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FORUM

Sevoflurane inhalation conscious sedation for children having dental treatment

G. Y. G. Lahoud,[1] P. A. Averley[2] and M. R. Hanlon[3]

1 Consultant Anaesthetist, Scarborough General Hospital, Scarborough YO12 6QL, UK
2 Principal Dental Surgeon and 3 Associate Dental Surgeon, Queensway Anxiety Management Clinic, 170 Queensway, Billingham TS23 2NT, UK

Summary
An audit at the Queensway Anxiety Management Clinic of 2014 children, referred for dental treatment, showed that relative analgesia by inhalation of nitrous oxide and oxygen failed in 40% of cases successfully to complete treatment. We therefore investigated the efficacy of a new inhalation conscious sedation technique, which reduced the need for general anaesthesia. Seventy-five children aged 3–15 years were given inhalation conscious sedation, with sevoflurane 0.1–0.3% and nitrous oxide 40% in oxygen. In 69 children (92%) the dental treatment was completed successfully. Most children (93%) had recovered fully within 10 min without side-effects. Treatment was fully accepted by 88% of children and 91% of their parents. The use of sevoflurane in low concentrations to supplement nitrous oxide and oxygen for conscious sedation in children appears to be safe and effective and warrants further study.

Keywords dental anxiety, general anaesthesia, inhalation conscious sedation, intravenous conscious sedation, paediatric sedation, relative analgesia, sevoflurane.

Correspondence to: Dr G. Y. G. Lahoud
E-mail: queensway@talkzi.com
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There is consensus among policy makers and professionals that the use of dental general anaesthesia should be minimised [1–5]. The use of conscious sedation in primary dental care contributes to this outcome. Reducing the need for general anaesthesia, particularly for children, is consistent with public expectations and professional concerns [6–8]. A recent review of general anaesthesia and conscious sedation in the UK recommended a 'hospital setting' for dental general anaesthesia from the beginning of 2002 [5]. Our options for preventing anxiety in children having dental treatment will therefore be limited to local anaesthesia combined with either relative analgesia or intravenous conscious sedation. Relative analgesia is an inhalation sedation technique which consists of three elements. Firstly, the administration of low to moderate concentrations from 0% to a maximum of 70% of nitrous oxide in oxygen to patients who remain conscious, with the precise concentration of nitrous oxide fully titrated to the needs of each patient. Second, as nitrous oxide begins to exert its pharmacological effects, the patient is subjected to a steady flow of reassuring and semihypnotic suggestions by the operating dentist. This establishes and maintains a rapport with the patient. Third, the use of fail-safe equipment with a range of safety features; most importantly the equipment should not allow either deliberate or accidental administration of 100% nitrous oxide [9–11].

The Queensway Anxiety Management Clinic was established and supported by Tees Health Authority, with the aim of reducing the use of general anaesthesia in dental practice, by substituting conscious inhalation and intravenous sedation techniques [12].

An anxiety management protocol was developed and applied to anxious patients referred for dental treatment. Over an 18-month period (January 1998 to June 1999)

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this resulted in a reduction in general anaesthesia for children from 100 to 25%; this was accompanied by an increase in inhalation conscious sedation (relative analgesia) from 0 to 35% and in intravenous conscious sedation from 0 to 40%. However, an audit showed that in 40% of cases, at an average mixture of 40% nitrous oxide in oxygen, relative analgesia did not allow the successful completion of dental treatment due to poor patient co-operation. Failure of relative analgesia usually required progression to intravenous conscious sedation or general anaesthesia.

Intravenous conscious sedation for children delivered by an anaesthetist usually means giving increasing doses of the benzodiazepine drug midazolam, or a sedative dose of propofol, or a combination of these drugs with or without an opioid such as fentanyl. Patients must be fully monitored by experienced personnel who are trained to carry out advanced life support. Intravenous conscious sedation can be unpredictable in children. It may precipitate loss of consciousness, a compromised airway, loss of protective reflexes, hypoxaemia and delayed recovery.

We therefore decided to try to improve the results of inhalation conscious sedation, which is safe but not always effective.

