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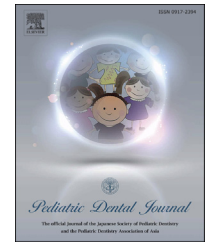

Research Paper

LARAGA – Pharmacological behaviour management in paediatric dentistry in the UK

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ABSTRACT

Introduction: While non-pharmacological behaviour management plays an important role in paediatric dentistry, it is not the solution for all children and a proportion will still require an adjunctive pharmacological approach such as local anaesthetic, relative analgesia or general anaesthetic (LA-RA-GA).

Aims: Paediatric conscious sedation at Newcastle Dental Hospital (NDH) is distinctive in that RA is provided by both the Child Dental Health (CDH) and Sedation (SED) departments. The primary aim of this study was to evaluate the outcomes of the NDH paediatric sedation service and analyse the effect of various confounding factors involved in treatment.

Materials and methods: This cross-sectional analysis forms part of a retrospective service evaluation of the inhalation sedation service provided by Newcastle Dental Hospital. Anonymised data were collected on 200 patients attending NDH (100 CDH, 100 SED) between September 2019 and March 2020. Data were cleaned manually and analysed using descriptive statistics, exploratory analysis with chi-squared tests and multivariable analyses (logistic regression) to identify any factors associated with failed RA appointments.

Results: Overall success for the NDH paediatric inhalation sedation service was 90.5%; CDH %/n = 89%, SED %/n = 92. There was a significant association between a failed RA appointment and no RA experience, a mother attending as chaperone and patients being under six years old. The odds of failure in an afternoon appointment were 1.6 times higher than a morning appointment, and girls were 1.5 times more likely than boys to have a failed RA appointment.

Conclusion: Dental treatment under combined RA and LA is a successful technique for managing mild-to-moderately anxious paediatric patients. Careful patient selection, based on patient cooperation at the initial consultation, alongside an episode of acclimatisation, may help increase treatment success rates.

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1. Introduction and background

Dental treatment in the paediatric populace frequently involves the delivery of invasive surgical treatment using injections and sharp, high-speed instruments in one of the most personal and sensitive parts of the body. In order to be successful, a clinician must establish a dynamic relationship with patient and accompanying adult, based on trust, to not only ensure compliance with prevention regimes, but to allow treatment to proceed, thus forming a "treatment alliance" [1]. The most recent Children's Dental Health Survey found that over half of adolescents in the UK reported moderate dental anxiety, with around a fifth (17–21%) of five and eight-year-olds moderately-to-extremely dentally anxious [2]. Not only are dentally anxious children more likely to have higher caries incidence and more missing teeth, but they also tend to irregularly access services, typically only when experiencing symptoms [3,4].

One of the most important yet challenging aspects of paediatric dentistry is pain control, especially as children who undergo early painful experiences during dental procedures are likely to carry negative feelings and anxiety toward dentistry into adulthood [5]. Non-pharmacological behaviour management techniques (NPBMT) such as Tell-Show-Do (TSD), positive reinforcement, distraction and systematic desensitisation are just a few among many examples successfully employed across paediatric dentistry, including the more recent introduction of cognitive behavioural therapy (CBT) [6]. Although it is quite possible for the majority of children to accept dentistry with NPBMT and local anaesthetic (LA) alone, for those who cannot, a spectrum of pharmacological behaviour management strategies such as relative analgesia (RA) and general anaesthesia (GA) are available – Fig. 1 [7].

In 1990, the publication of the Poswillo Report surrounding anaesthesia, sedation and resuscitation in dentistry recommended a move away from GA use in dental practice, and where patients did not respond to NPBMT and LA alone, the next treatment option of choice should be conscious sedation; a move championed by the Department of Health, General Dental Council, Royal College of Anaesthetists, Intercollegiate Advisory Committee for Sedation in Dentistry and the Society for Advancement of Anaesthesia in Dentistry [8,9].

In the UK, the standard method of paediatric sedation is RA, an inhalation technique which uses sub-anaesthetic, titrated doses of nitrous oxide (N_2O) and oxygen (O_2), alongside hypnotic suggestion, to induce a state of psycho-pharmacological sedation [10]. Nasally inhaled nitrous oxide has both a rapid onset (a few minutes) and rapid reversal, with N_2O exhaled from the lungs at the cessation of its inhalation [11]. Patients remain awake and responsive to verbal commands, hence nitrous oxide sedation is designed to complement and not replace NPBMT, as although RA provides appropriate levels of anxiolysis, it has a weak analgesic effect, with LA still required for provision of high-quality treatment [11]. It is typically delivered via a nasal hood using a Quantiflex® MDM relative analgesia machine (Fig. 2) until the maximum therapeutic level for each individual patient is achieved. These machines have multiple inbuilt safety features, including ensuring a minimum of 30% O_2 (maximum 70% N_2O) is delivered, thus preventing the delivery of hypoxic levels of sedation [12].

