was significantly increased from baseline at one minute after induction, intubation and at aortic dissection. SBP decreased significantly at all time intervals. Over 90 per cent of the anaesthetics were rated by the anaesthetists as being either good or satisfactory which was a significantly higher incidence than would have been expected by chance. No adverse reactions were experienced by 41.8 per cent of patients. Of those reported, only 13.8 per cent were classified as possibly "drug related" and of "disturbing" severity. Within this sub-category reported experiences were: tachycardia (7 pts), hypotension (6 pts), hypertension (4 pts), chest wall rigidity (3 pts), nausea (2 pts) and bradycardia (1 pt). Of the 177 patients, 107 (60.5 per cent) were given additional inhalational agents during the surgical procedure (Group II). They had a significantly higher HR and SBP from baseline to sternotomy. The time to arousal (3.76 hr), time of response to verbal commands (4.91 hr) and time to extubation (19.02 hr) was comparable in both groups. No patient had any recollection of the operation.

Discussion

The outstanding finding of this multi-centre study was the high degree of acceptance by the anaesthetists in spite of the marked diversity in preoperative medications and cardiac drug regimens. The low incidence of side effects during this study demonstrates the safety of this technique. There were, however, 23 reported drug-related disturbing events in 19 patients among which cardiovascular instability predominated. However, increases in SBP and HR were similar to those experienced with high-dose fentanyl.⁴ Hypotension may have been accentuated by decreases in SVR from preoperative medications. Other adverse reactions attributed to the drug were rare and of no consequence. The high incidence of the use of volatile drugs in this study may suggest that many anaesthetists electively used this method to prevent hypertension and tachycardia. This is supported by the significantly higher baseline HR and SBP in patients who received volatile drugs compared to those who did not. We conclude that the absence of awareness, high degree of anaesthetist compliance and low incidence of disturbing drug-related side effects in this multi-centre trial indicates that sufentanil, as used in this study, is a safe and effective anaesthetic for CABG surgery.

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The effect of different rates of administration of pancuronium on the incidence of myocardial ischaemia during induction for coronary artery bypass graft

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Recent studies have suggested that the use of pancuronium in patients for coronary artery bypass graft surgery (CABG) may be undesirable^{1,2} due to the possible tachycardia caused by its effect on noradrenaline reuptake.³ This effect may be further accentuated by the catecholamine releasing effect seen during the early administration of high-dose narcotic anaesthesia.⁴ Hypertension and tachycardia, which may occur during the concomitant administration of these two drugs, has been implicated as a cause of prebypass myocardial ischaemia (PBI). It may be possible to avoid this synergistic effect on the sympathetic nervous system by slowing the rate of administration of pancuronium. This study was designed to compare the effect of the rate of injection of pancuronium on the incidence of haemodynamic responsiveness and myocardial ischaemia during induction of anaesthesia for CABG.

Methods

Forty-eight patients scheduled for elective CABG surgery were studied. Cardiac medications were continued up to the time of surgery and all patients received the standard premedication of diazepam, morphine and scopolamine. A Holter monitor recording modified V₆ and V₉ leads was run from prior to entry into the OR until the start of CPB to detect left ventricular ischaemia. Routine monitoring lines were inserted under local anaesthesia. Induction of anaesthesia was with fentanyl 40 µg·kg⁻¹ given over three minutes. The total dose (t_d) of pancuronium was 0.15 mg·kg⁻¹. All patients received 0.2 × t_d 1 min before the start of induction. In a randomized double-blind fashion patients received at loss of consciousness either 0.8 × t_d over 10 sec followed by a 5 min infusion of an equal volume of saline (Group PF) or a bolus of saline followed by a 5 min infusion of 0.8 × t_d (PS). Haemodynamic measurements were recorded before induction (baseline), 1 min post-induction (IND), post-intubation (INT), post-sternotomy (STERN) and at aortic dissection (AoD). Hypertension (20 per cent above ward values)

and tachycardia (HR > 90 BPM) were treated with enflurane and propranolol respectively. Differences between and within the groups were compared using ANOVA and Student's t test with the Bonferroni correction for multiple comparisons. The incidence of ischaemia in each group was compared using Chi-square analysis. The null hypothesis was rejected when p < 0.05.

Results

Five patients (10.4 per cent) developed myocardial ischaemia during induction: three in group PS (13 per cent) and two in group PF (eight per cent) (X²:NS). In all five patients these periods of ischaemia were associated with hypertension and in four of the five with concomitant tachycardia. All five patients were receiving chronic calcium channel blockers but only two chronic beta adrenergic antagonists (28 per cent). This is in marked contrast to the 78 per cent taking long-term beta blockers in those patients who did not have PBI (X² 0.02 < p < 0.05). Of the five patients with PBI one developed a possible postoperative myocardial infarction (PMI) (20 per cent) compared to four patients with no PBI. Three patients had a period of ischaemia during insertion of monitoring lines also associated with haemodynamic abnormalities which did not continue up to induction. Two of these three patients developed a further episode of PBI during induction. Only one other patient had a period of PBI not related to induction. Compared to baseline values the heart rate (HR) rose significantly in Group PF at IND and INT but had returned to baseline values by STERN. In Group PS HR was only significantly increased at INT. There were no other significant differences in haemodynamic data in either group during IND or INT nor were there any significant differences between the two groups at any time. There was no significant difference in the use of propranolol nor enflurane between the two groups.

Discussion

We had postulated that by separating the synergistic effects of pancuronium and fentanyl on the sympathetic nervous system, one might reduce the incidence of hypertension and tachycardia previously reported with the use of this combination. We were unable to show any difference in the incidence of PBI at induction between the two methods. However, in contrast to a recent clinical report by Slogoff *et al.*,⁵ all patients with PBI developed hypertension and four of the five tachycardia associated with the ischaemic period. There was a significantly greater incidence of these haemodynamic abnormalities in patients who were not receiving long-term beta blockade therapy preoperatively. We conclude that it is more the presence or absence of adequate preoperative beta blockade than the method of administration of the muscle relaxant that is important in the aetiology of PBI.

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Myocardial metabolism and haemodynamic responses with fentanyl-isoflurane anaesthesia for hypertensive coronary patients

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Treated hypertensive patients needing coronary vein grafts (CABG) are at risk of ischaemia from elevated BP during anaesthesia. We have reported that with moderate dose fentanyl plus either halothane¹ or enflurane² in these patients, BP can be kept at or below normal and myocardial O₂ balance preserved. Evidence of ischaemia (myocardial lactate production - MLP) was infrequent. Fentanyl-isoflurane in normotensive CABG patients³ produces more MLP post-bypass than the other regimens. This report is of haemodynamic and myocardial O₂ effects in hypertensive CABG patients studied before, during and after fentanyl-isoflurane anaesthesia.

Methods

Eleven (9 male, 2 female) patients (means 58 yr, 81 kg) gave informed consent. All needed CABG but had ventricular func-

tion preserved (means EF = 0.73, LVEDP = 12 mmHg). Beta (ten patients), Ca (eight patients) blockers and a diuretic (three patients) were maintained preoperatively. Ten patients had Class III or IV disability. Premedication was with diazepam (mean dose 12 mg) and morphine (mean 13 mg). In the OR with the patients awake, a radial artery catheter, PA and coronary sinus catheters were placed as previously described.¹⁻³ Variables were measured and calculated serially (see Table).

Induction began with fentanyl (30 µg·kg⁻¹), pancuronium (0.1 mg·kg⁻¹) and O₂ followed by isoflurane to reduce BP 27 per cent before intubation. Maintenance was with isoflurane alone to keep BP below the awake level.

Results

Heart rate remained slow prebypass; mean BP fell on induction and was kept below that awake. Cardiac index decreased by sternotomy and SVR then increased. Coronary sinus flow and CVR did not change. CSO₂ content rose on induction as stroke work fell. MLP in one patient awake became greater after induction; otherwise extraction continued prebypass. MLP was present after bypass in more patients than with other regimens. NTG was infused in all patients in the ICU; six also needed nitroprusside for BP control.

Discussion

Fentanyl-isoflurane effectively maintained BP below that awake with adequate preservation of myocardial O₂ balance prebypass in long-term hypertensive patients. Postbypass, a high incidence of ischaemia (i.e., MLP) occurred, as seen in normotensive patients,³ not accompanied by ST depression. The possibility of a different effect of isoflurane on the coronary bed is thus supported.

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TABLE Results (mean ± SD)

n = 11	Awake	Post-induction	Post-intubation	After sternotomy	Post-bypass	Chest closed	Postoperative	
							1 hour	24 hours
Rate beats·min ⁻¹	61 ± 9	63 ± 9	62 ± 8	54 ± 8	77 ± 10*	73 ± 11*	80 ± 12*	91 ± 13*
MAP mmHg	96 ± 6	70 ± 6*	74 ± 9*	82 ± 11*	70 ± 7*	85 ± 11*	92 ± 17	83 ± 10*
PC wedge pressure mmHg	16 ± 3	11 ± 8	10 ± 4	7 ± 3	16 ± 7	12 ± 4	12 ± 5	12 ± 6
Cardiac index L·min ⁻¹ ·m ⁻²	3.12 ± 0.41	2.75 ± 0.47	2.7 ± 0.67	2.0 ± 0.49*	2.39 ± 0.63*	2.21 ± 0.58*	2.29 ± 0.88*	2.94 ± 0.54
Stroke work index g·m ⁻²	80.8 ± 10.5	48.9 ± 10.5*	53.5 ± 16.9*	52 ± 17.3*	31.5 ± 10.1*	38.6 ± 8.4*	41.7 ± 12.6*	41.6 ± 4.8*
Syst. vasc. resist. dyne·sec·cm ⁻⁵	1228 ± 308	1016 ± 308	1135 ± 400	1741 ± 428*	1158 ± 350	1531 ± 563	1729 ± 759*	1140 ± 300
CSBF ml·min ⁻¹	146 ± 54	110 ± 54	127 ± 50	95 ± 57	140 ± 87	138 ± 75	191 ± 87	173 ± 66
Cor. vasc. resist. dyne·sec·cm ⁻⁵	0.92 ± 0.36	0.72 ± 0.36	0.67 ± 0.41	1.34 ± 1.2	0.57 ± 0.28	0.70 ± 0.40	0.52 ± 0.22	0.48 ± 0.16
CSO ₂ content ml·dl ⁻¹	6.9 ± 2.2	9.3 ± 2.2*	8.6 ± 2.1*	8.2 ± 1.1	5.5 ± 1.4	6.7 ± 2.1	6.7 ± 1.9	8.9 ± 2
MVO ml·min ⁻¹	13.5 ± 4.5	9.1 ± 4.5	9.6 ± 3.9	7.4 ± 5.2	6.4 ± 4*	6.5 ± 4.9	10.4 ± 4.3	10.6 ± 5.2
Art. lactate mEq·L ⁻¹	1.0 ± 0.51	1.13 ± 0.51	1.16 ± 0.43	1.48 ± 0.59*	2.30 ± 0.89*	1.90 ± 0.85*	1.78 ± 0.76*	1.19 ± 0.67
CS lactate mEq·L ⁻¹	0.9 ± 0.55	1.0 ± 0.55	0.8 ± 0.26	1.1 ± 0.6	2.4 ± 0.74*	1.9 ± 0.76*	1.8 ± 0.72*	1.1 ± 0.69
Lactate extraction %	+14.8	+1.2	+17.6	+25.1	-13.1*	-7.4*	-4.8*	+1.3*
No. hearts producing lactate	1/11	1/11	1/11	0/10	5/10	5/8	3/10	3/9

