Improved Oxygenation During Thoracotomy with Selective PEEP to the Dependent Lung


“Adequate oxygenation during thoracotomy in the lateral position may become difficult to maintain due to reduction in the arterial oxygen tension (Pao₂).... The reduced Pao₂ and the associated increased alveolar-arterial O₂ differences (Aao₂D) are due to ventilation: blood flow maldistribution and pulmonary arteriovenous shunts.... The majority of studies have shown that during anesthesia pulmonary arteriovenous shunt is the major cause of the increased alveolar-arterial oxygen differences.

“During thoracotomy in the lateral position, gravity causes the blood to flow predominantly to the dependent lung. This combined with the following factors which reduce ventilation to the dependent lung results in ventilation: blood flow maldistribution and shunt....

“Theoretically, if loss of the end-expiratory volume of the dependent lung were a major factor in contributing to the maldistribution of ventilation, absorption atelectasis in the dependent lung, and the observed pulmonary arteriovenous shunt, then maintaining the end-expiratory volume of the dependent lung should prevent these changes. We tested this hypothesis by constructing a circuit which, together with a Carlens double-lumen endobronchial tube, applied 10 cm H₂O of positive end-expiratory pressure (PEEP) to the dependent lung and allowed the nondependent lung to be ventilated with the same ventilator but at zero end-expiratory pressure (ZEEP). The effect of this circuit on Pao₂, Aao₂D, and inspired O₂ concentration required to maintain safe oxygenation were examined in patients undergoing thoracotomy in the lateral position for pulmonary and esophageal surgery....

“The circuit...consists of a common inspiratory path for both lungs and for expiration of the nondependent lung, a one-way valve separating expiratory flow of each lung, and a 10 cm H₂O ‘dead weight’ PEEP. The circuit was used with a Carlens double-lumen endobronchial tube and a standard circle system with CO₂ absorber and a ventilator. The circuit for each lung was tested... at ranges of flow and volume encountered in adult thoracic surgery. The circuit was reliable.... During clinical use, insertion of the circuit into the anesthesia breathing circuit and onto the Carlens catheter did not cause any increase in the inflating pressures.

“Twenty-two patients were studied during thoracotomy in the lateral position for resective pulmonary surgery (20) and Belsey hiatal hernia repairs (2). The patients were randomly divided into 2 groups: group I, experimental, and group II, controls. Groups were sim-
ilar in age, weight, preoperative spi-
rometry, and duration of the surgical
procedure. . . . Group I patients were in-
tubated with a Carlen's double-lumen en-
dobronchial tube (39 or 41), and during the
lateral thoracotomy both lungs were
ventilated and selective PEEP was ap-
plied to the dependent lung with ZEEP
to the nondependent lung. Group II pa-
tients were intubated with a cuffed endo-
tracheal tube and both lungs were ven-
tilated with ZEEP.

"Both groups were premedicated
with diazepam (0.2 mg/kg) and the anes-
thetic agents for the 2 groups were
similar. . . . Both groups were ventila-
ted with a similar pattern of large tidal
volumes, . . . slow respiratory frequency,
. . . and with sufficient minute ventilation
to maintain a normal PaCO₂. Throughout
operation, temperature, acid-base bal-
ance, and electrolytes were normal,
blood loss was replaced as required, and
the arterial and central venous pressures
remained within the patients' normal
range. . . .

"Both groups were initially ven-
tilated with 30 to 50 percent O₂ . . . ar-
terial blood gases were measured. . . .
Throughout the thoracotomy, the pa-
tients given selective PEEP to the de-
pendent lung . . . were ventilated with
the same inspired O₂ concentration.
There was no significant decrease in the
PaO₂ . . . or increase in AaO₂D . . . By
contrast, of the patients who did not re-
cieve selective PEEP to the dependent
lung, 8/11 required an increase in the
inspired O₂ concentration to maintain
an adequate PaO₂. Despite this increase
in inspired O₂ concentration, there was
a significant decrease in the PaO₂. . . .