Recent data from the NHS Business Services Authority shows that between 50,000–60,000 dental sedation procedures (inhalation and intravenous) are carried out each year on children in England and Wales [13]. While the majority of conscious sedation is provided across specialist, hospital and community dental settings, there is a relative paucity in the literature on how commonly RA is used in general practice in the UK [14]. In contrast, during 2019–2020, there were 55,137 finished consultant episodes for children and adolescents (aged 0–19 years) in England who were admitted for dental extractions under general anaesthetic, with tooth decay remaining the most common reason for hospital admissions in the 6–10-year-old age group [15].

Paediatric conscious sedation at Newcastle Dental Hospital (NDH) is provided by both the Child Dental Health (CDH) and Sedation (SED) departments. The sedation department provides an exodontia-only service, whereas the full complement of paediatric dental treatment is provided by the CDH department, providing the unique opportunity for an evaluation of the service as a whole and a comparison between the departments, including by type of treatment provided. The primary aim of this study was to evaluate the outcomes of the NDH paediatric sedation service and analyse the effect of various confounding factors involved in treatment.

2. Materials and Methods

This cross-sectional analysis forms part of a retrospective service evaluation of the inhalation sedation service provided by the Child Dental Health and Sedation departments of Newcastle Dental Hospital, England - registered with the Newcastle upon Tyne Hospitals (NUTH) Clinical Effectiveness Register (Ref. 10,149).

Anonymised data were collected on 200 patients attending NDH (100 CDH, 100 SED) between September 2019 and March 2020. As 100 patient records were chosen for each department, when department results are presented separately, the number chosen will also represent the percentage (%/n). All children included were aged 16 years old or younger and were free of nasal disease. Behaviour and treatment outcome were recorded using the Houpt Behaviour Rating Scale (Table 1), a validated and reliable tool used to score a patient's response to specific elements of treatment – in our clinics, observers provided an overall 'Houpt Score' for each session, which allowed for comparison across different treatment visits [9,10,14]. Parameters recorded included (but were not limited to): age, sex, operator level, justification for RA usage, appointment duration, previous RA experience, treatment undertaken, Houpt Score and number and type of teeth treated. Patient records were identified using the Scheduling Appointment Book (SchApptBook) of the Cerner Scheduling Management Programme (Cerner Corp., North Kansas City [MI], US) utilised by NDH to book patient appointments. The first 25 records for each operator level were chosen in consecutive order: CDH (Consultant, Specialty Registrar, Dental Core Trainee [DCT], General Professional Trainee); SED

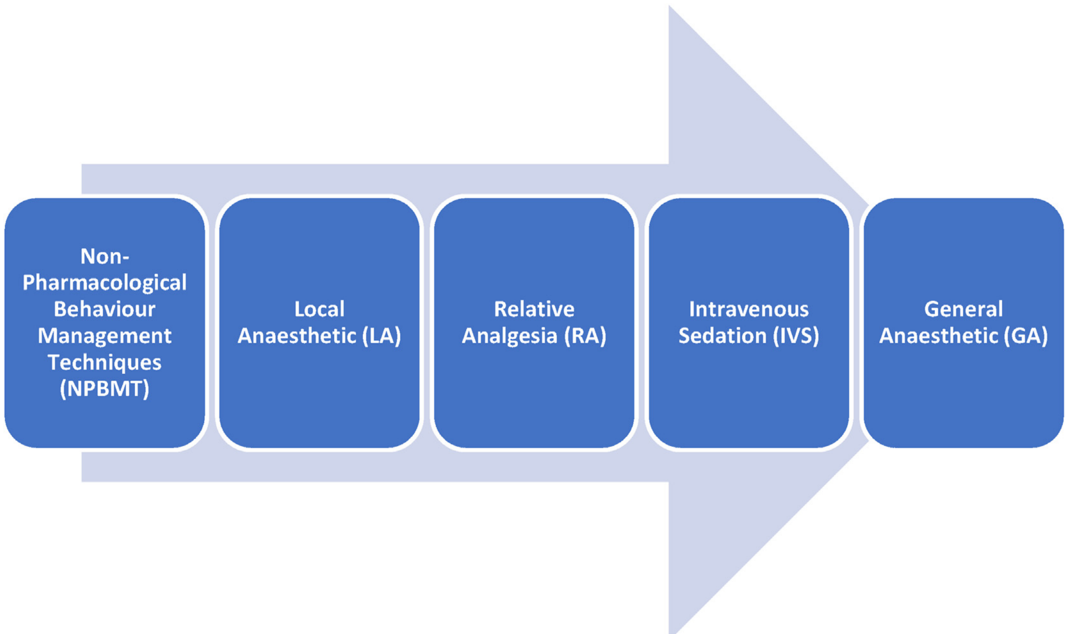

Fig. 1 – Behaviour management spectrum in paediatric dentistry.