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Pulmonary dysfunction after cardiopulmonary bypass

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Noncardiogenic pulmonary oedema has been demonstrated in a significant number of patients after cardiopulmonary bypass. Pulmonary dysfunction after cardiopulmonary bypass may be the result of complement activation resulting in increased pulmonary capillary permeability and increased lung water.¹

Methods

Thirty patients with good left ventricular function undergoing elective aortocoronary bypass surgery were studied. Utilizing a standard anaesthetic technique, Swan Ganz and femoral arterial lung water catheters were inserted in all patients. Extravascular lung water (EVLW) was measured by the double indicator dye dilution technique after induction of anaesthesia, but before institution of cardiopulmonary bypass (CPB), after the operation when the patient was stable in the Intensive Care Unit, again 12 hours post-bypass and then 12h as long as significant pulmonary dysfunction existed ($Q_s/Q_t > 0.20$). Pulmonary and systemic pressures as well as cardiac outputs were measured. Pulmonary capillary wedge pressures were maintained in the normal range in all patients during the course of the study. Blood gases (arterial and mixed venous) were drawn for calculation of intrapulmonary shunt (Q_s/Q_t). Complement levels (C3a) were measured with the baseline EVLW determination pre CPB, then serially 10 min, 30 min and 60 min on CPB, 10 min after protamine sulfate administration and then serially along with EVLW determinations in the Intensive Care Unit.

Results

Forty-two per cent of patients exhibited pulmonary dysfunction (Group II, $Q_s/Q_t > 0.20$) post-CPB; however, no significant difference was demonstrated in EVLW at one hour and EVLW was significantly decreased at 12 hours compared with pre-bypass measurements (Table I).

Significant elevation of complement was seen during CPB but had returned to baseline by 12 hours post-CPB. There was, however, no significant difference in C3a between the no pulmonary dysfunction group (Group I no $Q_s/Q_t > 0.20$) and Group II at any time period (Table II). Patients in Group II exhibited maximum C3a post-CPB and significant correlation was seen with max C3a post-CPB and total pump time.

TABLE I Extravascular lung water ($\text{ml} \cdot \text{kg}^{-1}$)

	Baseline	1 hr post-CPB	10 hr post-CPB
Group I	6.49	6.6	5.4
Group II	5.73	5.8	4.7

TABLE II C3a ($\text{ng} \cdot \text{ml}^{-1}$)

	Time during bypass (min)			Post-bypass (hr)		
	10	30	60	Protamine	1 hr	10 hr
Group I	921	2324	3054	3312	2203	330
Group II	760	1942	2153	2950	1349	297

Discussion

Complement activation is associated with cardiopulmonary bypass. However, this did not result in an increase in extravascular lung water in the presence of normal hydrostatic pressures. Pulmonary dysfunction did occur in 42 per cent of the patients studied but does not appear to be related to loss of pulmonary microvascular integrity as evidenced by increased lung water.

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Effect of sufentanil on regional myocardial metabolism during acute ischaemia in dogs

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We evaluated the effect of sufentanil on haemodynamic function, regional myocardial metabolism, and extracellular acid-base and electrolyte balance during ischaemia produced by left anterior descending coronary artery (LAD) occlusion (LAD-O).

Methods

Fourteen dogs were anaesthetized with chloralose, intubated, and ventilated. Catheters were introduced into the pulmonary artery (PA) and aorta (Ao) from the femoral vein and artery. After a left thoracotomy, the LAD was isolated proximal to the first apical diagonal branch. The left ventricle (LV) was cannulated with a transducer-tipped catheter to measure LV pressure and LV dP/dt. Catheters (24-ga) were placed into the distal LAD, into the adjacent coronary vein (LADv), and into a distal circumflex vein (CFXv). Each experiment contained two observation periods separated by a 60-min reperfusion interval. In each observation period measurements and samples were obtained before and during LAD-O (15 min). Sufentanil ($10 \mu\text{g} \cdot \text{kg}^{-1}$)

TABLE Lactate and K changes during LAD occlusion with and without sufentanil (mean $\pm$ SEM)

	Period 1		Period 2	
LADv lactate (mg%)				
C	13.1 $\pm$ 3.4	39.5 $\pm$ 4.9*	13.8 $\pm$ 2.4	39.3 $\pm$ 4.8*
S	8.1 $\pm$ 1.5	32.7 $\pm$ 5.6*	7.5 $\pm$ 2.0	47.7 $\pm$ 7.0††
CFXv lactate (mg%)				
C	14.1 $\pm$ 2.9	12.1 $\pm$ 4.6‡	10.2 $\pm$ 3.6	13.1 $\pm$ 3.6‡
S	7.2 $\pm$ 1.0	11.9 $\pm$ 3.0‡	7.9 $\pm$ 1.1	16.2 $\pm$ 4.1‡
LE (%)				
LADv				
C	32.4 $\pm$ 7.3	-127.7 $\pm$ 22.4*	16.0 $\pm$ 4.7	-182.0 $\pm$ 53.4*
S	25.3 $\pm$ 7.0	-156.4 $\pm$ 28.2*	28.5 $\pm$ 11.7	-278.3 $\pm$ 41.7*†
Ao/CFXv				
C	20.9 $\pm$ 6.3	39.9 $\pm$ 12.7‡	37.8 $\pm$ 15.6	9.6 $\pm$ 10.2‡
S	18.8 $\pm$ 5.7	-18.9 $\pm$ 30.7‡	17.3 $\pm$ 7.1	-52.1 $\pm$ 41.6‡
LADv K (mEq·L ⁻¹)				
C	2.9 $\pm$ 0.2	3.3 $\pm$ 0.3	3.1 $\pm$ 0.1	4.0 $\pm$ 0.3*†
S	4.1 $\pm$ 0.3	4.5 $\pm$ 0.4	4.1 $\pm$ 0.3	5.8 $\pm$ 0.7*†

* $p < 0.05$ when compared with corresponding before LAD-O value.

† $p < 0.05$ when compared with the change in period one for the same subgroup.

‡ $p < 0.05$ when compared with corresponding LADv or LAD/LADv value.

Abbreviations are defined within the text.

was given to seven of the dogs (S) over 15 min before the second ischaemic period and the seven other dogs (C) received no further treatment. An atrial pacemaker was used to maintain heart (HR) after sufentanil. HR, ECG, Ao and LV pressures, and LV dP/dt were recorded continuously and cardiac output (CO) was measured before and during LAD-O by thermodilution. Also, blood was sampled from the Ao, LAD, LADv, and CFXv before and during LAD-O for measurement of blood gas tensions and lactate, glucose, hydrogen ion, sodium and potassium (K) concentrations, and for calculation of base excess (BE).

Results

Haemodynamic, metabolic, electrolyte, and acid-base data obtained before LAD-O were the same in both observation periods and in both groups. Systolic LV and coronary perfusion pressures and systemic vascular resistance decreased during LAD-O after sufentanil, but CO, HR, and LV dP/dt were unchanged. Glucose extraction, arteriovenous O₂ content difference, PvCO₂, pHv, and BE during LAD-O were not altered by sufentanil. Although during each LAD-O period lactate extraction (LE) became negative (net production), this was greatest following sufentanil (Table). LAD-O increased K in LADv samples in both groups, but the increase was greatest during period two.

Discussion

The principal finding of this investigation is the increased lactate production during ischaemia, in association with decreased coronary perfusion pressure, when animals receiving sufentanil are compared with animals treated similarly but without sufentanil.

Premedication and high-dose fentanyl anaesthesia for myocardial revascularization

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Narcotics, antimuscarinics, and sedative-hypnotics are used for premedication in patients having myocardial revascularization under high-dose fentanyl anaesthesia. Information about the efficacy and effects of various premedications is scanty. This study compares two commonly used regimens.

Methods

After institutional approval and informed consent 42 patients with ejection fractions (EF) ≥ 0.40 undergoing elective coronary surgery entered a randomized, double-blind, placebo-controlled experiment. Group L ($n = 23$) received lorazepam 0.06 mg·kg⁻¹ PO 90 min, and Group M ($n = 19$) morphine 0.1 mg·kg⁻¹ IM plus scopolamine 0.006 mg·kg⁻¹ IM 60 min preoperatively. In the operating room ECG leads II and CS5 were attached. Intravenous, arterial, and pulmonary arterial catheters were inserted. Fentanyl 100 μ g·kg⁻¹ and atracurium 0.50 mg·kg⁻¹ were then infused IV over 10 min. End-tidal CO₂ was monitored throughout. Patients were ventilated with 100 per cent oxygen after loss of consciousness (LOC), and intubated after fentanyl infusion. Rigidity was scored on a scale of one to three. Sedation and anxiety were rated, using objective criteria, by patient, investigator, and anaesthetist. Haemodynamics were measured at: (1) control, (2) end-induction, (3) intubation, (4) sternotomy, (5) sternal spread. Blood for serum fentanyl (F) determination by gas chromatography with nitrogen phosphorus detection, was drawn at times 1, 3, and 5. Analysis of variance (ANOVA) was used to compare haemodynamics in Groups L and M, and the Least Squares Means Test with Bonferroni's correction, for multiple comparisons. Elsewhere, Student's *t* test, Chi-square analysis, Fischer's Exact test, and Rank-Sums Test, were used as appropriate. A *p* value ≤ 0.05 was considered significant.

Results

Preoperatively Groups L and M were identical in age, sex, weight, EF, LVEDP, heart rate (HR) and systolic arterial pressure (SAP). The groups did not differ in sedation or anxiety either before or after premedication. On induction, LOC occurred at similar times (Group L 108 $\pm$ 21 sec, Group M 110 $\pm$ 36 sec). There was a trend ($p = 0.12$) to less rigidity in Group L. Premedication significantly altered control HR, and the haemodynamic response to induction (Table). After sternotomy haemodynamics were identical in both groups. At time 2 increases in SAP of ≥ 20 per cent of control were significantly more frequent (4 vs 0) in Group M, but decreases were more frequent (10 vs 3) in Group L. Hyperdynamic responses to intubation or surgery requiring intervention occurred in 11 Group L and 8 Group M patients ($p = ns$). Serum [F] was significantly higher in Group L at time 3 (110 $\pm$ 44 vs 89 $\pm$ 30 ng·ml⁻¹). One Group M patient recalled intubation. No patient had new ECG ST-depression of 0.1 mV or more.

