410 DENTAL ANAESTHETICS

PART I: INTRODUCTION, METHODS, MATERIAL AND 
ANAESTHETIC TECHNIQUES

BY

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SUMMARY

Four hundred and ten dental anaesthetics administered at the Royal Dental Hospital, 
during August 1961 were studied by recording: (1) the gas mixtures delivered; (2) 
the pressures developed within the nosepiece; (3) the indirect systolic blood pres-
sure; (4) the brachial pulse. Recording was supplemented by direct observation when 
possible. Most of the patients studied were adults, the youngest child being 11 years. 
Nitrous oxide, oxygen and halothane, and nitrous oxide and oxygen were the anaes-
thetics usually employed, but fifteen different anaesthetic techniques were recorded. 
The deliberate use of hypoxia, of varied degree, was frequent. The reactions of patients 
to anaesthesia and surgery will be reported in Part II.

An ample supply of oxygen, a clear airway, and 
adequate ventilation and circulation are funda-
mental requirements of the anaesthetized patient; 
yet during dental anaesthesia one or more of them 
may be unfulfilled. For example, it is common 
practice to give oxygen at a partial pressure of less 
than half that in air. Control of the airway is not 
always maintained. Respiratory obstruction can 
occur, particularly during dental extractions, and 
the airway pressure may be raised due to the 
use of high anaesthetic flow rates and of expira-
tory valves having a high flow-resistance. Un-
recognized or untreated hypotension in a patient 
sitting in a dental chair may result in deficient 
cerebral and coronary circulations, and this is 
potentially a very dangerous state of affairs in the 
presence of pre-existing hypoxia.

Such disregard of basic principles can only be 
justified on the grounds that this type of anaes-
thesia is safe in practice, and that alternative 
anesthetic techniques have significant disadvan-
tages. The consequences may be no more serious 
than a narrowing of the margin of safety; but 
deaths have occurred (Seldin, 1947; Bourne, 1957, 
J., 1963), and the patients concerned have 
often been apparently fit and active before suc-
cumbing to what should have been no more than 
a safe minor procedure lasting a few minutes.

For every patient who has died, a number 
have probably been near to death. This may be 
so when patients take an unexpectedly long time to 
recover due, presumably, to cerebral dysfunction 
or even damage. Seldin (1947) reported that one 
surgeon, who practised "secondary saturation" 
(McKesson, 1920) met one case of delayed 
recovery per 3,000 anaesthetics. Bourne (1957) 
estimated that there were probably about five 
hundred cases per year in the United Kingdom 
in which recovery was delayed for half an hour 
or more. McConnel (1958) suggested that an 
experienced dental anaesthetist might see the 
results of oxygen lack, with grave threat to life, 
about once in 2,000 cases. But even this incidence 
of serious hypoxic phenomena makes the investi-
gation of it under clinical conditions a formidable 
task.

For every patient who has been near to death, 
a number have probably given some indication 
of an approach to danger. Jactitation is an obvious 
example, but there may be other clues for the 
seeking, and it was partly with this possibility in 
mind that the present investigation was launched.

The main purpose of the investigation was to
find out what anaesthetic techniques were actually practised in a reputable teaching centre and how patients reacted to these techniques. Observations were made on 410 dental anaesthetics between July 26 and August 31, 1961. The anaesthetics were given by six consultant anaesthetists and four anaesthetic registrars, except on the very rare occasions during this holiday period when they were given by students. The majority of the extractions were carried out by house surgeons. The data recorded were: the anaesthetic mixtures delivered by the anaesthetic machine; the pressures developed within the nosepiece during their administration; indirect systolic blood pressure; and the brachial pulse. The possible significance of these measurements in relation to the safety of dental anaesthesia, and preliminary trials with the apparatus used, have been discussed and described elsewhere (Smith, 1963a, b). Additional clinical observations were noted whenever possible. The investigation was designed to cause as little interference with normal routine as possible. The anaesthetic techniques used during the particular month of the investigation are reported in this paper. The reactions of the patients will be reported in Part II.

Bearing in mind the findings of Seldin, Bourne and McConnel mentioned earlier, 410 dental anaesthetics represents a very small sample, so this investigation should not be regarded as more than a pilot study. Discussion of its findings will be deferred to Part II.

METHODS

Anaesthetic apparatus.