(Associate Specialist, Specialty Doctor, Clinical Trainer, Dental Core Trainee). Outcomes were defined as success (completion of the treatment session) or failure (referral for treatment under general anaesthetic).

CD and TF were involved with data extraction, collection and entry on the data collection form and input into a Microsoft Excel spreadsheet (Microsoft Excel for Mac 2016, Version 16.38 20061401). Discussion and final agreement for data entry between researchers was performed through meetings. Ten records were piloted initially using the data collection form. A third data collector (BD) checked accuracy of the pilot data – a discrepancy in recording of the Houpt Score was discovered where the scale was being used in reverse by one researcher, and a further 10% of the data entry was checked following recalibration. No further discrepancies were discovered following discussion with the research team.

Data were cleaned manually and analysed in Statistical Package for the Social Sciences (Mac Version 26.0.0.0; SPSS Inc. Chicago [IL], US) using descriptive statistics, exploratory analysis with chi-squared tests and multivariable analyses (logistic regression) to identify any factors associated with failed RA appointments. The independent variables chosen for evaluation were based on previous research in the field, alongside clinical judgement, and not via stepwise regression methods [9,10,14]. The independent variables selected were: patient age, patient sex, appointment session, operator level, previous RA experience, treatment undertaken, appointment duration, maximum level of nitrous oxide used, tooth type, total number of appointments and chaperone. The Bonferroni correction was used to adjust for significant effects, relative to the independent variables, to avoid an inflated likelihood of error; an adjusted p-value to test for significance was set at $p \leq 0.005$. An assessment for multicollinearity in each logistic regression model was performed by calculating the variance inflation factor (VIF) for each independent variable analysed; all independent variables had a VIF of less than 5.0 and were therefore included in the analysis.

3. Results

The mean age of all children attending NDH for treatment under inhalation sedation was 9.76 years, (Range 4–16 years, SD 2.79); CDH 10.17 (Range 4–16 years, SD 2.86), SED 9.35 (Range 5–16 years, SD 2.66). Eighty-seven (43.5%) children who attended were male (CDH %/n = 47; SED %/n = 40) and 113 female (56.5% [CDH %/n = 53; SED %/n = 60]). Overall, 89 appointments (44.5%) were in a morning session (09:00–12:30) and 111 (55.5%) in an afternoon session (14:00–17:00). The majority of children attended with their mother as chaperone (n = 122, 61%) with a small minority attending with a grandparent (n = 4, 2%) and one patient attending alone (0.5%).

One hundred and seventy-six treatment sessions (88%) comprised operator-sedationist and dental nurse, with 23 sessions (11.5%) having a trainee nurse present and 0.5% (n = 1) a senior colleague present with a DCT. Eighty-two percent (n = 164) of treatment sessions were justified due to dental anxiety, with dental anxiety alongside the type of treatment being carried out (n = 18, 9%) the next most common reason for justification of RA. All RA appointments in the sedation department (100%) were 45 min in duration, with 59 appointments (29.5%) in CDH also 45 min in duration, 30 appointments (15%) 60 min long and eight appointments (4%) lasting 30 min (Table 2).

Overall success rate for the NDH paediatric inhalation sedation service was 90.5%; CDH %/n = 89%, SED %/n = 92. Just under a third of all patients had previous RA experience (31%, n = 62); CDH %/n = 29, SED %/n = 33. Ninety-one percent (n = 10) of failed RA appointments in CDH had no RA experience, whereas over a third of SED patients (37.5%, n = 3) who

Fig. 2 – Nasal hood and Quantiflex MDM relative analgesia machine.

Table 1 – Houpt behaviour rating scale.

Score	Descriptor
1	Aborted: No treatment completed
2	Poor: Treatment interrupted, only partially completed
3	Fair: Treatment interrupted but eventually completed
4	Good: Difficult but all treatment was completed
5	Very Good: Some limited interruption e.g. crying or movement
6	Excellent: No interruption (e.g. crying or movement) to treatment

had a failed RA appointment had a history of previous treatment under inhalation sedation. Similar numbers of failed appointments in each department were on the patient's first visit; SED, 62.5% (n = 5), CDH 72.7% (n = 8). All patients (n = 19) who had a failed RA appointment did not receive above 40% N_2O, of which ten (52.6%) received 30% N_2O or less, and 78.9% (n = 15/19) were attending for exodontia appointments. With regards to patient behaviour during each session, generally (both overall and independently), patients scored between 4 and 6 on the Houpt Behaviour Rating Scale (n = 172, 86%).