TABLE Results (mean $\pm$ SD)

		Time		
		1	2	3
HR $\cdot \text{min}^{-1}$	L	54 $\pm$ 9*	51 $\pm$ 12*	51 $\pm$ 12*
	M	59 $\pm$ 13	61 $\pm$ 11	62 $\pm$ 11
SAP mmHg	L	147 $\pm$ 27	130 $\pm$ 26*†	128 $\pm$ 30*†
	M	144 $\pm$ 24	147 $\pm$ 22	149 $\pm$ 26
CI $\text{L} \cdot \text{min}^{-1}$	L	2.47 $\pm$ 0.49	2.15 $\pm$ 0.59*†	2.12 $\pm$ 0.55*†
	M	2.45 $\pm$ 0.69	2.53 $\pm$ 0.70	2.44 $\pm$ 0.71

		Time	
		4	5
HR $\cdot \text{min}^{-1}$	L	48 $\pm$ 12†	50 $\pm$ 13
	M	52 $\pm$ 9†	52 $\pm$ 9†
SAP mmHg	L	140 $\pm$ 27	137 $\pm$ 27
	M	140 $\pm$ 16	140 $\pm$ 26
CI $\text{L} \cdot \text{min}^{-1}$	L	2.02 $\pm$ 0.39†	2.03 $\pm$ 0.47†
	M	2.00 $\pm$ 0.46†	2.00 $\pm$ 0.57†

$p \leq 0.05$, *Between groups, †vs time 1.

Discussion

Both regimens produced equivalent anxiolysis and sedation. Since the incidence of hyperdynamic responses to noxious stimuli was identical, and no ECG changes occurred, neither regimen was clearly superior. However, lorazepam premedication reduced HR preinduction and decreased HR, AP and cardiac index (CI), after induction and intubation. The higher serum [F] at intubation in Group L probably reflects the pharmacokinetic result of a decreased CI. Cardiovascular depression in Group L after induction likely reflects a sympatholytic response to lorazepam-fentanyl similar to that seen after IV diazepam.¹ In addition, scopolamine may have exerted an independent haemodynamic effect in Group M. Based on these results with fentanyl and atracurium, we expect that premedication would exert an effect of similar magnitude during induction with other narcotic-relaxant combinations. If so, conflicting reports regarding the haemodynamic response to induction with specific narcotic-relaxant combinations may be easily resolved.

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Alpha₂ adrenoceptor stimulation increases regional spinal cord blood flow

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Recent studies have demonstrated that the vasoconstrictive response to exogenous catecholamines may be mediated primarily via post-synaptic alpha₂ adrenoceptor stimulation.¹ Intrathecal norepinephrine and epinephrine (exogenous catecholamines which possess combined α_1 and α_2 adrenoceptor agonist properties), however, do not produce spinal cord arteriolar vasoconstriction, and may produce vasodilation.² The reason for the apparent paradoxical response of the spinal cord vasculature to exogenous intrathecal catecholamines remains an enigma. In an attempt to define the role of exogenous adrenoceptor agonists on the spinal cord vasculature, the effects of clonidine (a primary α_2 adrenoceptor agonist) were studied in the canine model.

Methods

Eleven mongrel dogs weighing 18-23 kg were anaesthetized with pentobarbitone, intubated, and ventilated with an $\text{FiO}_2 = 1.0$ to a PaCO_2 of 35-42 mmHg. The radioactive microsphere technique was used for spinal cord blood flow (SCBF) measurements. ¹⁴¹Cerium, ⁵¹Chromium or ⁸⁵Strontium labelled 15 $\pm$ 0.5 micron microspheres were injected through a left ventricular catheter and sampled from an aortic arterial catheter. Haemodynamic measurements were made using an aortic arterial line and a Swan-Ganz thermodilution catheter. Following completion of the surgical preparation and stabilization of PaCO_2 , pH, temperature, and blood pressure a control SCBF measurement was made. The animals were randomized into two groups. Dogs in Group I received clonidine 150 μg (5 ml) intrathecally at the L₅-L₆ or L₆-L₇ interspace, while dogs in Group II received clonidine 150 μg intravenously infused over 20 minutes. Intravenous 0.9 per cent saline solution was administered to maintain central venous pressure at control values. Repeat determinations of SCBF were performed at 20 and 40 minutes following either intrathecal injection or completion of intravenous infusion.

The data were analyzed using repeated measures and one way ANOVA with individual comparisons being performed using Duncan's Test. A value of $p < 0.05$ was considered statistically significant.

Results

Summarized in the Table.

Intrathecal clonidine produced a significant reduction in MABP (118 ± 3 vs 94 ± 6 mmHg, $p < 0.01$) without significantly affecting CO (3.5 ± 0.5 vs $2.8 \pm 0.6 \text{ L} \cdot \text{min}^{-1}$) or SVR (37 ± 5 vs 37 ± 6 units) at 20 min after administration. Intravenous clonidine did not affect MABP (126 ± 3 vs 122 ± 4 mmHg), but produced a significant reduction in CO (4.1 ± 0.7 vs $2.5 \pm 0.3 \text{ L} \cdot \text{min}^{-1}$, $p < 0.01$) and a significant increase in SVR

TABLE Spinal cord blood flow ($\text{ml} \cdot 100 \text{ gm}^{-1} \cdot \text{min}^{-1}$) (mean $\pm$ SEM)

	Intrathecal clonidine (n = 5)			Parenteral clonidine (n = 5)		
	Control	20 min	40 min	Control	20 min	40 min
Cervical	19 $\pm$ 4	16 $\pm$ 3	14 $\pm$ 3	16 $\pm$ 3	19 $\pm$ 4	16 $\pm$ 3
Upper thoracic	19 $\pm$ 4	16 $\pm$ 3	16 $\pm$ 3	24 $\pm$ 5	28 $\pm$ 3	21 $\pm$ 3
Middle thoracic	18 $\pm$ 2	27 $\pm$ 8	25 $\pm$ 5	20 $\pm$ 3	15 $\pm$ 2	15 $\pm$ 2
Lower thoracic	15 $\pm$ 3	32 $\pm$ 9	29 $\pm$ 7	19 $\pm$ 5	15 $\pm$ 1	15 $\pm$ 3
Lumbo-sacral	24 $\pm$ 2	34 $\pm$ 5	39 $\pm$ 7*	22 $\pm$ 4	21 $\pm$ 4	18 $\pm$ 3

*p < 0.05 compared to control.

(34 $\pm$ 5 vs 51 $\pm$ 6 units, p < 0.05) at 20 min. Blood flow to the five regions of the spinal cord examined was, however, not altered by intravenous clonidine. Intrathecal clonidine had a tendency to increase mid-lower thoracic and lumbo-sacral spinal cord blood flow, however only at 40 min post-injection did lumbo-sacral SCBF increase significantly (p < 0.05).

Conclusions

The present study indicates that regional spinal cord α_2 adrenoceptor stimulation with intrathecal clonidine increases canine lumbo-sacral SCBF. The data suggests that the α_2 adrenoceptor appears responsible for the increase in SCBF following intrathecal catecholamines. Further work is required to validate the conclusions and to resolve the enigma of why intrathecal exogenous catecholamines do not produce spinal cord vasoconstriction.

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The effect of local anaesthetics on epinephrine absorption following rectal mucosal infiltration

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Mucosal infiltration of epinephrine in local anaesthetic solutions is employed clinically to optimise local haemostasis, prolong analgesia and reduce systemic toxic effects of local anaesthetics. The effect of local anaesthetics on the absorption of epinephrine is uncertain. A recent study by Ueda *et al.*¹ concluded that lidocaine accelerates the absorption of epinephrine and postulates the vasodilatory effect of lidocaine to be the reason. The objectives of this study were to investigate the effect of lidocaine and bupivacaine on the absorption of epinephrine; to study the systemic absorption of the local anaesthetic employed; and to assess the cardiovascular and metabolic

FIGURE 1 Plasma epinephrine levels.

effects of absorbed epinephrine following rectal mucosal infiltration.

Methods

Three groups of five dogs, weighing 23–33 kg, received $1.5 \mu\text{g} \cdot \text{kg}^{-1}$ of 1:200,000 epinephrine in either normal saline, 0.5 per cent bupivacaine or 0.5 per cent lidocaine. Following induction of anaesthesia with thiopentone $20 \text{ mg} \cdot \text{kg}^{-1}$ IV and intubation, normocapnic ventilation with 1.5 per cent halothane in oxygen was employed to maintain anaesthesia. Following a five-minute interval after cannulation of the femoral artery, baseline arterial blood samples were taken for plasma epinephrine, local anaesthetic, glucose, lactate and potassium determinations. Further samples were taken at 1, 2, 5, 10, 15 and 30 minutes after rectal mucosal infiltration of each epinephrine-containing solution. Blood pressure and heart rate were recorded at each sampling time. Circulating catecholamine concentrations were determined by high-performance liquid chromatography with electrochemical detection. Data were analysed by paired Student's t test and analysis of variance. P < 0.05 was considered significant.

Results

The rectal mucosal infiltration of $1.5 \mu\text{g} \cdot \text{kg}^{-1}$ epinephrine was not associated with dramatic rises in circulating plasma epinephrine concentrations in any of the study groups (Figure 1). The plasma epinephrine level in the lidocaine group was, however, significantly higher at one and two minutes following infiltration compared to the bupivacaine and saline groups. Plasma bupivacaine levels were significantly higher than plasma lidocaine levels at 5, 10, 15 and 30 minutes following infiltration (Figure 2). There was no significant differences in metabolic and biochemical indices between the three treatment groups.

Discussion

Mean plasma epinephrine and local anaesthetic concentrations following rectal mucosal epinephrine infiltration were much lower than reported data from studies using other infiltration sites.² Following rectal mucosal infiltration, a significant pro-

FIGURE 2 Plasma lidocaine and bupivacaine levels.

portion of the rectal venous drainage may enter the portal circulation³ resulting in lower plasma concentrations and thus lower bioavailability due to first pass metabolism. Bupivacaine is more highly protein-bound and undergoes less hepatic degradation than lidocaine and thus has a greater bioavailability. This study confirms the enhanced epinephrine systemic absorption in association with 0.5 per cent lidocaine solution. Local anaesthetic-epinephrine rectal mucosal infiltration during ano-rectal procedures are less likely to produce untoward haemodynamic or metabolic effects compared with other infiltration sites.

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Dual peribulbar block, a safe method of regional anaesthesia for ophthalmic surgery, with improved standards of patient comfort: a report of 3,500 administrations

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Traditional regional anaesthesia methods for ophthalmic surgery use a retrobulbar block with local anaesthetic drug to achieve an anaesthetic and akinetic globe, and a separate seventh nerve block outside the orbit to obtain akinesia of the lids and periorbital musculature. These blocks include two painful transcutaneous injections often requiring the use of preoperative sedation and carry the risk of retrobulbar haemorrhage, optic nerve damage, optic atrophy, scleral puncture and brain stem anaesthesia.

