Clinical Application of Nitrous Oxide in Pediatric Dentistry

5

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Contents

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Learning Objectives

1. To get acquainted with the process of introducing nitrous oxide to parents and children.
2. To realize the importance of basic behavior management techniques as an adjunct to the use of nitrous oxide.
3. To understand various aspects of using nitrous oxide in child patients.
4. To have a thorough knowledge about the need for monitoring, technique of monitoring, and operators response during the administration of nitrous oxide in child patients.
5. To be aware about the adverse events related to the use of nitrous oxide in pediatric population.
6. To be well versed with the documentation of nitrous oxide sedation in children.
7. To know about the importance of having a team for administration of nitrous oxide.

5.1 Technique of Administration

Proper technique of administration is critical for the success of nitrous oxide inhalation sedation, especially in pediatric patients. Since most of children are unable to communicate what they are experiencing during the course of inhalation sedation, the proper administration of nitrous oxide becomes extremely important.

5.1.1 First Nitrous Visit

First nitrous visit implies the visit when nitrous oxide is introduced to the child for the first time.

It is as important as the first dental visit. If the introduction of nitrous oxide, especially the mask, is done appropriately, then its successful administration in subsequent visits is very likely.

Objectives of the First Nitrous Visit

1. To familiarize the child with the technique of nitrous oxide, using euphemisms
2. To inform, demonstrate, and let the child experience (IDE—Inform, demonstrate, and experience) the nasal hood
3. To understand the cooperative ability of the child and decide if the child will be a good candidate for use of this technique

4. To explain the benefits of using nitrous oxide to the parents
5. To inform parents of possible minimal side effects
6. To examine the child properly, take records, radiographs
7. NOT to start the dental treatment on the first nitrous visit

Importance of Communication and Basic Behavior Management Skills

Careful use of the conventional behavior management/modification techniques, such as tell-show-do, modeling, and distraction along with tender, love and care, when introducing nitrous oxide inhalation sedation to children, will ensure the success of the first nitrous visit, which in turn is important for carrying out the treatment under nitrous oxide.

> Dentist's gestures, facial expressions, general behavior with the correct choice of words and tone of voice play an important role for acceptance of nitrous oxide by a child.

Steps of First Nitrous Visit

Introduction to nitrous oxide begins with an effective communication with the parents and understanding the temperament of the child.

Effective communication is the key to gain confidence of the parents through well-expressed explanation of the technique, expectations, and outcomes. A dentist should be able to speak with assurance to the parents for them to gain trust in this technique.

Child's behavior on the first dental visit is governed by various factors [1]. The prominent factors are child's developmental age and corresponding level of cognition. Recognition of the behavior is the stepping stone to successful first nitrous visit in children. Dentist's proficiency in gauging the child's willingness to cooperate is a major determining factor in introducing nitrous oxide effectively to facilitate a positive dental experience [2].

> Dentist's thorough explanation with conviction, of using nitrous oxide in children, plays a pivotal role in acceptance by parents.

1. Introduce the technique of nitrous oxide to the parents by explaining the benefits and purpose of using nitrous oxide inhalation sedation in their child (Fig. 5.1). However, a successful outcome using nitrous oxide for a highly anxious child should not be promised to the parents.

2. Explain that nitrous oxide is used because it helps in reducing anxiety in their child, relaxes the child, and also decreases pain to some extent during the procedure.
3. Following this, tell them that the child will have to breathe through the nasal hood throughout the procedure.
4. Inform them that nitrous oxide is very safe and has minimal side effects such as nausea/vomiting during the administration or slight dizziness/headache after the treatment.
5. Give preoperative instructions to the parents such as fasting for 2 h prior to appointment and that the child should not be having nasal congestion on the day of the procedure.
6. Following this, inform the child about using the technique using euphemisms such as let's do some exercise of deep breathing through the nose, let's see how big a balloon can you blow from your nose, and let's check how strong you are by the size of balloon you will blow.
7. Demonstrate the nasal hood to the child and how it has to be kept on the nose (Fig. 5.2). Sometimes modeling can be carried out on parents for children to understand the process in a better way (Fig. 5.3).
8. Let them experience the process of nasal breathing through the nasal hood. Let the child practice nasal breathing by keeping the mouth open. This enables the child to understand that he/she should not be breathing from the mouth during the procedure.
9. Gradually increase the concentration of nitrous oxide and let them experience the clinical effects of nitrous oxide.
10. Motivate the child that he/she did a good job and carry out positive reinforcement for subsequent visits.

Fig. 5.1 Introduction of nitrous oxide technique to parents

Fig. 5.2 Tell-show-do for nitrous oxide technique on a child patient

Fig. 5.3 Modeling of nitrous oxide technique on parent

Introduction of Nitrous Oxide Based on Different Behaviors

1. *Definitely positive child (a child who smiles, greets, and communicates with the dentist)*
   Introduction of nitrous oxide is simple, easy, and predictable for such children. It can be done in the manner outlined above (Fig. 5.4).
   Dental examination records, and radiographs can be done before introducing nitrous oxide to these children.

2. *Positive child (a child who does not smile or interact with the dentist in a care-free manner)*
   Establishment of good personal rapport is important for such children before the introduction of nitrous oxide to such children. Sometimes, modeling is the key to remove the initial inhibition of the child. Also use of situation appropriate euphemisms is beneficial for such children (Figs. 5.5 and 5.6a, b).

Ability to establish communication with the child is crucial for the acceptance of nitrous oxide nasal hood by him/her.