Overall, the most common titration of $N_2O:O_2$ administered to patients was 30%:70% (n = 81, 40.5%), with 40%:60% (n = 47, 23.5%) and 35%:65% (n = 41, 20.5%) the next most popular (Fig. 3). Independently, the CDH and SED departments both followed the same general trend of titration mixture popularity, however, the SED department had more patients who were titrated to 50:50 - %/n = 7. A flow rate of 6–10L/min was generally used; 64.5%, n = 129.

With regards to treatment, overall, 108 patients (54%) had topical local anaesthetic placed prior to administration of local anaesthetic; CDH %/n = 58, SED %/n = 50. Lidocaine alone (n = 129, 64.5%) was the most common type of local anaesthetic used across both departments; CDH %/n = 62, SED %/n = 67. Infiltrations were the most common mode of local anaesthetic delivery; n = 146 (73% [CDH %/n72, SED %/n74]). Extractions (n = 125, 62.5%) were the most common overall procedure performed; 82 appointments for primary teeth (41%), 86 appointments for permanent teeth (43%) and 32 appointments for a mixture of primary and permanent teeth (16%). Fifty-one patients underwent conservative treatment (25.5%); 47 appointments for permanent teeth alone (23.5%) and four appointments for primary teeth (2%). In addition, eight patients (4%) had successful conservative treatment of permanent teeth and exodontia of primary teeth in the same visit. Conservative management was twice as likely to be performed in CDH compared to exodontia (2.04:1 ratio). There was a significant association between treatment performed and appointment time in CDH, with conservative treatment significantly more likely to command an appointment longer than 45 min (χ^2 [1, n = 51] = 7.306, p = 0.004). Overall, the majority of sessions involved treatment of a single permanent tooth (n = 60, 30%), followed by a single primary tooth (n = 41, 20.5%) and multiple primary teeth (n = 41, 20.5%) respectively. Multiple primary teeth were most commonly treated in SED department sessions (%/n = 33), whereas single permanent teeth were most commonly treated in the CDH department (%/n = 40). Treatment in CDH was generally carried out between 1 and 4 appointments (range 1–9, mean 2.53, SD 1.53), however, treatment in the SED department was most commonly (%/n = 50) carried out across two appointments (range 1–3, mean 1.62, SD 0.59).

A logistic regression was performed to ascertain the effects of the independent variables on the likelihood that children would have a failed RA appointment. The logistic regression model was statistically significant, $\chi^2(11) = 846.977$, $p < 0.000$. The model explained 67.8% (Nagelkerke R^2) of the variance in failed RA appointments and correctly classified 97.0% of cases. Females were 1.5 times more likely to have a failed appointment than males. Afternoon appointments and being aged less than six were associated with an increased likelihood of

Table 2 – Independent variable results.

Independent Variable	CDH Department (%/n)	SED Department (%/n)	Overall n(%)
Gender			
Male	47	40	87 (43.5)
Female	53	60	113 (56.5)
Age (Years)			
4–5	3	4	7 (3.5)
6–7	15	25	40 (20)
8–9	26	28	54 (27)
10–11	21	23	44 (22)
12–13	17	11	28 (14)
14–15	17	6	23 (11.5)
16	1	3	4 (2)
Appointment Session			
Morning	67	22	89 (44.5)
Afternoon	33	78	111 (55.5)
Chaperone			
Mother	56	66	122 (61)
Father	12	14	26 (13)
Mother AND Father	14	11	25 (12.5)
Grandparent	4	–	4 (2)
Self	1	–	1 (0.5)
Sibling	0	2	2 (1)
Other	13	7	20 (10)
Additional Personnel Present			
Nurse	99	77	176 (88)
Nurse AND Student Nurse	–	23	23 (11.5)
Other	1	–	1 (0.5)
Justification for RA			
Anxiety	89	75	164 (82)
Nature of treatment	–	8	8 (4)
Anxiety AND nature of treatment	5	13	18 (9)
Anxiety AND age	3	2	5 (2.5)
Other	3	2	5 (2.5)
Appointment Duration			
30 min	8	–	8 (4)
45 min	59	100	159 (79.5)
60 min	30	–	30 (15)
≥90 min	3	–	3 (1.5)
Previous RA Experience			
Yes	29	33	62 (31)
No	71	67	138 (69)
Topical LA			
Yes	58	50	108 (54)
No	42	50	92 (46)
Treatment Provided			
Exodontia	25	100	125 (62.5)
Restorative procedure	51	–	51 (25.5)
Exodontia AND restorative	8	–	8 (4)
Other	16	–	16 (8)
Tooth Type			
Primary	27	55	82 (41)
Permanent	57	29	86 (43)
Mixture	16	16	32 (16)
Treatment Outcome			
Success	89	92	181 (90.5)
Referred for GA (Failed)	11	8	19 (9.5)