"Ventilation of both lungs during thoracotomy often results in unaccept-
able conditions for surgery, and even
ventilation with high concentration of
O₂ may not provide a sufficiently high
PaO₂ for oxygenation. . . . Arterial hy-
poxia has been observed during one-
lung anesthesia with PEEP to the de-
pendent lung. Therefore our circuit was
designed to selectively ventilate the de-
pendent lung with PEEP, and at the
same time ventilate the nondependent
lung with ZEEP. . . . Selective PEEP to
the dependent lung while ventilating the
nondependent lung at ZEEP maintains
adequate arterial oxygen tensions on
30-50 percent inspired oxygen con-
centrations, and was associated with stable
PaO₂ and AaO₂D's during thoracotomy.

"Two major factors contribute to
AaO₂D: (1) ventilation-blood flow mal-
distribution, and pulmonary-arteriove-
nous shunt, and (2) decreases in car-
diac output. . . . Hughes and associates
have shown that low alveolar volumes
are associated with high extra-alveolar
vascular resistance, and blood flow is
deflected away from these zones (zone
IV). As a result of reduction in end-
expiratory volume and absorption atelec-
tasis in the dependent lung, areas with
zone-IV conditions may exist, and dur-
ing the course of a thoracotomy the dis-
tribution of blood flow to these areas
would be reduced.

"In the context of the . . . argument
that the reduced PaO₂ and the increased
AaO₂D largely result from an increase in
pulmonary arteriovenous shunting, a
similar interpretation may be used in
examining the differences in AaO₂D ob-
erved while breathing 100 percent O₂
at the end of operation. However, re-
cent studies . . . give cause to question
the interpretation of the AaO₂D ob-
tained while breathing 100 percent O₂.
. . . These studies have shown that pul-
monary arteriovenous shunt is the major
contributor to the increased AaO₂D and
that ventilation-blood flow maldistri-
bution other than shunt is relatively
unimportant. . . .

"During anesthesia with N₂O-O₂
mixtures, areas of low ventilation-perfu-
sion ratio may behave in a similar man-
ter to when receiving high concentra-
tions of O₂ until there is equilibration
of the alveolar and tissue N₂O. Due to
the low solubility of N₂O, equilibration
is achieved during the first 20 min-
utes of anesthesia, although uptake con-
tinues at a reduced rate for many hours.
No data are available on the problem of
overestimation of pulmonary arteriovenous shunt and underestimation of ventilation-blood flow maldistribution in patients breathing N₂O during anesthesia.

"Since completion of this study, we have used this technic with success for cardiovascular surgery in the lateral position via thoracotomy.... We have demonstrated that a circuit which applies selective PEEP to the dependent lung while the nondependent lung is ventilated at ZEEP, when used with a Carlens double-lumen endobronchial tube, enables ventilation of patients during thoracotomy with 30 to 50 percent O₂, maintains satisfactory PaO₂, and prevents increases in Aao₂D during thoracotomy."

**Cardio-Respiratory Changes During Pneumoencephalography**


"The physiological changes associated with alterations in posture have always concerned anaesthetists. These changes are probably most marked in patients undergoing pneumoencephalography. At The London Hospital the installation of a Phillips Isocentric chair has accentuated the problem.... The main design feature of the chair is that it has a single fulcrum common to all its movements.... This technique has the advantage that film quality is improved. Skull tomography is possible and that there is no need to lift the patient once he is strapped in the chair. However, there is a disadvantage in that to achieve stability within a small arc, the patient must assume a 'fetal' position in which the thighs are doubled up to the abdomen and the head flexed...."

"The anaesthetic technique employed for pneumoencephalography, prior to the acquisition of the chair, was oxygen and halothane with spontaneous ventilation. This investigation was carried out to test the hypothesis that the cardiorespiratory changes in patients in the required fetal position were minimal using this anaesthetic technique.... Fifteen adult patients were studied and in none of them was there evidence of raised intracranial pressure. Premedication was with pethidine 50 mg and promethazine 25 mg or atropine 0.6 mg alone...."