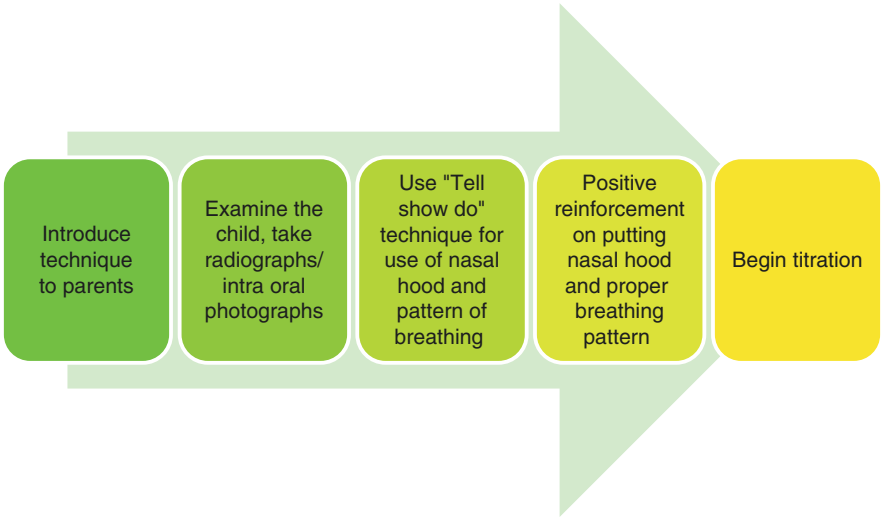

Fig. 5.4 Sequence of "first nitrous visit" for a child with definitely positive behavior

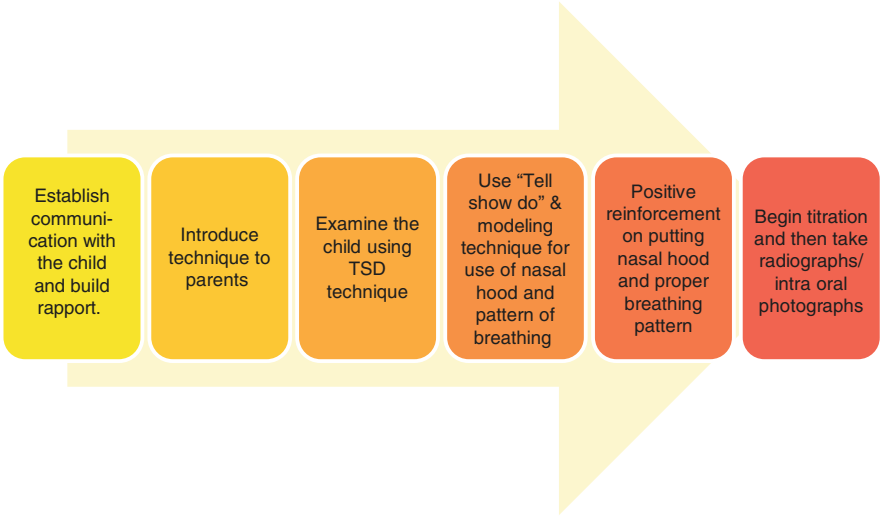

Fig. 5.5 Sequence of "first nitrous visit" for a child with positive behavior

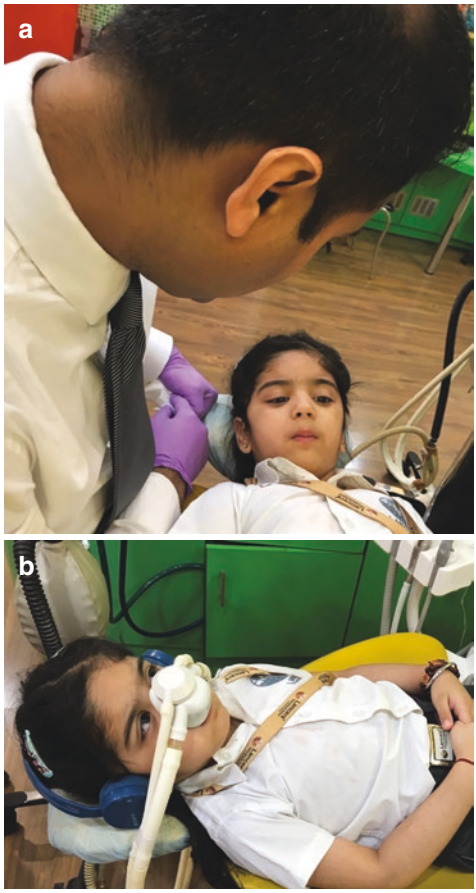

Fig. 5.6 (**a**) A child who does not want to make eye contact and talk to the dentist. (**b**) Child after using nitrous oxide looks relaxed

Dental examination, can be done before introducing nitrous oxide to these children, following which the child is explained and demonstrated about using nitrous oxide. Subsequent to this, records and radiographs are taken under the effect of nitrous oxide.

3. *Negative child (a child who hides behind parent, does not want to interact with the dentist, and asks the parents to take him/her away from the clinic/had a previous negative dental experience)*

Such children may already be anxious or fearful and hence will need more time to introduce nitrous oxide. Understanding the anxiety of the child by effective communication will guide the introduction of nitrous oxide. Nitrous oxide must be proposed to them using the following sequence. Firstly, explain to them about the new technique using euphemisms. Then, do modeling on self or parents or older siblings and let them see the movement of the reservoir bag which may encourage them to try the technique. Following this, let them experience that in their comfortable

position which may be in standing position away from the dental unit (when the child is quite anxious probably due to previous negative dental experience) or sitting on parents lap on the dental chair. Audiovisual distraction can also be used for such children during the introduction of the nasal hood.