having a failed treatment session and having no previous RA experience increased the likelihood of a failed appointment by 4.1 times. There were statistically significant relationships between a patient's mother attending as chaperone and a failed RA appointment and an appointment lasting longer than 45 min with a failed RA appointment (Table 3).

4. Discussion

Growing and developing children often lack the necessary coping mechanisms to successfully navigate their dental experiences without some form of non-pharmacological behavioural management as a minimum. Whilst NPBMT plays an important role in paediatric dentistry, it is not the solution for all children and a proportion will still require an adjunctive pharmacological approach such as conscious sedation or general anaesthesia [16]. No single technique will be successful for all patients, and with an increasing emphasis towards adopting the principal of minimal intervention i.e. utilising the simplest and safest technique available [12], the provision of conscious sedation instead of a reliance on general anaesthesia is more essential now than ever.

Conscious sedation, namely RA, is a tried-and-tested, well-accepted method of pharmacological behaviour management for children, with success rates in the literature typically ranging from 83% to 93% [9,17–19]. The outcome of dental treatment has been shown to have a marked effect on ratings of its acceptability [19], and our study shows similar levels with a 90.5% overall success rate (CDH 89%, SED 92%) for the exodontia and comprehensive care provided. This also confirms the continued requirement for an accessible general anaesthetic service, when RA fails and all other options have been explored, a sentiment also echoed in previous studies [9,20,21].

The literature is almost equivocal with regards the impact of gender and dental anxiety; whereas some studies associate no gender difference, several studies associate girls being more dentally anxious than boys [9,22,23]. Our study compliments the latter, with girls 1.5 times more likely to have a failed appointment. Patient behaviour during treatment was similar for both boys and girls, with the majority scoring 4–6 on the Houpt Behaviour Rating Scale, a finding in agreement with previous authors [9,17]. The majority of patients treated were aged between 6 and 11 years old, with patients aged below six, nearly two and a half times more likely to have a failed RA appointment. This is similar to previous studies which also showed a significant relationship between decreasing age and failure of the sedation appointment [9,21,22,24,25]. Appointment time has previously been considered to have a negative impact on treatment success, where PM sessions are assumed to result in dentally anxious patients spending the morning worrying and thus affecting cooperation during treatment [26], our study further adds to the evidence available, with a PM appointment 1.6 times more likely to result in a failed RA session.

It is universally acknowledged that the physical and mental development of children varies widely and may not necessarily correlate with their chronological age [12,27]. It is for this very reason that the treatment plan for each patient