"Anaesthesia was induced with methohexitone and following the administration of suxamethonium, the larynx was sprayed with lignocaine, and the trachea was intubated. Spontaneous respiration was then established and anaesthesia maintained with halothane 0.5-1.5% in oxygen.... The arterial blood pressure and central venous pressure were measured by Statham transducers and recorded continuously together with the pulse rate.... A continuous display of the electrocardiograph (ECG) was also available.... Arterial blood-gas analysis... was carried out...."

"After induction the patient was placed supine in the isocentric chair and baseline recordings were made. The patient was then sat upright and strapped firmly into position to assume the fetal position.... Lumbar puncture was then performed and the needle left in position to allow incremental injections of oxygen into the subarachnoid space.... Before each change in position arterial blood samples were taken for measurement of blood-gases and blood-halothane levels. The continuous record was marked at each change of position, and the transducers re-zeroed immediately after each change in position.

"The recordings were analysed to determine the changes that occurred in the 3 minutes following the injection of increments of oxygen into the subarachnoid space. The changes in the cardiovascular parameters following alterations in posture, after allowing 3 minutes to minimise the effects solely due to movement, were subjected to statistical tests...."
“Cardiovascular effects

“Sitting up from supine. There was a mean rise in systolic blood pressure of almost 10 mmHg on sitting up from the supine position. This change was not statistically significant. . . . There was a statistically significant rise in pulse rate . . . but not in central venous pressure. . . .

“Tilted back. There was a mean rise in blood pressure of nearly 4 mmHg on tilting the patients backwards which was not statistically significant. . . . There was no change in mean pulse rate and only a minor increase in mean CVP readings.

“Supine and prone positions. No statistically significant changes occurred in either position.

“Back to upright. There was a mean fall in blood pressure of 23 mmHg and in CVP of 13 mmHg. Both these falls were statistically significant. . . .

“Respiratory effects

“Pao2. The mean Pao2 remained relatively constant throughout. There were no significant changes.

“Paco2. The only statistically significant rises in Paco2 occurred in the prone position. . . .

“Response to injection of intrathecal oxygen . . . .

“The increase in blood pressure over all was statistically significant. . . . Taken separately the 0-5 ml and 16-20 ml increments did not produce statistically significant rises in blood pressure.

“Halothane level

“There was no statistically significant change in blood halothane level throughout the procedure. This indicates a stable level of anaesthesia unaffected by the position changes.

“Premedication

“There was no statistically significant difference between those patients premedicated with pethidine and promethazine, and those premedicated with atropine alone. . . .

“Of the 475 pneumoencephalograms performed at this hospital during the past 2 years, only two cases have presented complications and in both cardiac arrest occurred. . . . Halothane has been shown to be a cause of increased intracranial pressure during anaesthesia but we prefer to use the technique of spontaneous ventilation with halothane in oxygen in those patients in whom there is no evidence of raised intracranial pressure. . . .

“The anaesthetic technique of spontaneous respiration with oxygen and halothane in patients undergoing pneumoencephalography in the Isocentric chair is safe in patients with normal intracranial pressure provided that there is no pre-existing respiratory disease, which may require an intermittent positive pressure technique. . . . The haemodynamic changes are of a minor nature in most cases. Increments of oxygen injected intrathecally should be limited to 5 ml.

“Cardio-respiratory changes associated with changes in posture and injection of intrathecal oxygen were studied in fifteen patients undergoing pneumoencephalography in a Phillips isocentric chair, while breathing spontaneously and anaesthetised with halothane in oxygen. Haemodynamic changes associated with changes in posture were of a minor nature. A rise in Paco2 occurred in the prone position in two obese patients. There were significant rises in blood pressure following injection of more than 5 ml of oxygen as a bolus into the subarachnoid space.”

Enflurane Anesthesia for Surgical Removal of Pheochromocytoma


“The anesthetic management of the patient with a pheochromocytoma (PCC) remains a challenge. . . . Much of the preoperative and intraoperative management is directed toward the prevention
of potentially dangerous alterations in heart rate and rhythm and the avoidance of extreme elevation or decrease in arterial blood pressure (BP).