Sometimes, rapid titration (*Refer Sect. 5.1.5*) can be used to reduce the anxiety in a child quickly. Also, rapid titration can be used with a higher flow of nitrous oxide for children who do not want the mask to be placed very close to them or have a feeling of claustrophobia or may complain that they don't like the smell of the mask. The child should be placed in a supine position as this would cause heavier nitrous oxide gas to settle down around the nose [3, 4] (Fig. 5.7a, b). Once the child has inhaled some amount of nitrous oxide, then the mask may be placed closer to the child with a reduction in flow rate as well as the concentration of nitrous oxide. **This method**

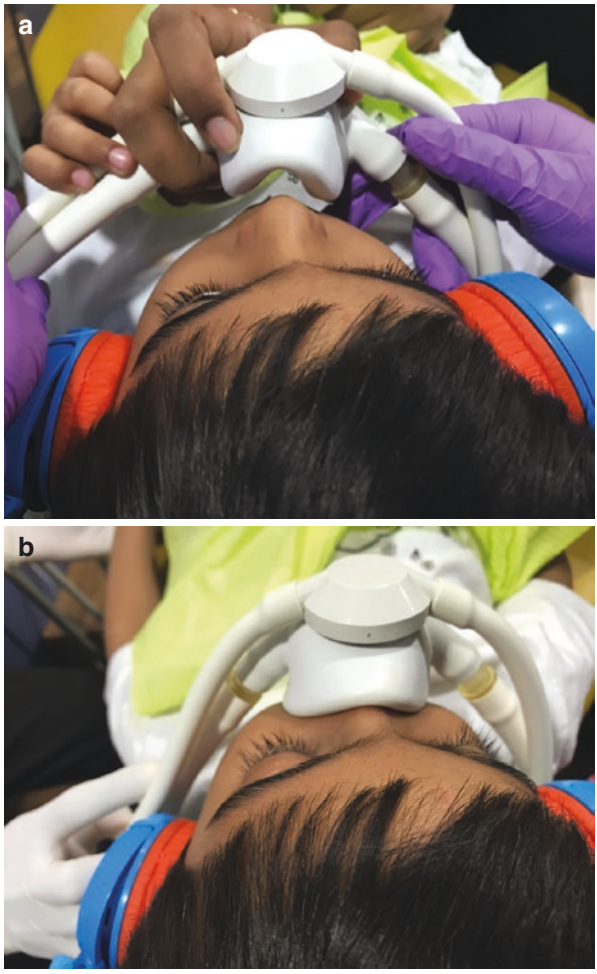

Fig. 5.7 (**a**) Nasal mask placed slightly away from the nose with the child in a supine position. (**b**) Nasal mask resting on the nose after the child's anxiety is reduced during rapid titration

should be seldom practiced as nitrous oxide gas would leak into the operatory from the nasal mask.

Rapid titration with a large-sized mask using high concentration and flow rate without resting on the nose may be used to reduce the initial anxiety in a child with negative behavior. However, this method carries the risk of contamination of ambient air in the operatory with nitrous oxide.

Dental examination is done under the effect of nitrous oxide following which records and radiographs are also taken under its effect (Figs. 5.8, 5.9a–c, and 5.10a–d).

4. *Definitely negative child (a child who cries without any provocation, pulls the parents outside the clinic, or does not want to enter the clinic)*

In children with this kind of behavior, it is important to let the child be only in formed about the technique. Experiencing the technique can be carried out on the subsequent visit. This is because in very anxious children, just the introduction of a new concept is a surprise. They have to be "sensitized" towards the technique for them to accept it. Parents should be informed that they can reinforce at home about the use of nasal hood before visiting the dental clinic for the subsequent appointment.

For a child with definitely negative behavior, the introduction of nitrous oxide may have to be postponed to the next visit.

If the parents are willing for slight physical restraint, then rapid titration along with physical restraint can be used till the child calms down. Use a large-sized mask, so that it covers both nose and mouth (ensure a proper seal is maintained around the nose and mouth to present any leakage of nitrous oxide into ambient air). Even if the child is crying initially, use of large-sized mask will ensure that the child is breathing in nitrous oxide (if a small-sized mask is used, child will not breathe in nitrous oxide if he/she is crying). Once the child calms down, large-sized mask should be quickly changed to an appropriately sized one.

This technique of restraint should be used in special circumstances such as when an emergency treatment has to be performed for a definitely negative child or the child does not require multiple visits and may be requiring just an extraction. Voice control or parents separation may also be used in these special circumstances (Figs. 5.11 and 5.12a–e).

Dental examination is also postponed for the "desensitization" visit. On the second visit, the child may be considered as one with "negative behavior," and dental examination, records, and radiographs carried out under the effect of nitrous oxide.