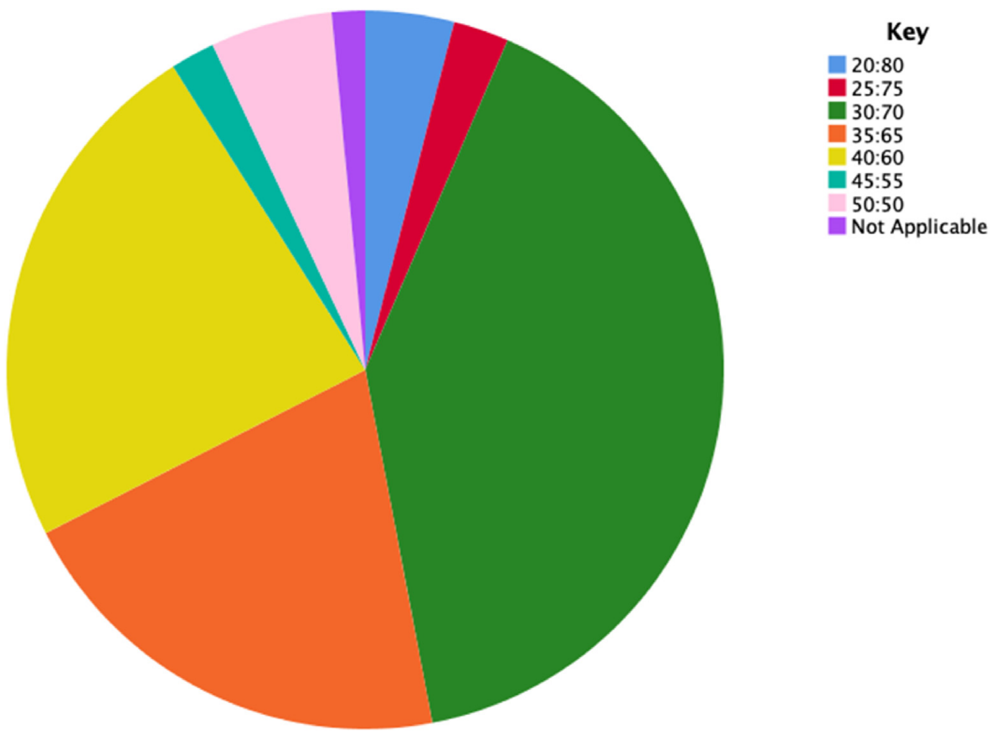

Fig. 3 – Ratio of maximum $N_2O:O_2$ – overall.

Table 3 – Logistic regression model for failure of RA treatment.

Variable	*p*-value	OR	95% CI for OR	
			Lower	Upper
Age <6	0.003[a]	2.4	1.04	4.48
Female Sex	0.003[a]	1.5	0.78	2.97
Afternoon Appointment	0.006	1.6	0.84	3.25
Junior Operator	0.024	1.4	0.95	1.86
No RA Experience	<0.001[a]	4.1	2.9	5.74
Restorative Treatment – Permanent Teeth	0.048	1.5	0.86	1.92
<30% N_2O	0.002[a]	2.3	1.23	4.25
Chaperone - Mother	0.005[a]	1.8	1.03	3.31
Permanent Molar Teeth - Extraction	0.015	1.4	0.82	2.67
>45 Minute Appointment	0.002[a]	2.2	1.14	4.08
≥2 teeth treated per session	0.083	2.7	1.26	6.99
Restorative Treatment with Lidocaine Infiltrations	0.025	1.9	1.21	3.74

Hosmer and Lemeshow Test: $\chi^2 = 846.977$; df = 11; *p*-value = 0.000.
CI – Confidence interval; OR – Odds Ratio; RA – Relative Analgesia; N_2O – Nitrous Oxide.
[a] *p*-value ≤0.005 following Bonferroni correction denotes statistical significance.

should depend on a thorough assessment of their psychological and physical maturity, with careful attention paid to their behaviour at the new patient appointment, which may be a foreshadow into their compliance at future appointments. Patient preparation and engagement is key and given that evidence shows cognitive pamphlets do not help paediatric dental patients cope better with inhalation sedation, suggestion toward the provision of electronic formats of patient information in child-friendly language would certainly be supported [14,28]. *Nelson and Xu* [29] suggest that children who are shy, cling to parents or have difficulty tolerating simple tasks such as radiographs may be better suited to alternative methods such as general anaesthesia or delayed treatment.

Delaying treatment, where possible, permits an episode of 'acclimatisation' to take place [30,31]. Acclimatisation permits familiarisation to the sights, sounds and smells of the surgery, as well as to the clinician in charge of their care and to some of the instruments to be used in future care. Acclimatisation feeds into the latent inhibition theory where children with low anxiety and high compliance have a history of multiple previous positive dental experiences [32]. The application of fissure sealants is a relatively non-invasive technique, frequently used to acclimatise a patient. Sedation is a continuum; a trial of non-invasive treatment under RA, at a similar level to that which would be used for planned future treatment, may be a good indicator toward future levels of cooperation and indicate those patients for which RA may not be suitable. Not only did our results find a significant relationship between a failed RA appointment and no previous RA experience ($p < 0.001$), but our regression also found that patients with no experience were 4.1 times more likely to fail than those with some history of conscious sedation. Three patients who had a failed RA appointment, who also had previous experience of RA, were undergoing exodontia for the first time, and it may be that lack of specific treatment experience for some patients is the deciding factor between success and failure, as exodontia has been shown to cause the greatest stress to children and adolescents undergoing invasive dental treatment [33,34]. Acclimatisation under RA has historically been suggested and even the most recent guidance by the Scottish Dental Clinical Effectiveness Programme (SDCEP) goes as far to suggest, "*a brief trial of nitrous oxide/oxygen at the assessment appointment may be helpful for the psychological preparation of some children*" [12,35,36].