Thirty-five hundred cases of dual peribulbar block are reported, in which, because there was minimal discomfort for the

TABLE The incidence of complications, including orbital haemorrhage, extraocular muscle paresis, and vasovagal problems, and the overall success rate of the block compared with more traditional methods

	Low-volume retrobulbar with separate 7th nerve block	High volume retrobulbar	Dual peribulbar
Patients	1025	486	1614
% given sublingual lorazepam	Not recorded	5.6%	4.7%
Vasovagal problems	0.29%	0.73%	0.44%
Retrobulbar haemorrhage	Not recorded	3.29%	0.74%
Lid ecchymosis and conjunctival haemorrhage	—	—	1.36%
Block score:			
Excellent	90.05%	90.77%	88.10%
Good	6.44%	6.22%	10.29%
Fair	3.51%	3.01%	1.61%
Block supplement required	19.8%	9%	In orbit 13.2% Lower lid 7.9%
Extraocular muscle paresis	Not seen	6 patients	Not seen
Brain stem anaesthesia	5 patients (faulty technique)	Not seen	Not seen

patient, sedatives were required in less than five per cent. By omitting sedation, drug side effects such as respiratory depression, emetic sequelae, and postural hypotension were avoided.

A local anaesthetic mixture containing 0.5 per cent bupivacaine, 0.6 per cent lidocaine, hyaluronidase 5 units ml^{-1} and epinephrine 1:600,000 was used.

Dual peribulbar block embraces the tissue compartment concept of regional nerve blocking. The technique consists of two injections through a 27-gauge 38 mm disposable needle into the extramuscular orbital fat compartment, the first infero-lateral to the globe and the second supero-medial to the globe. The first is through the inferior fornix of the conjunctiva, previously topicalized with local anaesthetic drops, and the second, two minutes later, is through the now anaesthetized upper lid. An orbital compression device, the "Super Pinky" ball, is applied to the front of the orbit for 30 to 60 minutes following the block. This results in the reduction of orbital and intraocular pressures and in the spread of the local anaesthesia drugs from their initial placement in the orbit out to the periorbital muscles, resulting in excellent surgical conditions and patient comfort.

Brachial plexus block and chronic renal failure

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Since 1972 it has been generally accepted that brachial plexus blocks have a shorter duration (38 per cent) in patients with chronic renal failure when the supra-clavicular approach is used.¹ We had the impression that such a difference was not present with the axillary approach. The present prospective study compares the latency and duration of analgesia after axillary block between patients with chronic renal failure and patients without chronic renal failure.

Methods

Sixty-seven patients of both sexes were studied. Thirty patients had chronic renal failure and 37 had normal renal function. The mean age was 52 years for patients with chronic renal failure and 51 years for patients with normal renal function.

A standardized axillary block was performed on all patients, with the assistance of a neurostimulator.¹ The local anaesthetic used was lidocaine CO₂ one per cent with epinephrine 1:200,000. The total volume was 30 ml per square metre of body surface with 75 per cent of the volume injected in equal parts on the two principal nerves implicated with the surgery site and the other 25 per cent injected in equal parts on the two other nerves.

Latency of analgesia was determined with pin-prick at the surgical site of the nerve first injected, and duration of analgesia was established as the difference in time between the time that analgesia was considered complete at the surgery site and the time of return of the first pain at that site in the postoperative period.

Results

The latency of analgesia was not different between the two groups, nor was the duration of analgesia, except for a trend to longer duration in patients with chronic renal failure (Table).

Discussion

The results of this study differ significantly from those previously published for patients with chronic renal failure.¹ The difference between the earlier study and the present study could be explained by the following factors: (1) the approach to the brachial plexus block was different (supra-clavicular vs axillary), (2) methodological differences with the study of Bromage and Gertel, where we noticed a lack of homogeneity. We

conclude that brachial plexus block by the axillary approach does not last longer in patients with chronic renal failure.

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Lumbar sympathetic block – volume requirements

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Local anaesthetics and neurolytic agents introduced anterolateral to the third lumbar vertebral body will produce an effective sympathetic block.^{1,2} In practice this is a simple technique performed under local anaesthesia utilising one 22-gauge needle and an image intensifier to ensure correct placement. However, volumes of local anaesthetic of the order of 15 ml or greater are advocated and may be larger than necessary. If a neurolytic block is performed, such large volumes may increase the incidence of lumbar neuralgia or somatic block. The present study was therefore undertaken to determine whether a smaller volume of local anaesthetic could achieve lumbar sympathetic block.

Methods

This study was approved by the Institutional Research Committee and informed consent obtained from all subjects. Nine patients referred to the Pain Management Unit for diagnostic or therapeutic lumbar sympathetic block participated and were randomly assigned into one of two groups. All lumbar sympathetic blocks were performed in a standard fashion described by Moore³ at the third lumbar vertebrae. Bupivacaine 0.5 per cent was diluted in an equal volume of radiopaque dye (Renograffin 76) to give a final concentration equivalent to 0.25 per cent bupivacaine. An image intensifier was utilised to confirm needle placement and satisfactory spread of the injectate. Group I, (four patients) had a total volume of 7.5 ml injected; Group II, (five patients) had a total volume of 15 ml injected. Successful block was determined by measuring skin temperature at three sites: the dorsum of the foot, the lateral calf and the posterior thigh, on both legs with a Yellow Springs Instrument Co. Ltd. six-channel temperature monitor.

Results

A summary of the results is shown in the Table. The mean change and standard deviation of the temperature gradient between the lower limbs pre-block and one hour after the block is shown at the three standard sites chosen to record skin temperature. The results are not statistically significant at any of the sites; however, the change in temperature gradient at the

TABLE Latency and duration of analgesia (mean $\pm$ SD)

Analgesia	Chronic renal failure	Normal renal function	α Probability*
Latency (min)	8.5 $\pm$ 2.6	8.3 $\pm$ 2.3	NS
Duration (min)	234 $\pm$ 52.4	211 $\pm$ 62.1	NS

* Student's t test for unpaired data.

TABLE Changes in temperature gradient (mean $\pm$ SD) between limbs – pre-block and one hour post-block

Site temperature sensor	Group I (7.5 ml) (n = 4) °C	Group II (15 ml) (n = 5) °C
Dorsum foot	0.85 $\pm$ 1.12	3.12 $\pm$ 2.55*
Lateral calf	1.0 $\pm$ 0.98	0.84 $\pm$ 0.83†
Posterior thigh	0.72 $\pm$ 0.88	0.5 $\pm$ 0.57†

*p = 0.1; †p > 0.5. (N.S.)

dorsum of the foot is much greater (3.12°C) in Group II (15 ml) than Group I (7.5 ml). In Group I (7.5 ml) one patient subjectively and objectively obtained a block, two patients did not obtain a block and in one it was equivocal. In Group II (15 ml) four of five patients obtained sympathetic blocks both subjectively and objectively. As only one of four patients in Group I obtained a sympathetic block, it was deemed unethical to continue with this volume of injectate (7.5 ml).

Discussion

This study suggests that 7.5 ml of a local anaesthetic at one level (L₃) is inadequate to produce a lumbar sympathetic block. Although none of the temperature gradient changes were statistically significant (partially due to the small group sizes), the changes involving the dorsum of the foot were much larger in Group II than Group I whereas there was little difference at other sites. This would indicate that the most useful point to measure temperature changes is on the foot. This study would also suggest that if a neurolytic agent is to be used then small volumes (5–10 ml) should be used at more than one level to produce a consistently effective block.

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Splanchnic haemodynamics: effect of ethanol and anaesthetics

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Ethanol administration leads to a marked increase in liver oxygen consumption which results in a state of hypoxia in Zone III of the liver acinus. When this increase in oxygen consumption, which is a result of ethanol metabolism, is accompanied by a reduction in oxygen delivery to the liver, hepatocellular necrosis may ensue. Normally, there is an increase in blood

TABLE I Results. Awake rats

	n	Cardiac output	HABF	PVBF	RBF
Control (H ₂ O)	7	264 $\pm$ 19	14.6 $\pm$ 2.9	44.3 $\pm$ 3.6	47.8 $\pm$ 5.6
Ethanol 0.5 g·kg ⁻¹	7	268 $\pm$ 15	5.6 $\pm$ 1.0	69.3 $\pm$ 6.8*	59.0 $\pm$ 6.0
Ethanol 2.0 g·kg ⁻¹	7	274 $\pm$ 22	10.3 $\pm$ 3.0	67.9 $\pm$ 9.6*	53.4 $\pm$ 5.7

HABF – hepatic artery blood flow; PVBF – portal vein blood flow; RBF – renal blood flow.

*p < 0.05 vs control.

TABLE II Results. Anaesthetic agents

	n	Cardiac output	HABF	PVBF	RBF
Control	7	224 $\pm$ 18	6.0 $\pm$ 1.0	43.0 $\pm$ 3.0	39.8 $\pm$ 3.4
Ketamine	8	232 $\pm$ 22	5.7 $\pm$ 1.1	42.1 $\pm$ 6.1	46.5 $\pm$ 5.8
Thiopentone	10	200 $\pm$ 6	6.3 $\pm$ 0.8	43.0 $\pm$ 3.4	47.6 $\pm$ 4.0
Fentanyl	9	224 $\pm$ 23	5.7 $\pm$ 1.0	36.3 $\pm$ 3.3	37.2 $\pm$ 4.6

flow to the liver via the portal vein following ethanol consumption, which compensates for the increased requirements for oxygen. In this study, we investigated the effect of three intravenous anaesthetic agents on splanchnic haemodynamics and on the compensatory increase in portal vein blood flow (PVBF) seen following ethanol administration.

Methods

Cardiac output and liver blood flow were measured using ⁴⁶Sc and ⁵⁷Co labelled 15 μ m microspheres in rats in which catheters had been placed into the left ventricle and femoral artery under brief ether anaesthesia. The rats were awake for 2–3 hr prior to blood flow studies. Blood flow was measured 60 min after oral ethanol or 15 min after IM anaesthetics.

Results

Ethanol increased PBF in the awake rat with little effect of cardiac output, mean arterial pressure, or hepatic arterial flow (Table I).

The anaesthetics, ketamine (75 mg·kg⁻¹), thiopentone (50 mg·kg⁻¹) and fentanyl (15 μ g·kg⁻¹) by themselves did not effect blood flows or cardiac output (Table II).

However, each of these anaesthetic agents inhibited the ethanol-induced increase in PVBF (Table III).

TABLE III Results. Ethanol plus anaesthetic agents

	n	Cardiac output	HABF	PVBF	RBF
Control	27	218 $\pm$ 20	5.9 $\pm$ 1.4	40.5 $\pm$ 4.3	44.6 $\pm$ 5.2
Ethanol (2 g·kg ⁻¹)	8	247 $\pm$ 43	5.8 $\pm$ 0.9	52.5 $\pm$ 6.9	52.5 $\pm$ 3.4
+ ketamine					
Ethanol (2 g·kg ⁻¹)	10	162 $\pm$ 21	6.6 $\pm$ 1.6	42.4 $\pm$ 4.6	49.8 $\pm$ 4.2
+ thiopentone					
Ethanol (2 g·kg ⁻¹)	10	223 $\pm$ 25	8.8 $\pm$ 1.6	51.4 $\pm$ 5.7	47.0 $\pm$ 7.2
+ fentanyl					

Discussion

Although ketamine, thiopentone, and fentanyl at the concentrations used do not affect liver or renal blood flow, these anaesthetic agents inhibit the ethanol-induced compensatory increase in PVBF, which could compromise blood flow to the liver in conditions of increased oxygen requirements. These data also show that caution must be used when interpreting physiological and pharmacological results obtained in animals under anaesthesia.