Except on one occasion when a CON apparatus was used (Stephens and Bourne, 1960), a Walton Five anaesthetic machine of known and published performance was used throughout the study (Smith, 1961a). A Goldman vaporizer (Goldman, 1959, 1960) was used when nitrous oxide was supplemented with trichloroethylene or halothane. The choice between using standard narrow bore twin tubes or single tubes between the anaesthetic machine and the nosepiece, and the use of the reservoir bag and of the mouth cover was left to the discretion of the anaesthetist.

The concentration of oxygen in the anaesthetic mixture.

The position of the anaesthetic mixture control, and therefore the concentration of oxygen delivered to the breathing system, was recorded...
continuously. A sliding electrical contact was attached to the arm of the mixture control so that it moved over the surface of a semicircular commutator placed behind it. Resistors were connected between adjacent segments of the commutator, and each time the sliding contact moved from one segment to the next a "step" change was recorded. The commutator system and the percentage of oxygen represented by each "step" are shown in figure 1. There are no certain means of knowing when and to what extent the anaesthetic mixture was diluted with air due to mask leaks or to mouth breathing. In some instances dilution of the anaesthetic mixture with air undoubtedly took place, but there can be no justification for assuming that this was always the case. The delay between an alteration of the gas mixture delivered to the breathing system and a corresponding effective change in the gas mixture reaching the nosepiece would have depended upon the supply flow rate of the anaesthetic mixture, upon the particular breathing system used, and upon the respiratory flow pattern of the subject. It was probably quite short.

**The measurement of indirect systolic blood pressure and pulse rate.**

Indirect systolic blood pressure was measured by the method of Ernsting (Smith, 1962). A sphygmomanometer cuff was used in the customary way. It was inflated either by means of oxygen supplied through an adjustable reducing valve and a tap, or manually by means of a standard sphygmomanometer bulb. The cuff was connected to a multi-electrode mercury manometer by means of which cuff pressure changes were recorded as a series of "steps". Each "step" represented a pressure change of 2 mm Hg. The complete sweep of the recording pen was used for each of the ranges 0–100, 100–200 and 200–300 mm Hg. A piezo-electric crystal was placed over the brachial artery beneath the lower margin of the cuff, the pulse signals from which were recorded simultaneously with the cuff pressure "steps". The interpretation of the records and the limitations of the system have been discussed elsewhere (Smith, 1962). The intermittent inflation of the cuff interrupted the recording of the brachial pulse.

**The measurement of the pressure fluctuations within the nosepiece.**

A pressure tapping in the nosepiece was connected to an electromanometer (Vickers Research Ltd., capacitance type, ±15 cm H₂O pressure.

**FIG. 2**

(Read from right to left.) Recordings of pressure within the nosepiece. Downward deflections indicate expiration: The superimposed time signal indicates the base line (i.e. atmospheric pressure). O = start or end of anaesthesia. H = start of halothane administration. P = pressure control setting on Walton Five anaesthetic machine. S = start of surgical stimulation.

Patient No. 58, male, 50 years, upper left 7. Twin delivery tubes used without a reservoir bag. Sub-atmospheric pressure during inspiration.

No. 60, f., 22, upper right 1. Twin tubes without reservoir bag. Positive pressure during inspiration when pressure control at 20 mm Hg. Breath held during surgical stimulation—glottis open (cardiac pulsations superimposed as described in text and shown in enlarged section).

No. 63, m., 23, upper left 7. Twin tubes with reservoir bag. Breath held for 12 seconds with glottis open (cardiac pulsations present); 15 seconds later a steady pressure of 2 mm Hg recorded without cardiac pulsations.

No. 69, m., 13, upper right 5. A "gas and air" anaesthetic. Atmospheric pressure indicated whenever air admitted.

No. 70, m., 23, lower left 4. The anaesthetist observed and commented upon mouth breathing, yet pressure fluctuations continued.

No. 81, f., 39, lower left 3, right 4, 3, 2. An 8-second interval between start of anaesthesia and close application of nosepiece. Absence of respiratory pressure fluctuations during observed mouth breathing.

No. 92, f., 20, upper left 1, 2, upper right 3, 2, 1. Twin tubes without reservoir bag. Peak inspiratory flow rates higher than supply flow rate. Tachypnoea and hyperpnoea, followed by respiratory depression 12 seconds after increasing oxygen concentration.