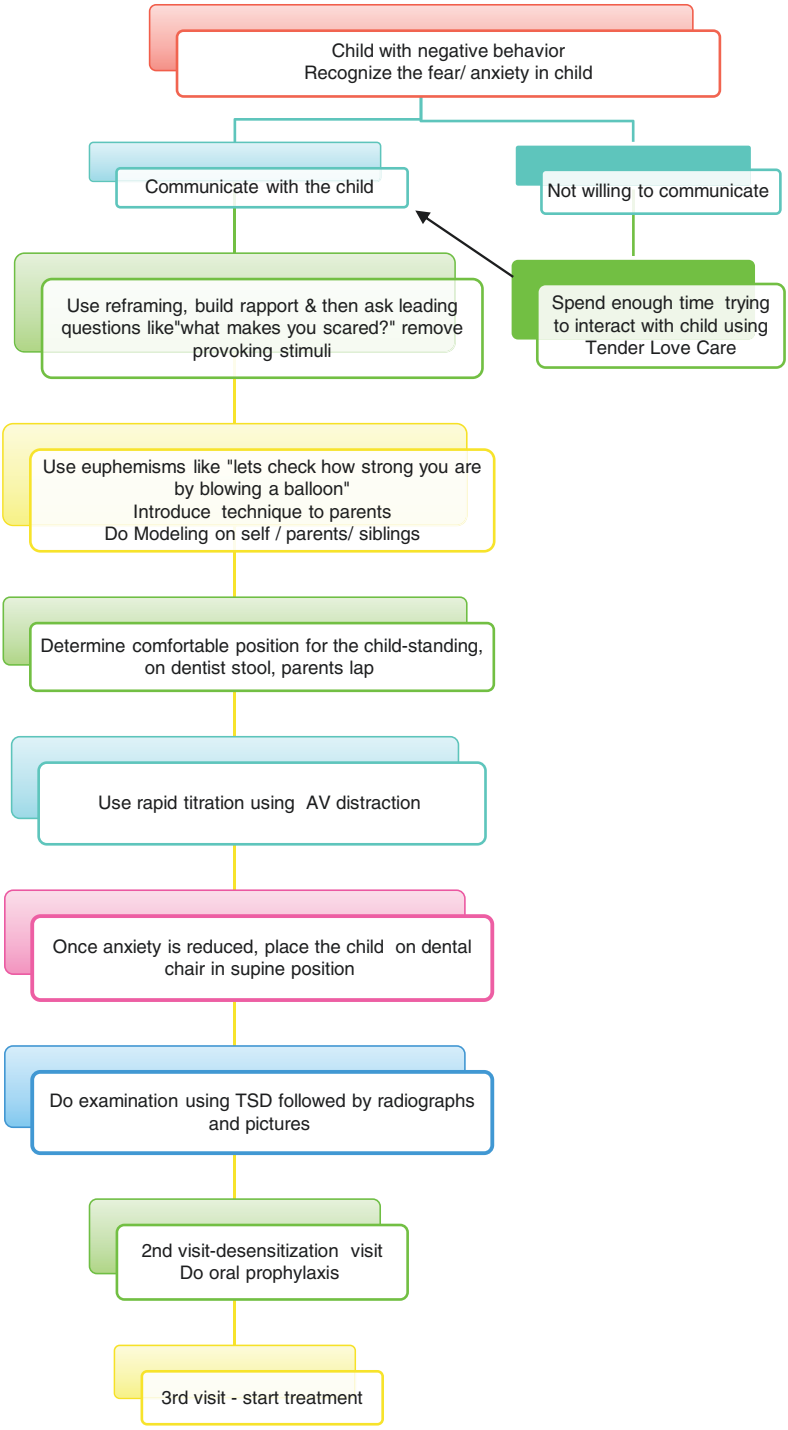

Fig. 5.8 Flowchart depicting sequence of first nitrous visit for a child with negative behavior

Fig. 5.9 (**a**) Negative child willing to communicate and ready to put mask in standing position. (**b**) After rapid titration, child agrees to sit on the parents lap on a dentist stool. (**c**) Child showing cooperation on parents lap in the dentist chair

Fig. 5.10 (**a**) Child with negative behavior. (**b**) Child not willing to communicate. (**c**) Child begins to communicate after tender love and care by the dentist. (**d**) Child willing for treatment on parent's lap

Desensitization Visit

This is an extra visit planned for children with negative or definitely negative behavior. During this visit, the child is allowed to inhale nitrous oxide for a while. When the child relaxes down, a proper dental examination is carried out along with records and radiographs using the tell-show-do technique.

After this, the child is also introduced to the compressed air from three way syringe, water spray from three way syringe, and also to the suction tube.

If the child is not accepting the mask or not ready for examination under the effect of nitrous oxide or not comfortable with suction and air, then the child should be considered for other modes of sedation such as oral/IV/IM or general anesthesia.

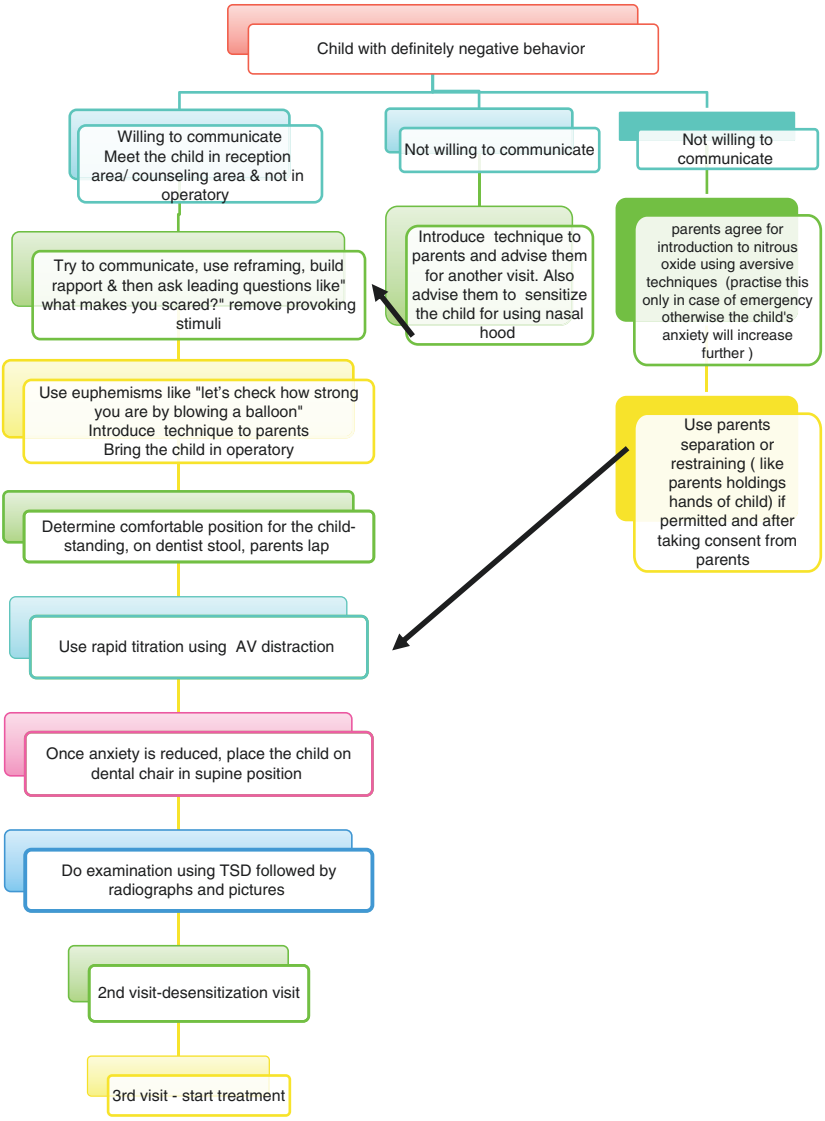

Fig. 5.11 Flowchart showing sequence of first nitrous visit for a child with definitely negative behavior

5.1.2 Pre-sedation Instructions

A certain set of instructions must be given to the parents for the day of the procedure, in order to perform sedation procedure effectively and to minimize the chances of possible adverse events.