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Mannitol administered during renal transplantation produces profound changes in fluid and electrolyte balance

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Maintenance of fluid and electrolyte balance during renal transplantation presents a considerable challenge to the anaesthetist. In our institution, mannitol is routinely administered prior to vascular anastomosis. While it is known that mannitol causes marked alterations in fluid and electrolyte balance in patients with normal renal function, the effects of mannitol during renal transplantation has not previously been studied.

The protocol received Ethics approval and informed written consent was obtained from seven subjects. To avoid confounding variables which alter fluid and electrolyte balance, patients with diabetes or patients who required intraoperative blood transfusion were excluded from this study.

Methods

Anaesthetic management was standardized. During surgery a maintenance infusion of five per cent dextrose and 0.45 per cent normal saline was given at a rate of $0.5 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{hr}^{-1}$. In addition, normal saline was infused to maintain central venous pressure (CVP) between 5 and 10 mmHg. Prior to vascular anastomosis 50 g of 20 per cent mannitol was infused over approximately 15 min. We monitored mean arterial pressure (MAP), heart rate (HR), CVP, oral temperature and end-tidal carbon dioxide (PetCO_2). Laboratory determinations of serum electrolytes, glucose, osmolality and haemoglobin were performed. Measurements of the above variables were made at the times indicated in the Table. One radial arterial blood sample was drawn just prior to the infusion of mannitol. Statistical assessment was performed using analysis of variance; a p value of 0.05 was considered statistically significant.

Results

Results are shown in the Table. Mannitol increased CVP and reduced MAP with a detectable difference in heart rate. The changes in temperature and PetCO_2 were minimal with overall means of 35.9°C and 37 mmHg respectively. After the infusion of mannitol, there was a reduction in sodium (Na), chloride (Cl) and bicarbonate (HCO_3^-) associated with an elevation in potassium (K) and osmolality (OSM). There were no detectable differences in glucose concentration. Haemodilution asso-

TABLE Results. Mean $\pm$ SEM

	Post-induction	Pre-mannitol	Immediately post-mannitol	30 min post-mannitol	60 min post-mannitol
CVP (mmHg)	9 ± 1	9 ± 1	$12 \pm 2^*$	10 ± 1	9 ± 2
MAP (mmHg)	91 ± 5	88 ± 3	87 ± 4	$80 \pm 2^*$	$80 \pm 5^*$
Na (mmol·L ⁻¹)	139 ± 1	140 ± 1	$132 \pm 1^*$	$133 \pm 1^*$	$134 \pm 1^*$
K (mmol·L ⁻¹)	4.3 ± 0.1	4.4 ± 0.2	4.6 ± 0.1	$4.8 \pm 0.2^*$	$5.1 \pm 0.3^*$
Cl (mmol·L ⁻¹)	102 ± 1	$104 \pm 1^*$	$98 \pm 1^*$	$100 \pm 1^*$	101 ± 1
HCO_3^- (mmol·L ⁻¹)	20 ± 1	21 ± 1	$18 \pm 1^*$	$18 \pm 1^*$	19 ± 1
OSM (mmol·kg ⁻¹)	300 ± 2	298 ± 2	$318 \pm 5^*$	$311 \pm 4^*$	$309 \pm 2^*$
Hg (g·L ⁻¹)	67 ± 2	$62 \pm 3^*$	$56 \pm 3^*$	$59 \pm 3^*$	$59 \pm 3^*$

*Statistically different from post-induction values.

ciated with the infusion of mannitol produced a reduction in haemoglobin concentration. Metabolic acidosis was present in only one subject, with a pH of 7.3 and a base excess of -8 .

Discussion

We conclude that the infusion of mannitol during renal transplantation produces profound changes in fluid and electrolyte balance. Most important is the rise in serum potassium. This study emphasizes the need for close intraoperative monitoring of these patients.

Dopamine and dobutamine cause hypokalaemia which is not attenuated by beta₁ or beta₂ blockade in dogs

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The inter-relationship between the sympathoadrenal system and plasma potassium (K^+) was first noted in 1934.¹ Adrenaline infusions produce a biphasic response in plasma K^+ in animals and in man; an initial transient elevation in K^+ is followed by a more profound and sustained lowering. The K^+ response to dopamine and dobutamine have not previously been examined nor has the effect of specific beta-adrenoceptor blockade on these responses. Continuous monitoring of plasma K^+ can now be achieved using indwelling potassium-sensitive electrodes which accurately follow any changes in plasma potassium.²

Methods

Twelve anaesthetised adult beagle dogs were studied. Ventilation was controlled and pH was maintained between 7.30–7.44 by infusion of 1.4 per cent sodium bicarbonate. The animals were randomly allocated to receive no beta blockade (controls), atenolol $0.5 \text{ mg} \cdot \text{kg}^{-1}$ (beta₁ blockade) or ICI 118551 $0.5 \text{ mg} \cdot \text{kg}^{-1}$ (beta₂ blockade). Dopamine and dobutamine (both $15 \mu\text{g} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$) were infused for 30-minute periods. The inotropic infusions were followed by a 30-minute infusion of saline. Monitoring included direct arterial blood pressure, ECG, pulmonary artery catheter for cardiac output (thermodilution) and continuous K^+ measurement using a catheter-tip potassium-sensitive electrode placed in the lower aorta via a femoral artery. Beta blockade was believed to be adequate as judged by haemodynamic responses.

TABLE Plasma potassium ($\text{mmol} \cdot \text{L}^{-1}$) during dopamine and dobutamine infusion

	Dopamine		
	Pre-inf K^+	Max K^+	Min K^+
Control	3.12 ± 0.31	$3.59 \pm 0.30^*$	$2.82 \pm 0.16^*$
Beta ₁ blockade	3.37 ± 0.57	$3.55 \pm 0.65^*$	$2.82 \pm 0.29^*$
Beta ₂ blockade	3.43 ± 0.25	$3.48 \pm 0.27^*$	$2.83 \pm 0.17^*$

	Dobutamine		
	Pre-inf K^+	Max K^+	Min K^+
Control	3.46 ± 0.44	$3.64 \pm 0.44^*$	$2.78 \pm 0.29^*$
Beta ₁ blockade	3.42 ± 0.78	$3.52 \pm 0.74^*$	$2.82 \pm 0.59^*$
Beta ₂ blockade	3.40 ± 0.22	$3.55 \pm 0.23^*$	$2.90 \pm 0.18^*$

Significant difference from pre-infusion value: $^*p < 0.05$; $^{**}p > 0.005$ (Analysis of variance/Wilcoxon's test for paired differences) ($n = 16$ for each group).

Results

Dopamine infusion produced an initial rise in plasma K^+ above the control level followed by a fall below the control level which was sustained until the infusion was discontinued (Table). Similar changes were also seen with infusion of dobutamine (Table). These changes were noted in all groups of animals; there was no significant difference in the magnitude of the potassium response in the beta₁ and beta₂ blocked animals when compared to the control animals (Table).

Discussion

The initial elevation in plasma K^+ during catecholamine infusion is due to K^+ release from the liver as a result of combined alpha and beta effects at hepatocyte membranes.³ A beta₂ mediated effect stimulating potassium uptake into cells in skeletal muscle and hepatocyte boundaries has been proposed as the mechanism of the hypokalaemia.⁴ Previous work in man has shown attenuation of the hypokalaemic response to adrenaline with ICI 118551 but also with atenolol.⁵ Our study demonstrates that both dopamine and dobutamine produce biphasic responses in plasma K^+ in dogs similar to those seen after adrenaline infusion. However, we have not demonstrated an attenuation of this response by beta₁ or beta₂ blockade. Although the dogs received a dose of beta blocker sufficient to block the cardiovascular responses this may not have been large enough to block the potassium responses. The dose of inotrope used was at the upper end of the clinical range and the effect of this may have been to swamp any blockade of the potassium response. Furthermore, dopamine and dobutamine have different activities to adrenaline at adrenoceptors and additionally dopamine has an action at dopaminergic sites. The hypokalaemic response to catecholamines may involve more than one receptor subtype as is the case with hepatic release of potassium.³ In this study beta adrenoceptor blockade did not protect against catecholamine induced hypokalaemia. As hypo-

kalaemia may be important in the genesis of cardiac arrhythmias the situation warrants investigation in man.

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Induced hypotension for cerebral aneurysm - isoflurane or sodium nitroprusside?

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Induced hypotension is routinely used during cerebral aneurysm to facilitate surgery and reduce the risk of aneurysm rupture. Sodium nitroprusside (NP) had been the drug of choice but recently isoflurane (ISO) has been introduced for this purpose. In addition to the easy control of blood pressure, isoflurane may also provide some protective effect on the brain by reducing its metabolic rate. Such protective effect, however, has never been demonstrated in a clinical setting. We have routinely used isoflurane to induce hypotension during cerebral aneurysm surgery since 1983. To assess any potential influence of hypotensive agents on patient outcome, we performed a retrospective analysis on two comparable groups of patients managed with these two hypotensive agents.

Methods

This retrospective review was approved by the Institutional Ethics Committee. The charts of 105 consecutive patients managed with ISO-induced hypotension for cerebral aneurysm surgery from 1983 to 1984 were analysed and compared with a similar series of 85 patients managed with NP during the previous year. Although there was some variation in the anaesthetic management, the basic approach was similar in all patients. Essentially all patients were induced with thiopentone and fentanyl, and either succinylcholine or pancuronium was administered to facilitate intubation. PaCO_2 was maintained between 28-35 mmHg and blood pressure was monitored invasively in all patients. In the NP group, the maintenance anaesthetic consisted of intermittent doses of fentanyl, nitrous oxide, oxygen and halothane (0.5 to 1.0 per cent). The maintenance anaesthetic in the ISO group was similar, except that isoflurane (0.5-2.0 per cent) was used for maintenance and ISO 2-3 per cent was used for induced hypotension. To compare between the two groups, patients were classified according to both their

TABLE I Blood pressure

		NP	ISO
Grade 1	BP (mmHg $\pm$ SD)	43 $\pm$ 5	46 $\pm$ 5
	Duration (min)	32 $\pm$ 10	36 $\pm$ 25
Grade 2	BP	41 $\pm$ 12	46 $\pm$ 6
	Duration	32 $\pm$ 25	36 $\pm$ 21
Grade 3	BP	44 $\pm$ 10	46 $\pm$ 7
	Duration	38 $\pm$ 13	35 $\pm$ 18

TABLE II Outcome

		Immediate recovery			Postoperative outcome		
		No. of patients	Satis.	Unsatis.	Good	Satis.	Poor
Grade 1	NP	62	40	22	52	7	3
	ISO	69	63	6	64	3	2
Grade 2	NP	12	6	6	8	2	2
	ISO	15	12	3	11	—	4
Grade 3	NP	5	1	4	1	2	2
	ISO	12	7	5	6	4	2

immediate recovery from the anaesthetic (satisfactory – conscious within 60 min; unsatisfactory – delayed return of consciousness) as well as their neurological status at the time of discharge (good – complete recovery except minor cranial nerve dysfunction; satisfactory – major focal neurological deficit; poor – vegetative state or death). Patients were compared within their own preoperative grade of subarachnoid haemorrhage (Bottrell's classification).