No. 145, m., 58, lower left 1, 2, 3, lower right, 2, 1. Twin tubes without reservoir bag. Peak inspiratory flow rates higher than supply flow rates.

No. 252, m., 28, lower right 7. Corrugated tube with reservoir bag. Note extreme tachypnoea before surgical stimulation. Patient had nightmare.

No 329, m. (extraction record not available). Corrugated tube with reservoir bag. Pressure never sub-atmospheric (cf. patients Nos. 58 and 145, for whom comparable pressure control settings were used). Respiratory obstruction and/or mouth breathing started when mouth prop was inserted.
transducer) which was used with a Respiratory Analyser (Scott and Williams, 1960; Williams, 1960), and a pen recorder. The system was calibrated between \( \pm 11 \text{ mm Hg} \) using a water manometer. Examples of pressure records are shown in figure 2.

**Interpretation of the pressure fluctuations within the nosepiece.**

In established nasal respiration the pressure in the nosepiece rises above atmospheric pressure during expiration, the pressure change depending upon the expiratory flow rate, upon the setting of the pressure control on the Walton Five anaesthetic machine, and upon the flow resistance of the expiratory valve. During inspiration the pressure within the mask falls. If the anaesthetic gases are supplied at a flow rate greater than the peak inspiratory flow rate of the patient, the pressure within the nosepiece remains above atmospheric pressure (fig. 2, patient No. 60). When a reservoir bag is used and connected with the nosepiece by tubing of negligible flow resistance, the pressure within the nosepiece falls almost to atmospheric pressure during inspiration, provided that the supply flow rate is greater than the patient’s inspired minute volume and less than his peak inspiratory flow rate (fig. 2, patient No. 329). If the reservoir bag empties, or if the peak respiratory flow rate exceeds the supply flow rate when a reservoir bag is not used, then the pressure within the nosepiece becomes sub-atmospheric (Smith, 1961b) (fig. 2, patients Nos. 58, 92, 145).

The presence of pressure fluctuations within the nosepiece which coincide with respiratory movements, however, does not necessarily mean that there is no mouth breathing. Provided that communication between the oropharynx and the nasal passages remains patent, the pressure within the nosepiece continues to fluctuate with respiration, but the more the mouth breathing the smaller the pressure fluctuations (fig. 2, patient No. 70 and probably No. 252). The pressure about which these fluctuations occur depends upon the setting of the pressure control on the Walton Five anaesthetic machine, the flow-resistance of the expiratory valve and the resistance to flow within the nose, the pharynx and the mouth.

The freer the passage between the nares and the mouth, the lower the pressure.

A reduction in the amplitude of the pressure fluctuations may also result from a small leak between the nosepiece and the face. Leaks of this nature, however, may be enough to reduce the pressure within the nosepiece to atmospheric pressure. This occurs at the start of the induction of anaesthesia before the nosepiece is applied properly to the face (fig. 2, patients Nos. 81, 145, 252).

A pressure within the nosepiece which is above atmospheric pressure but without respiratory fluctuations may indicate apnoea, respiratory obstruction, or closure of the communication between the oropharynx and the nasopharynx (fig. 2, patients Nos. 60, 63, 81). In the latter case there may be mouth breathing. In the presence of respiratory obstruction there may be large changes in intra-thoracic pressure. Sometimes small fluctuations, corresponding with heart beats, are superimposed upon an otherwise flat pressure trace (fig. 2, patients Nos. 60, enlarged record, and 63). These indicate that the patient is apnoeic, the glottis remaining open and the oropharynx remaining in communication with the nasopharynx.

**Recording apparatus.**

An Ediswan four-channel pen recorder was used and a record of sphygmomanometer cuff pressure, brachial pulse, oxygen concentration delivered by the anaesthetic machine and mask pressure is shown in figure 3 (patient No. 247).

Additional information, such as the start of the induction of anaesthesia, the time of intravenous injections and their dosage, the administration of supplementary inhalational anaesthetics, surgical stimuli, pallor, nausea, vomiting, etc., were written on the record manually. Precision in the timing of these notes cannot be guaranteed, nor is it likely that all incidents of interest were recorded because the observer had to divide his attention between the recording apparatus, the operation of the syphygmanometer inflating and deflating mechanism and the clinical events.