The SDCEP advise that consideration should also be given to providing a suitable child-friendly environment with posters suitable for children, relaxed waiting areas and surgeries, and paediatric only sessions [12]. As well as acclimatisation and child-friendly environments, the Institute of Medicine (IOM) has identified continuity of care as a core element in the successful oral care of children [37]; being treated by the same clinician who undertakes the initial consultation facilitates an ongoing relationship which can lead to increased success rates for treatment. It is noteworthy that our study contrasts these views where the sedation department actually had a higher overall success rate, despite: no acclimatisation sessions, a different clinician to that seen at the new patient appointment and a completely different environment to that in the CDH department. It may be here that the sedation department, where it is their day-to-day role to manage dentally anxious patients, are: more expectant of anxiety; better placed to assess how anxious a patient is; able to make the treatment journey less anxiety provoking whereby the assisting nurse will have a relaxed chat in a comfortable room with chaperone and patient, prior to coming into the surgery to complete pre-operative checks [31].

All children and adolescents under 16 years of age require an adult chaperone for treatment under RA [12]. The chaperone has the potential to be an operator's greatest ally in terms of delivery of behaviour management to a patient. *Freeman* [38] postulates that it is the mother whom a clinician forms the real relationship with and through her that the aforementioned 'treatment alliance' is not only created but strengthened. Successful delivery of paediatric RA is effectively reliant on a patient's cooperation as well as the allowance and maintenance of the nasal hood remaining securely in place – another aspect which may be tested during acclimatisation [32]. Nasal hoods are available in single-use scented versions or non-scented autoclavable versions – there may be a place for future research into success rates with either scented or non-scented varieties [39]. Sixty-two percent ($n = 11$) of failed RA appointments in our study were due to non-compliance either initially or intra-operatively with the nasal hood, an overall failure rate of 5.5% - comparable with a previous study carried out at the Glasgow Dental Hospital with a reported refusal rate of 11% ($n = 14$) [40].

When trying to relate the benefits of RA to children, mothers may also be best placed to do so, with nearly 80% reporting the use of Entonox® (50% N_2O and 50% O_2) during labour [41]. Our study, however, in contrast to the view of *Freeman* [38], actually found a significant relationship between a failed appointment and the child's mother present as chaperone ($p = 0.005$). It has been shown that maternal and paternal anxiety is observed in children who are dentally phobic, in addition to a study showing that non-anxious children who received anaesthetic induction in the presence of an overly anxious parent were significantly more anxious when compared with non-anxious children who were not accompanied by a parent [42–44]. The authors propose that clinicians should aim to reduce parental anxiety levels from the very first visit by providing them with appropriate information on dental treatments, teaching them simple relaxation techniques and aiming to restructure their negative thoughts and expectations to help mitigate or even neutralise passing on their dental anxiety to their children; through parents displaying calm and reassuring behaviours, alongside verbalising upbeat feelings such as joy and happiness, children are thus exposed to positive modelling and receive support on how best to approach the dental environment [44].

The most common titration delivered was 30:70 (%N_2O:%O_2), with patients 2.3 times more likely to have a failed appointment when the concentration of N_2O was less than 30%. This is comparable with the titrations used in the relevant literature, including as an adjunct to hypnosis, as well as a previous audit carried out in the NDH Sedation Department which showed the median level of N_2O used for 500 patients was 30% [9,10,45]. Although the average concentration of N_2O used in the literature has been reported at 30%, the majority of cases in this study utilised between 30 and 40% N_2O, as the ratio of N_2O:O_2 in the United Kingdom is carefully titrated according to the individual patient response - concentrations between 20 and 50% commonly allow for a state of detached sedation without any loss of consciousness or danger of loss of laryngeal reflexes [46]; no patients exceeded 50:50 (%N_2O:%O_2). Children undergoing RA need to be able to appreciate what the sedation is trying to do, hence the feeling among clinicians that it is more suitable for those who have mild-to-moderate anxiety as it will typically help with initial levels of inhibition, usually towards administration of local anaesthetic prior to comprehensive care and exodontia. Restorative treatment in permanent teeth (OR 1.5) and restorative treatment with lidocaine infiltrations (OR 1.9) were more likely to be linked to a failed RA appointment, when compared to treatment of primary teeth alone and use of articaine infiltrations respectively. Sedation appointments for conservative treatment typically have a longer duration than exodontia-only appointments ($\geq$60 min); we found a significant association between failed RA and longer appointment times ($p = 0.002$, OR 2.2), hence it has been suggested that shorter appointment times (e.g. 45–60 min) for conservative treatment may prove more successful and maximise the number of patients treated at each session [9]. Maxillary restorative treatment with articaine was actually 1.9 times less likely to lead to a failed RA appointment compared to those who had lidocaine; this may be important given that a recent randomised controlled trial has shown that invasive dental treatment on mandibular molar teeth can be completed successfully in children using buccal infiltrations of articaine, with comparable levels of perceived pain between inferior-dental blocks (IDBs) with lidocaine and buccal infiltrations with articaine [47]. Articaine is increasing in popularity with a move away from IDBs with lidocaine toward articaine infiltrations for restorations in mandibular teeth, with articaine outselling lidocaine in the UK over the last three years [48].