Results

There were too few patients in the grade 0 and grade 4 categories for comparison and these were excluded. The main findings are tabulated in Tables I and II. Both the level and duration of hypotension were comparable in the two groups and across all grades. Eleven of the NP patients, and eight of the ISO patients required beta blocker administration to control reflex tachycardia. ISO patients appeared to recover faster in the immediate postoperative period, but were similar to the NP patients at the time of discharge.

Discussion

Although it is interesting to note that patients in the ISO group appeared to awake as fast, if not faster, than the NP group, based on this retrospective review, we were unable to demonstrate any significant outcome advantage of isoflurane over sodium nitroprusside for the purpose of induced hypotension for cerebral aneurysm surgery. We therefore conclude that both hypotensive agents are acceptable and the choice should be decided by the anaesthetist's experience.

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Blood replacement therapy: decreases in coagulation factors

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New preservatives have improved red cell viability and increased the period of storage for packed red cell components. With these improved storage techniques and the increased use of plasma derivatives, most blood banks provide primarily red cells for transfusion. The changes and requirements for coagulation are unclear when red cells stored in these new preservatives are used to replace blood loss during major elective surgery.

The purpose of this study was to document the coagulation changes during transfusions and to determine when replacement of coagulation factors is required if packed cells and crystalloid solutions are used to replace blood loss during major surgery.

Methods

Eleven patients were studied after consent was obtained from the institution's human studies committee. In preparation for major elective surgery, the preoperative coagulation tests included PT, PTT, and platelet count. None of the patients had a history or physical examination suggesting a bleeding disorder.

After the start of surgery, an initial clotting profile which included PT, PTT, fibrinogen, FDP, thrombin time, platelet count and factor assays of V, VIII, and IX were obtained along with an haematocrit and arterial blood gas. After approximately every one-third blood volume was replaced, repeat measurements of the coagulation profile, haematocrit and arterial blood gas analysis were performed. These samples were drawn when vascular volume judged by central filling pressures, arterial blood pressure values and urine output were close to the pre-transfusion values. The number of units transfused, the haematocrit and the patient's weight and sex were used to estimate the fraction of blood volume replaced in each patient at the time of each measurement. No colloid solutions were used in replacement.

FIGURE 1 Platelet count related to volume replacement.

FIGURE 2 Factor I levels related to volume replacement.

FIGURE 3 Factor V levels related to volume replacement.

Results

Decreases in platelet count occurred as greater fractions of blood volume were replaced (Figure 1). Factor I (fibrinogen) and Factor V decreased as the original blood volume was diluted with packed cells and crystalloid (Figure 2 and Figure 3).

As greater fractions of blood volume were replaced, the incidence of prolonged PT and PTT increased (Table). Ineffective haemostasis during surgery was based on the observed condition of the operative site by the anaesthetist and surgeon

TABLE Frequency of elevated PT* and PTT†

Blood volume replaced	PT	PTT
0	0/11	1/11
0.5	4/11	3/11
1.0	8/10	8/10
1.5	4/4	4/4
2.0	2/2	2/2

*PT > 13 sec.

†PTT > 33 sec.

and occurred in only four of the 11 patients. The initial therapy for all of these patients was platelets; however, in two of the patients this therapy improved but did not resolve the bleeding problem. In these two patients, fresh frozen plasma corrected the clinical problem of poor clot formation at the surgical site. The PT in both of these patients was 25 sec or greater (normal = 10–13 sec) and the PTT was 80 sec or longer (normal 22–33 sec).

Discussion

These results suggest that a significant decline in clotting factors does occur when packed cell and crystalloid solutions are used to replace major blood loss. Although measurable changes in common coagulation tests (PT, PTT) frequently occur prior to the replacement of one blood volume, the increases in PT and PTT were not associated with ineffective haemostasis until marked prolongation of PT and PTT was present ($1.5 \times$ control). In the two patients who had excessive bleeding despite replacement of platelets, the level of Factor V was less than 30 per cent (27 and 7) and the PT was 25 sec or greater. In these two patients, the fibrinogen level was also less than 100 mg (normal 150–250 mg).

When clinical observation of an inadequacy of haemostasis is combined with laboratory confirmation of platelet count, PT, PTT and fibrinogen levels, appropriate component therapy for coagulation changes can be instituted. No predetermined formula for replacement of platelets or fresh frozen plasma can be recommended in this situation. Therapy must be guided by clinical signs with laboratory confirmation.

Evaluation of the Ambu CPAP system and the Servo ventilator 900C in CPAP mode

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Continuous positive airway pressure (CPAP) is a well established method for prevention and treatment of postoperative hypoxia and many other acute pulmonary disorders. It is commonly stated that the ideal system should maintain the airway pressure constant at the preset CPAP level throughout the whole breathing cycle. Due to the difficulties of constructing such a system for adults, few CPAP-circuits have been commercially available.

The aim of this experimental study was to investigate the pressure-flow characteristics of two recently introduced pieces of equipment for application of CPAP, during artificial breathing simulating a normal man and a patient in severe respiratory distress.

Methods

A computer-controlled lung model² was connected to either of the two systems – the Ambu CPAP-system (Ambu International, Denmark) and the Servo Ventilator 900C (Siemens-Elma AB, Sweden). The lung model was programmed with breathing patterns obtained from pneumotachographic recordings of a healthy, relaxed volunteer and a patient with severe ARDS.

The Ambu system was tested with two fresh gas flows – 15 and 25 L·min⁻¹. Both systems were tested at CPAP levels of 0.5, 1.0 and 1.5 kPa. Airway pressure and flow were measured and recorded both with a time axis and as volume–pressure and pressure–flow loops.

Results

Normal breathing

In the Ambu system, airway pressure variations could be reduced by 25–32 per cent by increasing the fresh gas flow from 15 to 25 L·min⁻¹. With the higher flow, the pressure drop during inspiration was always less than 0.16 kPa and the overshoot during expiration less than 0.1 kPa. Total airway pressure difference (ΔP_{aw}) at CPAP 1.0 kPa was 0.23 kPa. In the 900C, there was a short initial pressure drop of less than 0.2 kPa. The inspiratory pressure then increased above CPAP reflecting a weak insufflating effect. ΔP_{aw} at CPAP 1.0 kPa was 0.35 kPa.

ARDS breathing

When the systems were challenged with rapid breathing with higher flow rates, ΔP_{aw} increased. In the Ambu system the expiratory pressure was unchanged while in the 900C both the inspiratory and the expiratory pressures increased.

Examples of recordings will be shown and additional data on pressures, reactance and work-loop areas will be given.

Conclusions

Ambu system

ΔP_{aw} was rather small and comparable to that reported with home-made, high-flow, open circuit systems.¹ The circuit performed better when the fresh gas flow was increased to 25 L·min⁻¹. This system is inexpensive, comparatively small, easy to handle and safe in case of fresh gas failure (non-rebreathing valve).

900C

The pressure variations of the 900C were not directly comparable to those of the Ambu system, since the inspiratory pressure drop was of short duration and was followed by a pressure rise which reduces the inspiratory work of breathing of the patient. This system also has sophisticated monitoring facilities and alarms, and permits smooth change-over to other modes of ventilation. The 900C performs much better than its predecessor 900B.¹

Although neither of the circuits fulfil the criteria of the ideal CPAP system, both can be recommended for clinical use.

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Fibreoptic tracheal intubation of the pig: a teaching model

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Establishing a secure airway is fundamental to the practice of anaesthesia. Usually an endotracheal tube is placed easily during direct laryngoscopy; however, if a difficult airway is encountered, fibreoptic (F-O) laryngoscopy may be a valuable technique for facilitating tracheal intubation. Despite its usefulness, the F-O laryngoscope has not enjoyed widespread use among anaesthetists.¹ This may be due to insufficient instruction in the technique. The purpose of this project was to develop and assess an animal model simulating the clinical situation that permits the student to become comfortable with the technique of F-O laryngoscopy prior to attempting intubation of patients in the operating room and to compare the airway characteristics of this model to those of a standard intubating mannequin.

Methods

Anaesthesia was induced and maintained in an adult 40 kg pig by inhalation of halothane and oxygen. The pig was placed supine, IV access established and ECG and end-tidal CO₂ monitored. Spontaneous ventilation was maintained through an oral airway. Faculty, fellows and residents then performed both orotracheal and nasotracheal intubation on the anaesthetized spontaneously breathing pig. Immediately after completing the procedure on the pig model, F-O intubation was repeated using a Laerdal Adult Intubating Mannequin.

Following laryngoscopy and intubation of both models, each participant completed an evaluation form assessing the experience. The evaluations included appearance of the epiglottis, vocal cords and trachea; position of the larynx; effect of respiration; and the overall technique of F-O intubation for both the animal model and the mannequin. Each of the eight characteristics were rated on a four-point scale: 1 = poor, 2 = fair, 3 = good, 4 = excellent.

Finally the participants were asked which model, if either, would be most effective for learning the technique of F-O endotracheal intubation.

Results

Twenty-seven faculty, fellows and residents evaluated the two models. Their assessments of the characteristics of the airway in the anaesthetized pig and the mannequin are shown in the Table.

Of the 27 evaluators, 26 rated the pig as the most effective model for teaching physicians F-O tracheal intubation.

Discussion

Learning a complex technical skill, such as F-O intubation, during the course of patient care presents several problems. The patient may experience discomfort or be at risk of injury if the procedure is not successfully completed. Valuable operating time may be lost as the novice struggles to master a new skill and OR personnel frequently become impatient with the resulting delay. Intubation of a mannequin may be a useful

TABLE Comparison of the airway of the pig and intubating mannequin (mean $\pm$ SE)

Character	Pig	Mannequin
Presence of secretions	3.00 $\pm$ 0.15†	1.04 $\pm$ 0.04
Anatomy of tongue	2.56 $\pm$ 0.12†	1.52 $\pm$ 0.12
Appearance of epiglottis	2.50 $\pm$ 0.19	2.15 $\pm$ 0.15
Position of larynx	3.07 $\pm$ 0.14†	2.16 $\pm$ 0.16
Appearance of vocal cords	3.00 $\pm$ 0.15*	2.35 $\pm$ 0.18
Effect of respiration	3.27 $\pm$ 0.13†	1.09 $\pm$ 0.06
Appearance of trachea	3.23 $\pm$ 0.16†	1.64 $\pm$ 0.14
Technique of F-O laryngoscopy	3.67 $\pm$ 0.09†	1.85 $\pm$ 0.14

Independent t test.