**Procedure.**

It was the author’s impression that the presence of the apparatus caused more concern to the medical and dental staff than to the patients. The
Fig. 3
(Read from right to left). The record obtained during anaesthesia and during the early part of the postanaesthetic period with patient No. 247. She fainted in the postoperative period following a brief lucid interval. (The corresponding anaesthetic chart is shown in Part II, fig. 2.)
The layout of the apparatus in the gas room of the Royal Dental Hospital. The sphygmomanometer cuff and the pulse detector are on the arm of the dental chair. Twin delivery tubes and the nosepiece lie over the head-rest. The pressure tapping in the nosepiece is connected to the pressure-transducer in the tray above the Walton Five anaesthetic machine. The Respiratory Analyser is behind the anaesthetic machine. The investigator stood on the far side of the recorder trolley. The control for regulating the cuff pressure was at his right hand and is just visible on the top shelf. The multi-electrode mercury manometer is concealed on the lower shelf.

patients usually accepted the apparatus (fig. 4), as if it were part of the normal furniture, but reassurance and explanations were given when appropriate.

If the patient was wearing a jacket he was asked to remove it. When he was settled in the dental chair the pulse detector was secured over his left brachial artery and the sphygmomanometer cuff was wrapped around the arm above it. The systolic blood pressure was recorded before the induction of anaesthesia whenever possible. On the rare occasions when the patient appeared to dislike this procedure the cuff was not re-inflated until he was thought to have lost consciousness. The dentist usually inserted a mouth prop before the induction of anaesthesia and it was usually the anaesthetist who inserted the mouth pack at the end of the induction.

Recording was continued throughout anaesthesia. The anaesthetist often assisted in the recording of additional data by stating when he altered the position of the vaporizer control or the

![Fig. 4](image_url)

**Fig. 4**
The layout of the apparatus in the gas room of the Royal Dental Hospital. The sphygmomanometer cuff and the pulse detector are on the arm of the dental chair. Twin delivery tubes and the nosepiece lie over the head-rest. The pressure tapping in the nosepiece is connected to the pressure-transducer in the tray above the Walton Five anaesthetic machine. The Respiratory Analyser is behind the anaesthetic machine. The investigator stood on the far side of the recorder trolley. The control for regulating the cuff pressure was at his right hand and is just visible on the top shelf. The multi-electrode mercury manometer is concealed on the lower shelf.

![Fig. 5](image_url)

**Fig. 5**
The age and sex distribution of the patients anaesthetized in the dental chair.
pressure control on the anaesthetic machine. The dentist often announced when he was applying forceps, and to which tooth.

Sometimes the patient was kept in the dental chair slightly longer than he would have been under normal circumstances in order to obtain additional blood pressure recordings. The blood pressure cuff and the pulse detector were then removed and the patient was allowed to go. There was no other interference with normal routine. No further observations were made once the patient had left the “gas” room.

RESULTS

The patients and the surgery.

The efficacy of inhalational agents and techniques used for anaesthetizing ambulatory patients depends, among other things, upon their health, age, sex, build, activity and social habits, and upon the type and duration of the surgery to be carried out. All the patients observed during this study were capable of walking unaided up to the third floor of the hospital. They were not premedicated. Their age and sex distribution is shown in figure 5. Only the larger children were included in the study, the youngest being 11 years old. The oldest patient was 78 years old. Systematic records of build, medical history, occupation and of the consumption of alcohol and of drugs were not kept. The total number of teeth to be extracted per patient is given in table I and the time taken for extraction is indicated in figure 6(b).