Typically, in cases where RA treatment has failed, paediatric patients are referred for treatment under general anaesthesia. Despite the incidence rate now estimated at less than one death per 3.5 million GAs, it is a more complex and higher risk intervention than conscious sedation [49], as well as being nearly 2.5 times more expensive [13]. For some patients, it could be argued that a trial of RA is more beneficial than proceeding straight to GA without attempting acclimatisation, given the associated risks. RA has a higher parental satisfaction than GA; GA has been linked with increased physical and psychological post-operative morbidity, including feeling sick and poor sleep (with some symptoms lasting a week), in addition to parents being critical of ward waiting times prior to being taken to theatre [11,21,50,51]. In contrast, however, one paper into the experiences of ten children who had dental general anaesthetic, highlighted that pain was not the main concern, but rather anticipation of feelings of hunger, worry and having discomfort from the cannula [52]. Some consideration must also be given to the effect on the environment; N_2O is naturally present in the earth's atmosphere and has been associated with bio-environmental concerns due to its contribution to the greenhouse effect, around 5% in total; importantly, only 0.35–2% of this is thought to be from medical applications [53].Where RA is not successful, other techniques along the spectrum of pharmacological behaviour management in paediatric dentistry are available for consideration. Sedation with midazolam, typically administered intravenously (IVS) and often in combination with other drugs, is now the main alternative to N_2O for conscious sedation of adolescents aged 12 and above, with evidence provided in systematic reviews supporting its use [13,54]. A recent evaluation regarding the set-up and performance of an anaesthetist led IVS service experienced high success (91.5%), with only four children failing to complete treatment, three of whom could not tolerate cannulation [26]. In addition, when compared with transmucosal (buccal) midazolam or IV midazolam in adolescents for orthodontic extractions, RA was found to be as effective as midazolam, but required less time to reach the desired level of sedation and to recover, emphasising that IVS is a safe and effective alternative to both RA and GA [8,11,25,55].

4.1. *Strengths and limitations*

This study provides an insight into the paediatric inhalation sedation service provided at Newcastle Dental Hospital, both overall and independently per department. It provides unique insight into an exodontia-only service, versus a paediatric service providing the full armoury of paediatric treatment available and analyses multiple confounding factors and their impact on treatment outcomes. Our findings agree with the wider literature in that success of RA is influenced by factors such as the degree of cooperation and developmental age of the patient, however, we did not investigate other factors such as intellectual disability or patient hypersensitivity, which have also been shown to affect treatment outcome [56]. Future studies should also investigate these variables. The Houpt Behaviour Rating Scale has been found to be a reliable tool when used to score a patient's response to specific items of treatment e.g. delivery of LA [14] - the scale itself is subjective and there was no formal calibration of the nurses assessing patient behaviour. In addition, an overall Houpt Score was provided, rather than at specific points in the delivery of sedation and treatment, however, this permitted for comparison of Houpt Scores across different treatments. The findings from this study reflect practice from one centre and as such may not be generalisable to the rest of the UK. The data, however, can be used to allow comparisons with other similar centres in the UK.

5. Conclusions

Dental treatment under combined RA and LA is a successful technique for managing mild-to-moderately anxious paediatric patients and should be seen as part of an overall behaviour management strategy to help children accept dentistry. Careful patient selection, based on patient cooperation at the initial consultation, alongside an episode of acclimatisation to help with the nuances associated with nasal delivery, may well contribute to continued high success rates, however, more research regarding acclimatisation is required. Where RA is not successful, other techniques along the spectrum of pharmacological behaviour management in paediatric dentistry are available. Age-appropriate intravenous sedation offers an effective alternative to GA, especially as GA does little to enable children to cope with future dental treatment due to the emotionally traumatic experience it involves. Although providing quality treatment to anxious children and adolescents can be challenging, conscious sedation gives patients the opportunity for high quality care, while maximising their comfort and cooperation.

Conflict of interest

The authors declare no conflict of interest.

Author contributions

CD contributed to the conception, design, data acquisition, data interpretation, drafted and critically revised the manuscript. TF contributed to the data acquisition, data interpretation, drafted and critically revised the manuscript. KW contributed to the conception, design, data interpretation, drafted and critically revised the manuscript.

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