* $p < 0.05$.† $p < 0.001$.

teaching aid; however, it does not represent a realistic clinical experience.² The use of an anaesthetized cat to teach tracheal intubation by direct laryngoscopy has been shown to be an effective technique,³ but due to its small size a cat is not an appropriate model for F-O intubation. The pig was chosen for this project because intubation in this species is difficult. The jaw is long and narrow, the mouth and larynx are small and there is a ventral angulation from the larynx into the trachea. Successful intubation requires recognition of anatomic landmarks, overcoming complicating obstacles and manipulation of the F-O instrument through the larynx of a spontaneously breathing animal before advancing the endotracheal tube into position. This closely resembles the clinical situation. However, with unlimited time available to acquire the dexterity required for F-O intubation, students quickly gain confidence and expertise before attempting the procedure on patients in the operating room. The results of this study support the validity and superiority of the anaesthetized pig as a clinical model for teaching F-O tracheal intubation.

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A fresh gas flow and minute volume nomogram for Mapleson D systems

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Using figures presented in the literature a nomogram was constructed for fresh gas flow (FGF) and minute ventilation (V_E) settings in the coaxial Mapleson D (Bain) systems. When the body weight (BW) is indicated, the nomogram will present two alternatives for both spontaneous and controlled ventilation. The total FGF is displayed for each alternative as well as the rotameter setting to give 33 per cent of oxygen in nitrous oxide. In spontaneous breathing the two alternatives are based upon a FGF of 125 and 150 ml·min⁻¹·kg⁻¹. In controlled ventilation

TABLE Results (mean $\pm$ SEM)

	n	pH	PaCO ₂ kPa	PaO ₂ kPa
Normal flow	21	7.39 $\pm$ 0.010	5.6 $\pm$ 0.14	19.9 $\pm$ 0.85
High flow	18	7.46 $\pm$ 0.014	4.5 $\pm$ 0.14	18.7 $\pm$ 1.08

a "normal flow" alternative, based upon a FGF of 75 ml·min⁻¹·kg⁻¹ and a V_E of 150 ml·min⁻¹·kg⁻¹ is given as well as a "high flow" alternative, based upon a FGF and a V_E of 110 and 175 ml·min⁻¹·kg⁻¹ respectively. In accordance with the data of Seeley *et al.*¹ this should give a PaCO₂ of approximately 5.3 kPa and 4.0 kPa respectively.

The aim of the present clinical study was to test the validity of the nomogram in adults undergoing different types of orthopaedic, dental and general surgery.

Methods

Thirty-seven adults have been studied. Thirteen (eight men) breathed halothane spontaneously (age 18–58 years, 53–85 kg) and 24 (nine men) received general anaesthesia with controlled ventilation (age 26–87 years, 46–86 kg). Minute ventilation was measured by pneumotachography (spontaneous ventilation) or by a Wright spirometer (controlled ventilation). Arterial blood samples were drawn using the different alternatives for FGF and V_E given by the nomogram. Rebreathing during spontaneous ventilation was detected by comparing the results with those obtained in a non-rebreathing circuit.

Results

During spontaneous ventilation the number of rebreathers increased from 15 to 54 per cent and the minute ventilation by 17 per cent when the FGF was reduced from 150 to 125 ml·min⁻¹·kg⁻¹. Two patients increased their PaCO₂ considerably. During controlled ventilation the normal flow data resulted in normoventilation as predicted and the high flow data in a mild hyperventilation (Table). The PaCO₂ was found to be somewhat higher than expected from the data of Seeley *et al.* This may be explained by the fact that several patients had pre-existing cardiopulmonary disease.

Discussion

The nomogram appears to be an adequate guide during both spontaneous and controlled ventilation. If carbon dioxide monitoring is not used during spontaneous ventilation, we recommend a FGF of 150 ml·min⁻¹·kg⁻¹. During controlled ventilation the use of settings based on the nomogram will result in normo- or mild hyperventilation, in accordance with the chosen alternative. Preliminary data shows that the high flow alternative will result in normocapnoea in teenagers. Further studies have been started to extend the nomogram to incorporate infants and children.

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Improving arterial oxygenation during one-lung ventilation for thoracic surgery

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Hypoxaemia occurs frequently during one-lung ventilation (OLV) for thoracic surgery.¹ Application of continuous positive airway pressure (CPAP) to the non-ventilated lung can improve arterial oxygenation² but clinical reports show a wide variation in results.^{3,4} Human studies have not controlled for the method in which CPAP is applied. We compared the arterial oxygenation produced by two different methods of application of CPAP 5 cm H₂O (0.5 kPa) to the non-ventilated lung during OLV.

Methods

Twenty patients having elective thoracotomies for lung or oesophageal surgery were studied. Arterial oxygen tension (PaO₂) with FiO₂ 0.21, forced expiratory volume in one second (FEV₁), and forced vital capacity (FVC) were determined preoperatively.

General anaesthesia was induced with fentanyl (5 µg·kg⁻¹), thiopentone (2–3 mg·kg⁻¹) and pancuronium (0.08 mg·kg⁻¹) and maintained with oxygen and isoflurane (0.5–1.5 per cent inspired concentration). Isoflurane concentration was titrated to keep the systolic blood pressure ±20 per cent of the pre-induction value. An appropriate size left double-lumen disposable endobronchial tube was placed and its position verified by auscultation. A tidal volume of 10 ml·kg⁻¹ was used for both one- and two-lung ventilation with the rate adjusted to keep the arterial carbon dioxide tension between 36–40 mmHg. After intubation, the patient was placed in the lateral decubitus position and an initial arterial blood gas drawn during two-lung ventilation 15 min after the induction of anaesthesia.

CPAP was applied to the non-ventilated (non-dependant) lung using a 1 L·min⁻¹ flow of oxygen via a modified Mapleson D circuit with an underwater exhaust, after the non-dependant thorax was opened. The CPAP was applied to each patient by two methods used in an alternating fashion:

Method 1

Tidal volume inflation → atmospheric pressure (5 min)
→ CPAP 5 cm H₂O

Method 2

Tidal volume inflation → CPAP 2 cm H₂O (5 min)
→ CPAP 5 cm H₂O

Arterial blood gases were drawn 5 and 20 min after the application of CPAP 5 cm H₂O.

Patients were randomly allocated to either of two groups. In Group A (ten patients) after 25 min of OLV with Method 1, surgery was stopped, the non-ventilated lung re-inflated with oxygen and CPAP re-applied using Method 2. In Group B (ten patients) Method 2 preceded Method 1. The study was completed before ligation of any major pulmonary vessels.

The method of repeated measures analysis of covariance was used to compare the two methods of oxygenation while control-

ling for the effect of baseline variables. The Shapiro-Wilk test of normality was used to verify the normal distribution of the results.

Results

The assumption of normality for all 5 and 20 min PaO₂ results was verified. Using Method 1 the mean (±SD) PaO₂ tensions at 5 and 20 min were 201 (±97) mmHg and 186 (±92) mmHg respectively. Using Method 2 the mean PaO₂ tensions at 5 and 20 min were 329 (±94) mmHg and 293 (±106) mmHg. The ensuing repeated measures analysis of covariance demonstrated a significant mean difference (MD) in arterial oxygenation between the two methods both at 5 min (MD = 129 mmHg, *p* < 0.0001) and 20 min (MD = 107 mmHg, *p* < 0.0001) while adjusting for group, operative side, FEV₁/FVC ratio and initial intraoperative PaO₂.

Three patients (one Group A, two Group B) had PaO₂ levels during OLV less than 70 mmHg during the study. These three relative hypoxaemic episodes all occurred with Method 1. Surgical conditions were adequate at all times during CPAP applications.

Discussion

Allowing the fully inflated lung to collapse at a CPAP of 2 cm H₂O before raising to a maintenance level of 5 cm H₂O can improve arterial oxygenation, without interfering with surgical conditions. Delaying application of CPAP may allow the lung to collapse below its closing capacity and minimize benefits. Application of CPAP 5 cm H₂O to a fully inflated lung results in a lung which stays well above its functional residual capacity and impedes surgery. However, using a maintenance level of only 2 cm H₂O CPAP is often not enough to prevent progressive atelectasis. The optimal level and method of application of CPAP undoubtedly depends on individual lung mechanics. Both the clinician and the researcher should appreciate the importance of the relative deflation of the non-ventilated lung at the time of application of CPAP. CPAP to the non-ventilated lung can decrease the risk of hypoxaemia during OLV if it is applied in a controlled fashion.

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The effect of high-frequency positive-pressure ventilation versus high-frequency jet ventilation on expired tidal volume during lithotripsy

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In this study we compared the effect of high-frequency positive-pressure ventilation (HFPPV) versus high-frequency jet ventilation (HFJV) on tidal volume (V_T) in patients undergoing extracorporeal shock-wave lithotripsy (ESWL), as well as the difference in V_T necessary to maintain similar end-tidal CO_2 ($PETCO_2$) with each ventilator type. Twenty patients, ASA physical status I or II, ages 18–72 yr, were studied. General anaesthesia was established and monitors included an electrocardiogram, a blood pressure machine, a capnograph and a Nellcor pulse oximeter. A Heathdyne High Frequency Jet Ventilator and a Siemens-Elema 900D anaesthesia machine were used to generate high-frequency ventilation. Initially, conventional mechanical ventilation was instituted via a Hi-Lo jet orotracheal tube. After the patient was placed in the lithotripter bath, HFJV was begun. Drive pressures of 15–20 psi were used to maintain $PETCO_2$ between 30–38 mmHg with an inspiratory time of 0.33 and a respiratory rate of 100 breaths·min⁻¹. A pneumotach measured expiratory tidal volume (V_{TE}) and mean ($\bar{P}_{aw}$) and peak (P_{aw}) airway pressures. The V_{TE} that maintained $PETCO_2$ at 30–38 mmHg during HFJV was then used with HFPPV and the same parameters were recorded. During HFPPV, if the V_{TE} did not produce an acceptable $PETCO_2$, V_{TE} was increased until $PETCO_2$ was satisfactory. In eight patients (40 per cent) there were no significant differences in $PETCO_2$ with either ventilator when the identical V_{TE} was used. Overall, mean $PETCO_2$ during HFPPV was 4.6 mmHg

TABLE I End-expired PCO_2 ($PETCO_2$) during high frequency positive pressure ventilation (HFPPV) and high frequency jet ventilation (HFJV) with identical expired tidal volumes*

	$PETCO_2$ mmHg		
	Minimum	Maximum	Mean
HFPPV	30	57	38.15
HFJV	30	38	33.51

*Respiratory rate 100 breaths·min⁻¹ for all expired tidal volumes.

† $p < 0.001$ between mean values.

TABLE II Expired tidal volumes with high frequency positive pressure ventilation (HFPPV) and high frequency jet ventilation (HFJV) to maintain identical end-expired CO_2 *

	V_{TE} (L) mean $\pm$ SD
HFPPV	0.18 $\pm$ 0.03
HFJV	0.16 $\pm$ 0.04†
Mean difference	0.026 $\pm$ 0.005

*Respiratory rate 100 breaths·min⁻¹.

† $p < 0.001$ between mean values.