Sevoflurane [13, 14] is a well-established and safe anaesthetic agent. It has unique properties of rapid uptake and elimination. For children it is the most widely accepted and tolerated anaesthetic drug. The combination of a fixed ratio of nitrous oxide and oxygen (40/60%) with a variable but subanaesthetic concentration of sevoflurane [15], titrated clinically to allow dental treatment, seemed a natural way to improve the success of inhalation conscious sedation. Concentrations between 0.1 and 0.3% fulfil the criteria for conscious sedation adopted by the General Dental Council [2]:

'A technique in which the use of a drug or drugs produces a state of depression of the central nervous system enabling treatment to be carried out, but during which verbal contact with the patient is maintained throughout the period of sedation. The drugs and techniques used to provide conscious sedation for dental treatment should carry a margin of safety wide enough to render loss of consciousness unlikely.'

Patients and methods

Ethical approval was obtained from the North Tees local research ethics committee and a licence from the Department of Health, Medicines Control Agency.

Seventy-five children aged 3–15 years, ASA I and II, who had been referred to the Queensway clinic were recruited. Each child's degree of anxiety and need for dental treatment was assessed. Pre-assessment took place a few days before treatment. The standard pre-assessment document including a medical questionnaire was completed by the child's parent or guardian with the help of the dentist [12]. Full verbal and written explanation of the project was provided to parents and written informed consent was obtained. Each child was shown by the dentist >how to breathe spontaneously through a nasal hood. The criteria that identified these children as suitable for normal inhalation conscious sedation were applied; these criteria are listed below and make up $\approx 55\%$ of referred children.

1 Children who are anxious aged 3 years and over.

2 Children who speak English as a first language and are not educationally impaired.

3 Children who sit in the dental chair at assessment, are able to tolerate an examination and will accept a nasal hood.

4 Children who have non-obstructed nasal airways.

5 Children who do not present with acute oro-facial swellings.

6 Children and parents who are able to give informed consent to treatment with inhalation sedation and who would not be better served with intravenous sedation.

7 Children requiring elective treatment, e.g. orthodontic extractions.

Sedation technique

A mixture of lidocaine and prilocaine (EMLA® cream) was applied to the dorsum of both hands of each child by the parent, 1 h before the appointment, in case venous access was required should the inhalation technique fail.

Parents were invited to be present with their child in the treatment room throughout the dental procedure. Each child lay supine in the dental chair. A pulse oximeter probe was attached and a baseline Eve's test [16] was carried out. Eve's test is a simple control test of spatial awareness in which the child touches the tip of his/her nose with their forefinger with their eyes closed. The anaesthetist then gave a titrated concentration in the range $0.1-0.3\%$ of sevoflurane delivered by a Drager Vapour 2000 Vaporiser, in conjunction with 40% nitrous oxide in oxygen at a gas flow of 4–6 $l.min^{-1}$ delivered by a Drager Julian anaesthetic machine. The gases were delivered by continuous flow through an inspiratory limb connected to the nasal hood. From the nasal hood the expiratory limb incorporating a one-way non-return valve was connected to the scavenging system. The nasal hood was adapted to incorporate a probe to measure fractionated inspired and end-tidal oxygen, nitrous oxide and sevoflurane.

During the procedure the dentist chatted with the child using hypnotic suggestion and imagery, to reassure the child and distract attention. Before the planned dental treatment the child was given topical anaesthesia, and

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Anaesthesia, 2000, **56**, pages 1–6 **Forum**

Table 1 The six-point Venham Scale [17].

1. Relaxed: Smiling, able to converse, best possible working conditions. Displays the behaviour desired by the dentist spontaneously, or immediately upon being asked.
2. Uneasy: Concerned. During stressful procedure may protest briefly and quietly to indicate discomfort. Child willing and able to interpret experience as requested. Tense facial expression. Breathing is sometimes held in. Capable of co-operating well with treatment.
3. Tense: Tone of voice, questions and answers reflect anxiety. During stressful procedure, verbal protest, quiet crying, hands tense and raised but not interfering much. Child interprets situation with reasonable accuracy and continues to cope with his or her anxiety. Protest more distracting and troublesome. Child still complies with request to co-operate. Continuity is undisturbed.
4. Reluctant: Tends to reject the treatment situation, difficulty in assessing situational threat. Pronounced verbal protest, crying. Using hands to try to stop the procedure. Protest out of proportion to threat, or is expressed well before the threat. Copes with situation with great reluctance. Treatment proceeds with difficulty.
5. Anxious: Anxiety interferes with ability to assess situation. General crying not related to the treatment. Prominent body movements, needing restraint on occasion. Child can be reached through oral communication, and eventually with reluctance and great effort begins to cope. Protest disrupts procedure.
6. Out of Contact: Fails to grasp the reality of the threat, hard loud crying. Screaming, swearing. Unable to listen to oral communication. Regardless of age reverts to primitive flight responses. Actively involved in escape behaviour. Treatment impossible to complete.