Fig. 5.12 (**a**) Child with definitely negative behavior. (**b**) After much persuasion, child willing to observe nitrous oxide being demonstrated on parent. (**c**) Child agrees to accept nasal mask on parents lap. (**d**) Child cooperates for examination. (**e**) Child cooperates well for records

1. Child should not be having running nose on the day of the procedure.
2. Avoid eating 2 h prior to the treatment.
3. Light meal may be consumed up to 2 h before the procedure. Avoid fatty food (fried food) or milk/milk products (like pastries) up to 2 h before the procedure [5]. This is more important for children who have motion sickness (feel sick during traveling in car or aeroplane).
4. Child can consume water until just before the procedure.
5. Child should not be having stomach pain before the procedure.
6. Don't let the child wear contact lenses as the eyes may feel dry and sore [5]. (This is important for adolescents, as young children do not use contact lenses.)
7. Tight clothing should be avoided.

"Restrictions are for safety reasons since the reflexes are not reduced. However, there is no literature in support of this" [6]. Also, there is no consensus on this.

Readers can refer to Appendix VIII for the summary of four contemporary guidelines for pre-Inhalation Sedation instructions [7]. In view of this, we advise our readers to follow above mentioned instructions as a precautionary measure.

Pre-sedation fasting instructions vary in different guidelines, there being no consensus on the same.

5.1.3 Pre-administration Assessment

It is important to review the medical history (Table 5.1) and carry out a physical assessment before administering nitrous oxide sedation to a child [8].

Day of Treatment

Before starting the administration of nitrous oxide, recheck all the pre-sedation instructions given to the parents. Although these instructions do not require postponement of the treatment, nitrous oxide administration may be carried out with more vigilance. Advise the parents to make child visit restroom and void if necessary.

Recheck the medical status using following questions:

1. Does your child have asthma? If yes, when was the last attack?
2. Did your child have any recent URI?
3. Did your child have recent ear infections or surgeries?
4. Does your child have severe drug-related dependencies or emotional disturbances?
5. Is your child undergoing any treatment using bleomycin sulphate?
6. Does your child have MTHFR gene mutation?
7. Does your child have vitamin B_{12} deficiency?

If a child has nasal congestion, advise parents to postpone the appointment.

Table 5.1 Pre-sedation assessment of medical history and physical assessment

Medical history	Physical assessment
• Allergies or previous allergic/adverse drug reactions • Current medications including dose, time, route, and site of administration • Diseases, disorders, or physical abnormalities • Details of previous hospital admissions	• Respiratory system • Airway patency (nasal) • Breath sounds on inspiration and expiration

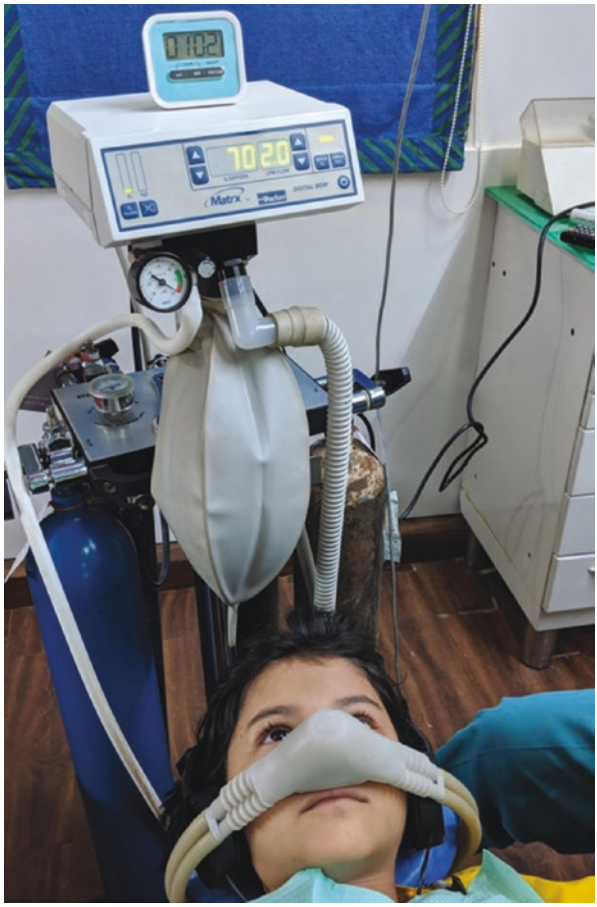

Fig. 5.13 Nitrous oxide unit kept behind the child to avoid developing anxiety

Positioning the Child Patient

Position the child in a semi-recline or supine position based on the comfort of the child. Some children may get anxious in supine position. For such children, it is better to place the child in semi-recline position, and as the anxiety level reduces on using nitrous oxide gas, the child may be placed in supine position.

In case, a portable unit of nitrous oxide is being used, it should be kept out of sight of child (behind the child patient), lest it may induce anxiety (Fig. 5.13).