TABLE III Peak airway pressure (P_{aw}) and mean airway pressure ($\bar{P}_{aw}$) with high frequency positive pressure ventilation (HFPPV) versus high frequency jet ventilation (HFJV) at identical expired tidal volumes*

	P_{aw} (cm H_2O)	$\bar{P}_{aw}$ (cm H_2O)
HFPPV	22.83 $\pm$ 1.91†	8.53 $\pm$ 3.03
HFJV	15.85 $\pm$ 1.26	8.16 $\pm$ 3.06

Values are means $\pm$ SD.

*Respiratory rate 100 breaths·min⁻¹.

† $p < 0.001$ between HFPPV and HFJV.

higher than that of HFJV using identical expired tidal volumes (Table I). On the average, a 0.026 L increase in V_{TE} was needed to match $PETCO_2$ values during HFPPV with those of HFJV (Table II). P_{aw} was significantly higher during HFPPV than with HFJV. $\bar{P}_{aw}$ was lower with HFJV than with HFPPV at identical tidal volumes (Table III). We conclude that both HFPPV and HFJV can produce acceptable levels of $PETCO_2$ during ESWL using similar tidal volumes. However, in some patients, a V_T that is adequate for ventilation with HFJV is inadequate during HFPPV, and a larger V_T will be required.

Flammability of endotracheal tubes in oxygen and nitrous oxide enriched atmospheres

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Endotracheal tube (ETT) fire is a recognized hazard of laser surgery. The report of a polyvinylchloride (PVC) ETT fire ignited by electrocautery during tonsillectomy with nitrous oxide (N_2O), oxygen (O_2) and halothane anaesthesia illustrates a different ignition source.¹ The Oxygen Index of Flammability is defined as the minimum O_2 fraction in nitrogen (N_2) that will support candle-like flame.² Since N_2O also supports combustion, we introduce the concept of the Nitrous Oxide Index of Flammability, i.e., the minimum fraction of N_2O in N_2 that will support candle-like flame. Part 1 of this study measures the O_2 Index and N_2O Index of Flammability of PVC, red rubber (RR) and silicone (SI) ETT's. Part 2 of the study measures the flammability of the ETT's in a combination of N_2O and O_2 .

Methods

Gases were routed through precision flowmeters, combined into a common line, passed through a column of glass beads which guaranteed mixing, and entered a test column. The ETT to be tested was supported within the column by a clamp. Ignition of the ETT was accomplished with a propane flame. The O_2 Index of Flammability was determined by slowly increasing the O_2 concentration in a N_2 environment until candle-like flame was maintained on the ETT when the propane flame was removed. The Nitrous Oxide Index of Flammability was determined by substituting N_2O for O_2 . The additive effect of the N_2O and O_2 indices of Flammability was determined by measuring the flammability of PVC, SI, and RR ETT's in an atmosphere containing O_2 , N_2O , and N_2 .

FIGURE Gas combinations supporting candle-like flame.

Results

The Oxygen Index of Flammability for PVC ETT is 0.26, for Si 0.19 and for RR 0.18. The Nitrous Oxide Index of Flammability for PVC ETT is 0.46, for Si 0.41, and for RR 0.37. The combination of $N_2O + O_2$ in N_2 that supports candle-like flame is represented in the Figure for each of the three types of ETT's. Points to the right of each line represent combinations of O_2 and N_2O that will render that ETT flammable while points to the left of each line represent combinations of N_2O and O_2 that will render that ETT non-flammable. Our results indicate that the Combined $O_2 + N_2O$ Index of Flammability is the proportional complement of the separate indices, e.g., $\frac{1}{4}$ of the O_2 Index plus $\frac{3}{4}$ of the N_2O Index equals the Combined Index.

Discussion

The Oxygen Index of Flammability is useful in determining the flammability of ETT's used in oxygen enriched atmospheres. We introduce the analogous concept of the N_2O index of flammability since N_2O and O_2 enriched atmospheres exist in the clinical setting and support combustion. A distinction must be made between ignition, i.e., the energy required to ignite a fuel in a given atmosphere, and the flammability, i.e., the ability of a fuel to sustain a flame in a given atmosphere. We measured the flammability, pertinent regardless of the source of ignition. Flammability is dependent only on the fuel, i.e., the type of ETT used, and the oxidizer, i.e., the O_2 and/or N_2O environment.

This study demonstrates that both the N_2O Index and O_2 Index of Flammability are higher for PVC tubes than for RR or Si tubes, and suggests that PVC tubes may be indicated in

situations where the possibility of endotracheal tube fire exists, provided appropriate gas mixtures are used, i.e., a mixture to the left of the PVC curve in the Figure. Considerations for laser surgery however should include the resistance of the ETT to laser penetration ($RR > Si > PVC$), the O_2 and N_2O indices ($PVC > Si > RR$) and the patient O_2 requirements.

Our data support the use of PVC endotracheal tubes in a ventilation mixture of 26 per cent O_2 or less, and the avoidance of N_2O where the possibility of a non-laser ignited ETT fire exists.

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Manual ventilation with the Humphrey A.D.E. system

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The use of the Humphrey A.D.E. low-flow universal anaesthetic breathing system for spontaneous and controlled ventilation has recently been described in the Canadian Anaesthetists' Society Journal.^{1,2} In an Editorial comment on universal breathing systems,³ the reviewers noted that while manual ventilation could be achieved with the A.D.E. system in the "A" mode, "the exact fresh gas flow requirements, the amount of ventilation and other limitations have not been fully defined." This paper presents the results of clinical trials designed to define these parameters.

Methods

Using capnography, inspired and end-expired (P_{ETCO_2}) carbon dioxide tensions were monitored in ten healthy anaesthetised subjects during manual ventilation. A reference value for P_{ETCO_2} was obtained for each patient by using a normocarbica controlled ventilation technique as associated with the Bain system but using the A.D.E. system set in the Mapleson "E" mode (Figure 1) with a fresh gas flow (FGF) of $70 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$.² With this same FGF two manual techniques in the "A" mode (Figure 2) were employed in each patient: (a) the rate and tidal volume were carefully maintained at $12-14 \text{ breaths} \cdot \text{min}^{-1}$ and $10 \text{ ml} \cdot \text{kg}^{-1}$ respectively and (b) these parameters were varied as would normally occur in clinical practice. The efficiency of these manual ventilation techniques with the A.D.E. system was also compared to the Magill (Mapleson A) system.

Results

The mean reference value for P_{ETCO_2} during automatic ventilation in the "E" mode of the A.D.E. system was 41.5 mmHg ($SD \pm 2.5$). A mean fall in P_{ETCO_2} of 5.6 mmHg to 35.9 mmHg was observed during manual ventilation when the A.D.E. system was switched to the "A" mode while maintaining the same ventilation parameters. Wide variations in these parameters during manual ventilation did not significantly alter the P_{ETCO_2} values

FIGURE 1 "E" mode – controlled ventilation.

FIGURE 2 "A" mode – spontaneous and manual ventilation.

provided total minute ventilation exceeded the FGF. Under identical conditions but using the Magill system the mean $P_{ET}CO_2$ was noted to increase by 9.2 mmHg to 50.5 mmHg.

Discussion

Manual ventilation in the "A" mode of the A.D.E. system was shown to allow efficient ventilation of the patient. In contrast, the Magill system was shown to be inefficient (confirming previous observations). Despite wide variations in tidal volume and respiratory rate, normo- or mild hypo-carbia was maintained in all patients with the A.D.E. system. It is concluded that this manual ventilation technique with the A.D.E. system is advantageous in situations where carbon dioxide wash-out is undesirable while adequate oxygenation needs to be ensured. Spontaneous or automatic controlled ventilation can be instituted at any time merely by the appropriate lever position.^{1,2} Since no special monitoring of ventilation volume is required, this technique with the A.D.E. system may have particular application in remote "Third World" or military environments where sophisticated monitoring equipment or even automatic ventilators are not available.

(Figures 1 and 2 reproduced with the permission of the Editor of Anaesthesia.)

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Suggested solutions to the problem of the T-piece anaesthetic breathing system

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The T-piece is popular in paediatric anaesthesia because of its size. However, being a Mapleson E system, it requires two to three times the fresh gas flow (FGF) relative to Mapleson A systems to prevent rebreathing during spontaneous respiration. It is also difficult to scavenge exhausted gases. Hatch¹ suggested that the Humphrey A.D.E. universal system^{2,3} had obvious attractions over the T-piece but these had yet to be assessed. This paper presents the results of comparative studies between the A.D.E. system and the T-piece during both spontaneous and controlled ventilation.

Methods

Using capnography, inspired $PiCO_2$ and end-expired ($P_{ET}CO_2$) carbon dioxide tensions were directly compared between the

FIGURE 1 "A" mode - spontaneous and manual ventilation.

FIGURE 2 "E" mode - controlled ventilation.

A.D.E. system and the T-piece under anaesthesia in two groups of ten healthy children. In Group 1, with the A.D.E. system set in the "A" mode (Figure 1), the FGF necessary to prevent rebreathing during spontaneous respiration (as detected by a simultaneous rise in both $PtCO_2$ and $PETCO_2$) was compared with that for the T-piece in each patient. In Group 2 during controlled ventilation with the A.D.E. set in its "E" mode (Figure 2), differences in $PETCO_2$ tensions caused by the two systems were compared in each patient with a fixed FGF (initially set to maintain normo-carbia) and standard ventilation technique.

Results

Comparative mean FGFs to prevent rebreathing during spontaneous respiration with the A.D.E. system set in the "A" mode and the T-piece were 1.95 and $6.1 \text{ L} \cdot \text{min}^{-1}$ respectively (mean age 4.1 yr, weight 15.8 kg). For controlled ventilation both systems behaved similarly, normocarbica being maintained with a mean FGF of $2.5 \text{ L} \cdot \text{min}^{-1}$ (mean age 4.6 yr, weight 17.9 kg).

Discussion

Under identical conditions the A.D.E. system was shown to require one third of the FGF necessary for the T-piece during spontaneous respiration. Since Mapleson A systems conserve dead space gas, a significant increase in inspired humidity may well result; current studies suggest such a trend (unpublished observations). The small "PEEP" effect of the exhaust valve ($1-2 \text{ cm H}_2\text{O}$) may also improve gas exchange and reduce the work of breathing. Generally, for both spontaneous and controlled ventilation, the A.D.E. system can be safely used with FGF's of $3 \text{ L} \cdot \text{min}^{-1}$ (or less) for all children under 20 kg. Such an overall reduction in anaesthetic gas consumption compared to the T-piece is not only economical but reduces the risk of theatre pollution at source. The latter can be completely controlled with the A.D.E. system as scavenging devices are always attached at the anaesthetic machine well away from the patient. The use of 15 mm tubing makes the A.D.E. system lightweight (90 gm at the patient's face) compared with some commercial T-pieces (210 gm without the additional mass of a scavenging device), while apparatus dead space is only 1.8 ml. The A.D.E. system offers further advantage in that it can be switched between spontaneous, manual and ventilator modes at any time merely by the appropriate lever position.^{2,3} The Humphrey A.D.E. system thus appears to offer a practical and efficient alternative to the T-piece.

References

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