"Halothane anesthesia has been recommended... because of its hypotensive effect. However, the high incidence of arrhythmias observed during halothane anesthesia and the well-known tendency of halothane to stimulate catecholamine activity have led... investigators to question its use in patients with PCC... Both methoxyflurane and fluroxene produce a low incidence of arrhythmias... but nephrotoxicity of the former and explosive properties of the latter are definitely disadvantageous.

"We employed enflurane anesthesia in 4 cases of PCC removal and feel that it may have several advantages over other currently advocated anesthetic technics for this procedure.

"Case 1.—A 31-year-old man admitted with an 18-month history of severe headaches.... A left renal anterogram revealed a tumor anterior to the left kidney consistent with a PCC. An ECG showed a diffuse ischemic change. The patient was premedicated with meperidine (100 mg), droperidol (5 mg), and atropine (0.4 mg) IM.... d-Tubocurarine (5 mg) was given IV and anesthesia was induced with thiopental (300 mg). Tracheal intubation was facilitated with succinylcholine (120 mg).... Anesthesia was maintained with enflurane (1 to 3% inspired concentration) and N2O (50 to 70%) in O2. Respiration was controlled.... No arrhythmias were noted throughout the entire procedure. One unit of whole blood was transfused rapidly after removal of the tumor. The postoperative period was uneventful and the patient was discharged 12 days after the surgical procedure.

"Case 2.—A 51-year-old woman was hospitalized for management of dizziness, visual blurring, palpitations, dyspnea, pounding headaches, nausea, substernal pressure, and cold, clammy skin.... The ECG showed a prolonged QT interval, left atrial hypertrophy, ST segment changes, and bradycardia.... Treatment with phenoxybenzamine (10 mg/8 hr) and propranolol (10 mg/8 hr) was started and the occasional hypertensive crises were managed with phentolamine (5 mg IV).

"Over a period of 10 days, Hb and hct fell from 16.2 gm/100 ml and 56 percent to 10.4 gm/100 ml and 30.8 percent.... On the night before operation, propranolol was discontinued and the patient was given 1 unit of whole blood.... Premedication was with morphine (10 mg), diazepam (5 mg), and atropine (0.4 mg). Two large-bore IV lines, a CVP, and an arterial line (radial) were inserted. ECG and arterial pressure tracings were continuously displayed and recorded.

"Anesthesia was slowly induced with IV thiopental and enflurane by mask. Approximately 7 minutes after the administration of pancuronium (6 mg), the trachea was intubated. During manipulation of the tumor, no arrhythmias or premature ventricular beats occurred despite a rise in BP.... There were no postoperative complications and the patient was discharged normotensive, without medications, on the 10th postoperative day.

"Case 3.—A 43-year-old woman was admitted with a history of severe headaches. Admission BP was 240/120. She also had generalized neurofibromatosis and was a known sickle cell carrier.... The ECG showed extensive anterolateral-wall ischemia, which normalized over 15 days. No clinical symptoms or laboratory evidence of myocardial infarction were found.

"On the day before operation, her Hb and hct were within normal limits and her BP was 110/80. Propranolol was discontinued the night before operation. The patient was premedicated IM with meperidine (100 mg), droperidol (5 mg), and atropine (0.4 mg). In the operating room, BP had risen to 200/100 and heart rate to 100/min. After preoxygenation, anesthesia was induced with thiopental (200 mg) IV, pancuronium (9 mg) was given IV.
and enflurane (2%) started by mask. With intubation 5 minutes later, BP increased to 215/120 and heart rate to 140/min. During manipulation of the tumor, a bigeminal beat was noted. After 2 injections of lidocaine (50 mg each within a 3 min period) failed to convert the arrhythmias, propranolol (0.5 mg) was given IV, converting the arrhythmias within 2 minutes. The remaining anesthesia course was uneventful.

"Removal of the tumor resulted in a moderate decrease in arterial BP and CVP and in catecholamine blood levels. . . . There were no immediate postoperative complications; however, several hours later, in intensive care, the patient's Pao2 fell from 101 to 57.9 torr and her respiratory rate rose to 40/min. A chest x-ray and lung scan showed multiple bilateral pulmonary emboli, which responded to anticoagulant therapy. The patient improved gradually and was discharged in satisfactory condition.