5.1.4 Preparation of the Equipment

Before starting to administer nitrous oxide/oxygen to a child, a quick check of equipment should be done for proper function, flow, calibration, and fail safe mechanism (Refer Sects. 4.1.4 and 4.1.5). This should be done before the child is seated on the dental chair, otherwise it may lead to anxiety in a child. The gas cylinders should be opened and pressure gauges checked for the adequacy of gases in cylinders (in case of centralized supply, this is done once in the morning); exhaust tubing should be connected to high vacuum suction and checked for the optimal level of suction. Choose an appropriately sized nasal hood and attach it to the breathing circuit. Turn the machine on.

5.1.5 Titration

Nitrous oxide is always administered using the titration technique. This implies that there is no standard dosage for children based on the weight or age of a child, whereas the dosage/concentration is completely dependent on the clinical symptoms achieved.

> Titration of a drug is the process of determining the medication dose that reduces symptoms to the greatest possible degree while avoiding possible side effects.

The technique of nitrous oxide administration can be divided into two types:

1. Slow titration or the standard titration
2. Rapid titration

Standard Titration Method

In this technique, nitrous oxide concentration is gradually increased by 10% every 2–3 minutes.

Standard titration method is divided into the following steps (Fig. 5.14a–d):

1. Introduction phase
2. Induction phase
3. Injection phase
4. Maintenance phase
5. Withdrawal phase

Introduction Phase

*P*ress oxygen flush to fill the reservoir bag to two-thirds of its capacity and then place the nasal hood on the child's nose. Ensure that the mask fits comfortably on the child's nose. Nasal hood can be secured in place using the tubing clamp.

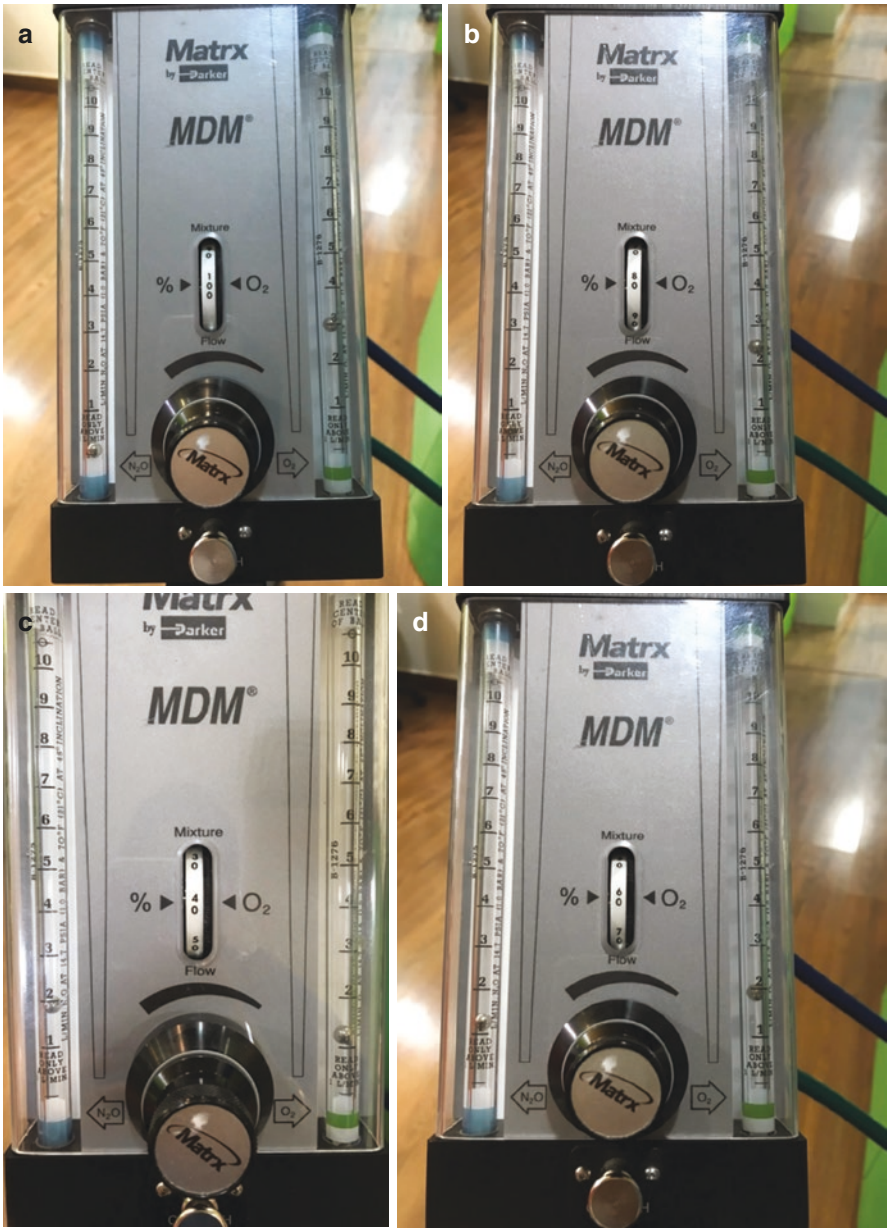

Fig. 5.14 (**a**) Introduction phase with 100% O_2 and flow rate of 3 L/min. (**b**) Induction phase with N_2O 20%, O_2 80% and flow rate maintained at 3 L/min. (**c**) Injection phase with N_2O 60%, O_2 40% and flow rate maintained at 3 L/min. (**d**) Maintenance phase with 40% N_2O and 60% O_2, flow rate at 3 L/min

In this phase, oxygen is administered for a period of 2–3 min in a concentration of 100% at a flow rate of 3–5 L/min (depending on the tidal volume of the child) (Table 5.2). Ask the child to take slow deep breaths.

Appropriate flow rate for the child should be determined at this stage. The flow rate is determined by ensuring that the reservoir bag is two-third filled. For example, if oxygen is being delivered at 3 L/min and the reservoir bag appears deflated, then increase flow rate of oxygen to 5 L/min. If the reservoir bag remains two-third filled at this stage, then the appropriate flow rate for this child is 5 L/min. However, if at 5 L/min, reservoir bag appears overinflated, then reduce flow rate of oxygen to 4 L/min to ensure that reservoir bag is now two-third filled and the appropriate flow rate for this child will be 4 L/min (Table 5.3).