2 min later a local anaesthetic was injected by the dentist. At intervals of 5 min the dentist made a simple assessment of the degree of co-operation using the six-point Venham scale [17] (Table 1). Oxygen saturation, heart rate, fractionated inspired sevoflurane and end-tidal sevoflurane were also measured and recorded every 5 min during the dental treatment.

Recovery

When treatment had been completed, sevoflurane was withdrawn and 100% oxygen was given through a nasal hood for 3 min. The child was then monitored during recovery by a nurse who recorded the following information:

1 the time of the child's arrival in the recovery room;

2 oxygen saturation and heart rate;

3 level of anxiety and co-operation using the six-point Venham scale [17];

4 the child's performance of an Eve's test [16] after 2 and 5 min;

5 when the children had completed the Eve's test they were asked to walk unaided in a straight line across the room under close supervision;

6 visual analogue scale for pain [18] as recorded by the child. (0–1, no hurt; 2–3, tiny hurt; 4–5, little more hurt; 6–7, hurts even more; 8–9, hurts a whole lot; 10, hurts as much as I can imagine);

7 parent's opinion of the overall management of the child (1 = excellent, 2 = good, 3 = satisfactory, 4 = fair, 5 = poor).

The child was then considered to be fully recovered and fit to go home.

Results

The characteristics of the children are shown in Table 2. The technique was effective in 69 of the 75 children (92%).

During treatment the dentist assessed the level of co-operation using the Venham scale. Sixty-three children (84%) had a score of 1 (relaxed), six (8%) had a score of 2 (uneasy) and six failed to co-operate. Of these, one child scored 4 (reluctant), four (5%) scored 5 (anxious) and one scored 6 (out of contact). The mean (SD) sedation time was 21 (8) min [range 10–40].

During treatment the oxygen saturation was $>98\%$ in all cases. Heart rates were all within normal limits $\pm 20\%$. Inspired and end tidal concentrations of sevoflurane were between 0.1 and 0.3% for all children. No adverse incidents or side-effects were encountered.

During recovery 67 of the 69 treated children (97%) completed Eve's test [12] satisfactorily and succeeded in walking unaided within 2 min; the other two children (3%) took 5 min to perform the tests.

The mean (SD) time to discharge was 7.2 (3.1) min [range 3–15 min; Table 2].

The results of the visual analogue scale [16] for pain by children during recovery are shown in Table 3. Treatment was fully accepted by 88% of children.

The level of anxiety and co-operation [17] of children during recovery as assessed by the recovery nurse are shown in Table 4.

Sixty-eight parents (91%) regarded the overall management of their children as excellent. One 15-year-old child rated the treatment as unsatisfactory and stated that she preferred intravenous sedation, which she had been given on two previous occasions.

Table 2 Characteristics of 75 children. Mean (SD) [range].

Age; years ($n = 75$)	6.4 (2.5) [3–15]
ASA classification; I : II	70 : 5
Weight; kg ($n = 75$)	22.4 (8.6) [13–62]
Sedation time; min ($n = 69$)	21.3 (7.9) [10–40]
Discharge time; min ($n = 69$)	7.2 (3.1) [3–15]

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Table 3 Visual analogue scale for pain (recorded by children during recovery [18]). Number (% of children completing treatment).