"Case 4.—A 60-year-old woman was admitted with an 11-year history of hypertension. . . . The lumbar anterogram showed a mass underlying the left kidney consistent with a finding of PCC. . . . The patient was premedicated with morphine (5 mg), secobarbital (100 mg), and atropine (0.4 mg). Before induction of anesthesia, BP was 170/80, with a heart rate of 100/min. Anesthesia was induced with thiopental (300 mg IV) and enflurane (1 to 3%) in N2O-O2 (50:50). . . .

"Occasional premature atrial beats were noted but disappeared after the BP was controlled by intermittent administration of phentolamine (0.01%) by drip, except during manipulation of the tumor. Packed red cells (2 U) were given after tumor removal. The systolic BP remained above 110 during the postoperative period and the patient was discharged normotensive and in satisfactory condition. . . .

"Although advances in the preoperative management of patients with PCC have greatly reduced intraoperative mortality and complications, the anesthetic management of the patient with such tumors still remains a challenge. . . . PCC is still too often complicated by abrupt and severe BP changes which result in severe cardiovascular crises. Treatment with alpha-adrenergic drugs, . . . in addition to competing for nor-epinephrine and epinephrine-sensitive receptors, tends to re-establish normal intravascular volume and thus decreases the possibility of severe hypotension following tumor removal. The preoperative management of PCC can also be enhanced by use of beta-adrenergic blocking drugs, both to protect against arrhythmias and to permit reduction of the amount of alpha-blocking drugs needed to control blood pressure.

"Whether propranolol should be continued during anesthesia or, if not, how long it should be discontinued, has been highly controversial. Previous reports have indicated that in certain disease states, the integrity of the sympathetic nervous system is important for maintaining circulatory stability, and have emphasized the potential dangers of beta-adrenergic blockade during anesthesia, even in a healthy individual. . . .

"In our study, all 4 patients received both alpha- and beta-adrenergic blocking drugs preoperatively, the propranolol being always discontinued 12 hours before operation to avoid intraoperative myocardial depression and possible cardiac collapse after removal of the tumor. . . .

"In retrospect, despite the short duration of treatment with propranolol, it would have been preferable to have gradually weaned the patients off propranolol. . . . However, no untoward events occurred in our cases. Arterial BP increased after intubation in every case, even though 'crash' intubation was avoided by mask administration of enflurane. . . . Deeper levels of enflurane anesthesia before intubation may well have avoided BP perturbations. However, the postintubation BP increases were accompanied by only slight increases in serum catecholamine levels.
producing tachycardia but no arrhythmias. In no case was removal of the tumor accompanied by a sudden and severe decrease of arterial BP; hence, no vasopressors were required.

"We believe that succinylcholine is not contraindicated in patients with PCC, especially if pretreatment with a small dose of nondepolarizing muscle relaxant is used. However, we chose to use pancuronium to facilitate intubation since pancuronium, unlike succinylcholine, does not directly stimulate the sympathetic nervous system."

"A review of the literature revealed that all principal anesthetic agents have been used in PCC operations, with varying degrees of success. Our choice of enflurane for PCC surgery was based on both empiric and pharmacokinetic considerations. While various agents have been recommended for possessing various combinations of favorable anesthetic properties, low incidence of arrhythmias, and hypotensive properties, these positive properties must be balanced against a variety of negative side effects. Our choice of enflurane for PCC surgery was based on both empiric and pharmacokinetic considerations.

"From our experience with enflurane and a review of the experience of other authors, we conclude that enflurane is not only as safe and effective an anesthetic as any now available for PCC excision but also that if offers such advantages as lack of flammability, cardiovascular stability, absence of cardiac sensitization to catecholamines, and controllability for rapidly changing anesthetic levels."