Induction Phase

In this phase, the nitrous oxide concentration is gradually increased by 10% every 2–3 mins till the desirable clinical symptoms are achieved. The point at which the child begins to experience the desired clinical signs is known as the "Critical Point." This is usually manifested as hand/wrist drop, dropping off a toy or ball in child's palm, relaxed appearance on the face, and reduced eye ball movements. This is usually in the range of 35–50%. Reassure the child, motivate the child during this process, and inform the child about the expected feelings. Adjust the flow rate based on flowmeter based on the respiratory volume of the child.

As the nitrous flow rate is introduced, then the total flow rate of gases would increase (total of oxygen flow rate and nitrous oxide flow rate). To maintain the same flow rate as deciphered during the introduction phase, oxygen flow rate should be reduced slightly to ensure the total flow rate remains the same (this has to be

Table 5.3 Table showing steps for determining the adequate flow rate for a child

	Oxygen (L/min)	Nitrous oxide	Reservoir bag	Total flow rate (L/min)
Start	3	–	Deflated	3
Few seconds later	4	–	Less than two-third	4
Few seconds later	5	–	Over inflated	5
Few seconds later	4 1/2	–	Two-third fill (appropriate flow rate)	4 1/2
After 2 min	3 1/2	1 L/min	Two-third fill	4 1/2
After 2 min	2 1/2	2 L/min	Two-third fill (critical point)	4 1/2

Table 5.2 Table showing tidal volume and respiratory rate at different ages

	Tidal volume (mL)	Rate	Total (mL/min)
Infant	75–125	30/min	2250–3750
Child	200–250	20–24/min	4000–6000
Adult	400–450	12–18/min	4800–8100

done in analog flowmeter Porter MXR; however, in analog flowmeter Matrx MDM, this is not required as there is a provision for auto adjustment of flow rate).

Injection Phase

When some painful procedure has to be performed such as the injection of local anesthesia or extraction of an abscessed tooth, the concentration of nitrous oxide should be increased to 50–60%, 2–3 min prior to the painful stimulus. Slow injection and verbal distraction may be done during while injecting or during extraction.

> Injection phase of nitrous oxide uses a higher concentration of nitrous oxide to produce better analgesia.

Maintenance Phase

Once the injection has been given, the nitrous oxide concentration is again brought about to the level at which the desired clinical symptoms were achieved. Keep reminding child, intermittently, to breathe through the nose.

Withdrawal Phase

After the dental procedure has been carried out, the nitrous oxide concentration is reduced to zero, thereby increasing oxygen concentration to 100%. The child is administered oxygen at this concentration for a period of 5 min.

Discharge or Seeing Off the Child

The child should be asked the following after he/she gets up from the dental chair

1. Are you feeling fine?
2. Are you feeling dizzy?
3. Are you experiencing any headache?
4. Do you have nausea? or are you feeling sick?

Inform the parents that the child is absolutely fine and may resume normal activities soon after exiting from the dental clinic.

Rapid Titration Method

> In this method, titration begins from a higher concentration of nitrous oxide and is gradually brought down to the maintenance level.

Rapid titration method is divided into the following steps (Fig. 5.15a–d):

1. Explosion phase
2. Maintenance phase
3. Withdrawal phase

Fig. 5.15 (**a**) Rapid titration with 60% N_2O and 40% O_2 and higher flow rate of 6 L/min. (**b**) Nasal mask covering nose and mouth to ensure that the child is inhaling most of nitrous oxide delivered to him. (**c**) N_2O reduced to 50% after child stops crying with flow rate maintained at a higher level. (**d**) N_2O reduced to maintenance level like 40% and flow rate reduced to 3 L/min

Explosion Phase

During this phase, nitrous oxide is administered at a high concentration (in the range of 55–65%) for the first few minutes, till the child begins to calm down.

Maintenance Phase

The nitrous oxide concentration is brought down to the level at which the desired clinical symptoms can be maintained or below which the desired clinical symptoms cannot be achieved.

Withdrawal Phase

After the procedure is carried out, the child is administered only oxygen at a concentration of 100% for a period of 3–5 min or little longer till the child appears normal as before.

Indications for Rapid Titration

1. Negative or definitely negative child.
2. Emergency treatment to be carried out for a child.
3. Introduction of nitrous oxide to a special child

5.1.6 Duration of Administration

Using nitrous oxide inhalation sedation, it is always advisable to practice quadrant dentistry for which 15–60 min may be required depending on the extent of decay and the type of procedure required. Duration of administration is also governed by the clinical signs of sedation. In a few children, as the time passes by, the child may start showing signs of increasing level of sedation, that is moderate sedation. At this juncture, it is prudent to reduce the concentration of nitrous oxide being administered to the child by 5–10%.

Also children who receive nitrous oxide for more than 30 min need more time for recovery (should be administered 100% oxygen for at least 5–7 min).

> There is no fixed limit on the duration of administration of nitrous oxide to a child. It is dependent on the time required by an operator to complete the procedures and also on clinical signs of sedation in a child.

5.1.7 Size of the Nasal Mask

Size of the nasal mask to be used is dependent on the length of the nose and the size of nostrils. Usually, a small-sized mask can be used for children less than 5 years old and medium-sized mask used for children 5–12 years.