Child's perception of pain	
0–1 No hurt	58 (84)
2–3 Tiny hurt	8 (12)
4–5 A little more hurt	3 (4)
6–7 Hurts even more	0
8–9 Hurts a whole lot	0
10 Hurts as much as I can imagine	0
Total (completing treatment)	69

Of the six children whose treatment was not completed under sevoflurane, one cried after the extraction of three teeth and required intravenous conscious sedation with propofol to complete the fourth and last extraction; another required general anaesthesia because neither sevoflurane nor intravenous conscious sedation with propofol and midazolam made the child co-operative; and the four other children refused local anaesthetic injections and required general anaesthesia. General anaesthesia was induced with sevoflurane using a closed circuit after which a laryngeal mask airway was introduced.

Discussion

We do not think that sevoflurane inhalation conscious sedation for children who require dental treatment has been assessed previously. The high failure rate of relative analgesia (40%) in children referred for anxiety management is distressing. This failure rate means that children will need either conscious intravenous sedation or general anaesthesia in order to proceed with their treatment.

An acceptable alternative to a intravenous conscious sedation technique is desirable for children with needle phobia, or when the risks of intravenous conscious sedation are considered unacceptable. Intravenous conscious sedation carries an increased risk of adverse outcome, particularly in young children. This risk is often associated with the use of more than one sedative drug even when the drugs being administered are within acceptable dose limits [19].

Table 4 Level of anxiety and co-operation recorded by recovery nurse (using the six-point Venham Scale [17]). Number (% of children completing treatment).

Venham scale co-operation score	
1. Relaxed	38 (55)
2. Uneasy	27 (39)
3. Tense	4 (6)
4. Reluctant	0
5. Anxious	0
6. Out of contact	0
Total (completing treatment)	69

Sevoflurane given in a titrated concentration of between 0.1 and 0.3% in conjunction with 40% nitrous oxide in oxygen fulfils the definition of conscious sedation adopted by the General Dental Council [2]. All children in the study remained responsive to verbal commands throughout their treatment. There were no adverse side-effects observed. Kihhara *et al.* [15] investigated the awakening concentrations [mean alveolar concentration (MAC)-awake] of sevoflurane in unpremedicated children (age range 2–10 years) and reported that the mean (SD) MAC-awake of sevoflurane alone was 0.78% (0.24). The MAC-awake of 0.1–0.3% sevoflurane and 40% nitrous oxide in oxygen was not studied. Clinical observations during this study confirmed that all children remained conscious. It is anticipated that the use of fractionated inspired sevoflurane between 0.1 and 0.3% in 40% nitrous oxide in oxygen would result in a MAC below that described by Kihhara *et al.* [15]. This technique relies on a careful titration of sevoflurane to promote anxiolysis and improve co-operation. The precise concentration required is tailored to each child's needs. We suggest that the concentration of sevoflurane should not exceed 0.3% given in 40% nitrous oxide and oxygen. Continuous monitoring of oxygen saturation, heart rate, inspired and end-tidal sevoflurane and a sedation or co-operation score [17] is essential. Because of the use of 60% oxygen, reduced oxygen saturation is unlikely with this technique. All children in the study recorded 98% oxygen saturation or above during treatment and in the recovery room.

The study showed that, of 75 children, 69 (92%) successfully completed treatment. This indicates that this technique is likely to prove more effective than inhalation conscious sedation with nitrous oxide alone. During treatment, the dentist assessed the child's level of co-operation using the Venham Scale [17]; 63 children (84%) had a score of 1 (relaxed) and six (8%) had a score of 2 (uneasy but capable of co-operating well with dental treatment). This co-operation resulted in 92% of children allowing the successful completion dental treatment. The results showed that 66 children (88%) and 68 parents (91%) considered that the overall treatment of their children was excellent.

All parents were instructed not to allow their children to have solid food or milky drinks for 6 h prior to treatment. Clear fluids were allowed up to 3 h before the scheduled treatment. We suggest that, for the time being, this fasting policy is maintained despite the fact that all children maintained full protective reflexes during the study.

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It seems that the advantages of sevoflurane sedation are its safety, practicality, effectiveness, acceptability and cost-effectiveness. Dentists were satisfied with the quality of sedation and the extent of co-operation by the children. Sevoflurane conscious sedation meets the definition laid down by the General Dental Council [2].

Sevoflurane is not marketed for this use in the UK at present, and sevoflurane conscious sedation is not licensed or approved for general use. A large randomised controlled clinical trial for over 500 children is currently in progress to compare sevoflurane with nitrous oxide inhalation sedation.

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