Observed and Predicted Accumulation of Local Anaesthetic Agents During Continuous Extradural Analgesia

"Continuous extradural analgesia, provided by either intermittent injection or an infusion of local anaesthetic agent, is being used increasingly for the relief of pain after operation and of pain associated with labour and childbirth. A potential problem with this technique is excessive accumulation of the local anaesthetic agent leading to systemic or local toxic effects, or both. Therefore, to circumscribe limits of safety it is essential to know whether the kinetic behaviour of the drugs is predictable during multiple or continuous dosage.

"In this communication we report experimental plasma concentrations of lignocaine and etidocaine after a single extradural dose for surgical anaesthesia followed by intermittent maintenance doses for pain relief following surgery. The drug concentrations obtained after the initial dose were used to predict those found following successive doses. The factors affecting the agreement between predicted and observed values are discussed, as are the implications of the accumulation of unabsorbed drug."

"Twenty-one patients were studied. Premedication consisted of diamorphine 5 mg and atropine 0.5 mg 1 h before surgery. A catheter, through which all doses of local anaesthetic were given, was inserted into the lumbar extradural space. Immediately following the initial dose general anaesthesia was induced with thiopentone 400 mg followed by halothane 0.5-1% in a mixture of nitrous oxide in oxygen. Blood loss was always less than 500 ml and no patient received an infusion of blood. Recovery of consciousness was rapid at the completion of the operation. Four further injections for the relief of pain were given in the period after surgery in those cases so treated.

"The patients were divided into groups according to dose:
Group I—lignocaine HCl (2% plain solution)
(a) \( n = 6 \) 400 mg for surgical anaesthesia followed by 200 mg at 1-h intervals until 4 h for pain relief after operation.

524 Journal of the American Association of Nurse Anesthetists
(b) \( n = 5 \) 400 mg for surgical anaesthesia only.

**Group II**—etidocaine HCl (1% plain solution)

(a) \( n = 5 \) 200 mg for surgical anaesthesia followed by 100 mg at 2-h intervals until 8 h for pain relief after operation.

(b) \( n = 5 \) 200 mg for surgical anaesthesia only.

Groups Ib and IIb were included to provide late plasma drug concentrations for predicting accumulation from single-dose data. Serial blood samples were taken via a central venous catheter and the plasma anaesthetic concentrations were measured by gas chromatography.

"All patients were free from signs of local anaesthetic toxicity and those receiving intermittent injections had satisfactory pain relief after operation.

"When potentially toxic drugs are injected repeatedly, it is important to know whether accumulation is likely to occur, as this may alter the dose required at each injection time. In the case of local anaesthetic agents, systemic accumulation may occur if the amount reaching the circulation during a dose interval exceeds that which the liver can metabolize. Accumulation may occur also at the site of injection and may alter the local anaesthetic effect on the nerves it is intended to block. This may be especially relevant in the extradural space. . . .

"In the present investigation, over the time periods studied, there was minimal plasma accumulation of both lignocaine and etidocaine when dose intervals of 1 and 2 h, respectively, and analgesic doses one-half of the loading dose for surgical anaesthesia were employed. Maximum concentrations were maintained below the thresholds usually associated with signs of c.n.s. toxicity. . . . Metabolites of the agents were not measured in this study and it is possible that their accumulation might contribute to unwanted effects. . . . Differences between predicted and observed plasma drug concentrations in the period following surgery were relatively constant through each of the four top-up doses. . . .

"Accurate estimation of the degree of local accumulation of the agents was not possible from an analysis of the present data, since this requires a knowledge of the i.v. disposition kinetics of the drugs in the same patients. . . . However, in the case of etidocaine, plasma concentrations obtained in this study were similar to those measured in the volunteer study . . . from which original calculations of drug absorption rate after single injections were made.

"The time profile of unabsorbed drug remaining in the extradural space and other local structures is readily calculated for the multiple dosage regime employed in the present study. . . . The result suggests that a significant local accumulation of etidocaine occurs and might alter the analgesic effect of top-up doses. Though detailed assessment of nerve block was not attempted in our patients, there were a few instances of very prolonged block with etidocaine after the injections were discontinued. Therefore, this possibility should be taken into account whenever highly lipid-soluble agents such as etidocaine or bupivacaine are being used."