<table>
<thead>
<tr>
<th>Total number of teeth extracted per patient.</th>
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<td>Total number of teeth</td>
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<td>11</td>
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<td>16</td>
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<tr>
<td>Other procedures</td>
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<td>Not recorded</td>
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<td>Total</td>
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<th>Table II</th>
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<td>The anaesthetic agents used and the sequence in which they were administered.</td>
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<tr>
<td>No. of patients</td>
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<tr>
<td>Nitrous oxide without supplementary anaesthetic agents</td>
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<td>Nitrous oxide and air</td>
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<td>Nitrous oxide, oxygen and air</td>
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<tr>
<td>Nitrous oxide and oxygen</td>
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<td>Nitrous oxide and oxygen with supplementary inhalational anaesthetics</td>
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<tr>
<td>Nitrous oxide, oxygen and trichloroethylene</td>
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<tr>
<td>Nitrous oxide, oxygen and halothane</td>
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<tr>
<td>Nitrous oxide, oxygen, halothane and ethyl chloride (on mouth pack)</td>
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<td>CON apparatus (cyclopropane 40 per cent, nitrogen 30 per cent and oxygen 30 per cent)</td>
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<tr>
<td>Inhalational anaesthesia with supplementary intravenous methohexitone</td>
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<td>Nitrous oxide, oxygen and methohexitone</td>
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<td>Nitrous oxide, oxygen, trichloroethylene and methohexitone</td>
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<tr>
<td>Nitrous oxide, oxygen, halothane and methohexitone</td>
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<tr>
<td>Inhalational anaesthesia after intravenous induction using methohexitone</td>
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<td>Methohexitone, nitrous oxide, oxygen and air</td>
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<td>Methohexitone, nitrous oxide and oxygen</td>
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<tr>
<td>Methohexitone, nitrous oxide, oxygen and ethyl chloride (on mouth pack)</td>
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<td>Methohexitone, nitrous oxide, oxygen and trichloroethylene</td>
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<tr>
<td>Methohexitone, nitrous oxide, oxygen and halothane</td>
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<tr>
<td>Endotracheal anaesthesia</td>
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<tr>
<td>Nitrous oxide, oxygen, halothane, methohexitone and suxamethonium</td>
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<td>Total</td>
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</table>
The anaesthetics.

The frequency with which the various anaesthetic agents were used, and the sequence in which they were administered, is given in table II.

The frequency distribution of different durations of inhalational anaesthesia is shown in figure 6. Figure 6(a) indicates the time of induction of anaesthesia using inhalational agents (i.e. excluding the time of injection of intravenous agents, when used, and excluding the interval between the end of intravenous injection and the start of inhalational anaesthesia). Figure 6(c) indicates the total duration of inhalational anaesthesia.

It is often claimed that anaesthesia is induced in outpatients as much by oxygen deprivation as by the administration of nitrous oxide. This "negative" anaesthetic of no-oxygen, however, has not been included in table II. Instead, the times during which no oxygen was delivered to the breathing system and the times during which the oxygen delivered did not rise above 5 per cent are given in figures 7 and 8. The longer periods of oxygen restriction in the gases delivered by the anaesthetic machine were probably associated with the admission of air due to mouth breathing or to leaks between the nosepiece and the face. Figure 9 also indicates the relationship between the use of pre-oxygenation and the duration of oxygen restriction.

Measurement of the mean pressure within the nosepiece during anaesthesia was not attempted. The maximum pressures recorded during expiration have been taken as an indication of the pressures which can be developed during anaesthesia.
<table>
<thead>
<tr>
<th>No. of patients</th>
<th>Patients pre-oxygenated</th>
<th>Jactitations</th>
<th>Depression of B.P. or pulse rate - pulse irregularities - nausea or vomiting</th>
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Average 45 seconds:
301 patients

**Fig. 7**
The duration of administration of 100 per cent nitrous oxide at the start of anaesthesia. The number of patients who were pre-oxygenated is indicated.
The duration of administration of not more than 5 per cent oxygen at the start of anaesthesia (patients receiving 100 per cent nitrous oxide, as shown in fig. 7, are included). The number of patients who were pre-oxygenated is indicated.
The relationship between the periods of pre-oxygenation used and the duration of gross oxygen deprivation at the start of anaesthesia. The right half of this figure relates to fig. 7 and the left half to fig. 8.

The maximum and minimum pressures developed within the nosepiece during anaesthesia (minimum pressures include only those of more than 2.5 mm Hg below atmospheric pressure during the first 30 seconds of anaesthesia).
and they are shown in figure 10. For present purposes, it has been assumed that the main significance of a subatmospheric pressure during inspiration is that it can be uncomfortable and can facilitate the dilution of anaesthetic mixture with air if there are any leaks in the system, such as between the nosepiece and the face. Only when the pressure within the nosepiece fell more than 2.5 mm Hg below atmospheric pressure within the first 30 seconds of inhalational anaesthesia has the pressure during inspiration been noted. These pressures are also given in figure 10. Individual pressure tracings are shown in figures 2 and 3.

ACKNOWLEDGMENTS

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REFERENCES