If a smaller nasal mask is used, it may cause a feeling of claustrophobia. If a large-sized mask is used than desired, then it may cover the upper lip and may interfere with the intra-oral procedures. It may also cause leakage from the upper border

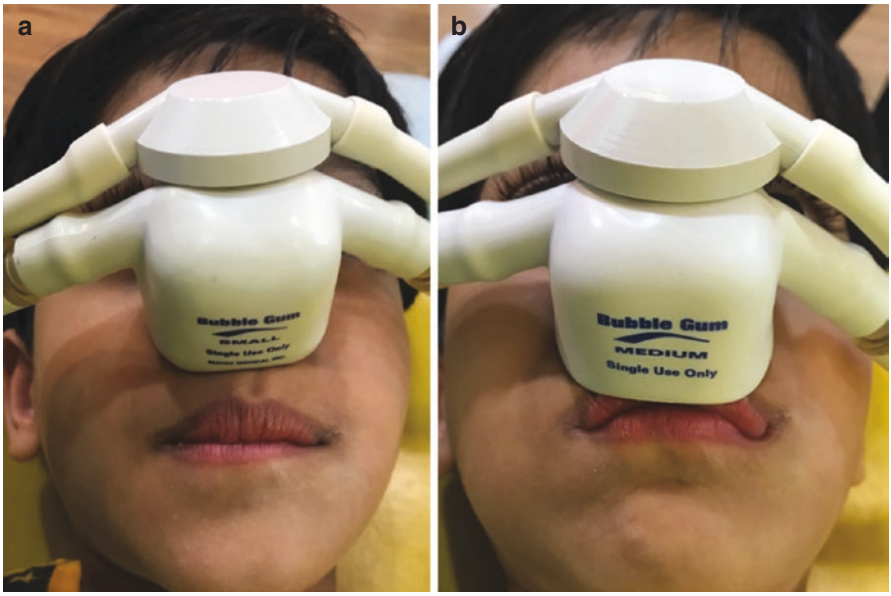

Fig. 5.16 (**a**) Figure showing correct placement of nasal mask. (**b**) Figure showing incorrect placement of nasal mask

leading to watering of eyes. The correct positioning is that the lower border of the mask should rest on the philtrum and not on the upper lip (Fig. 5.16a, b).

5.1.8 Concentration of Nitrous Oxide

Nitrous oxide sedation is an individual response, and it is inappropriate to recommend a specific or even mean concentration of nitrous oxide that would be an analgesic dose [9].

Most desirable concentration of nitrous oxide varies from child to child. Also the concentration may vary in the same child on different days. A child who is tired after school may require a lesser concentration of nitrous oxide.

Concentration for Procedures

Certain procedures require higher concentration (50–60%) as higher concentration provides better analgesia. These procedures include extraction, administration of local anesthesia, and gingival abscess drainage. Also a child who is rebellious or showing temper tantrums would need a higher nitrous oxide concentration till the child's anxiety is reduced.

> Invasive procedures like the administration of local anesthesia, extraction, and drainage of an abscess may require a higher concentration of nitrous oxide.

Other procedures like fluoride application and sealant application require lower concentration (30–35%) of nitrous oxide because the requirement for analgesia is negligible. However, this is again dependent on the pain threshold of the child. Few children may require slightly higher concentration for these procedures as well.

Actual Concentration Inhaled by a Child

Actual concentration inhaled by the child varies considerably (much lower) than what is being delivered by the flowmeter. This is because of the leakage which might be taking place at various levels, such as the area around the nasal hood and from the mouth (due to intermittent mouth breathing in many children and also due to talking) (Fig. 5.17).

Other factors which reduce the effective nitrous oxide concentration to the child are as follows [10]:

1. Incorrectly calibrated flowmeters.
2. Improperly adjusted scavenging rates.
3. Ill-fitting nasal mask which causes mixing of nitrous oxide with ambient air [11]
4. Sudden movement of the head in an uncooperative child, which dislodges nasal mask from the nose, and again causes mixing of nitrous oxide gas with ambient air.

Nitrous oxide concentration in nasopharynx is much lower than the concentration being delivered by the flowmeter due to leakage at various sources.

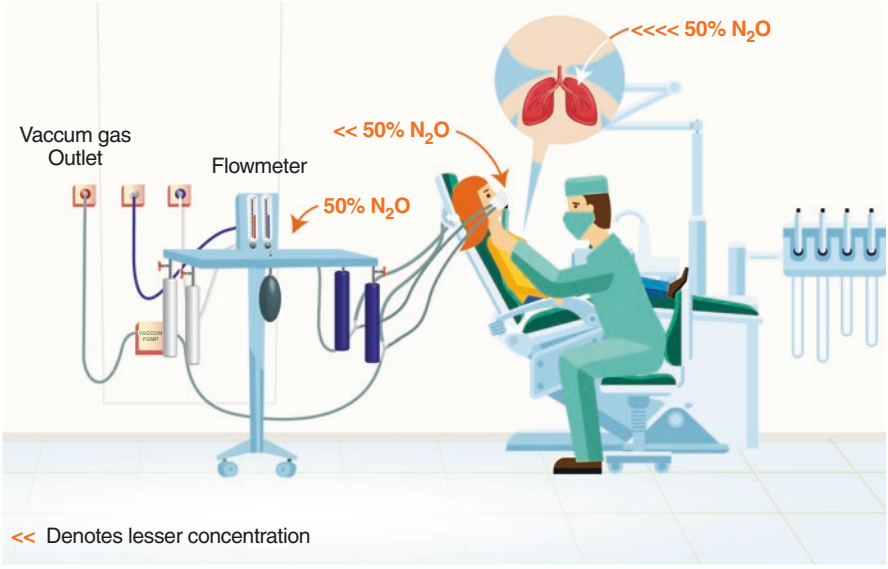

Fig. 5.17 Figure showing reduction of nitrous oxide concentration at various levels with actual concentration reaching nasopharynx being much lower than the concentration set at the flowmeter

A study reported in 2004 (Klein, Bucklin) [10] stated that there is a decrease by 31% of nitrous oxide delivered from the flowmeter to the nasal mask and by another 19% from nasal mask to nasopharynx. Thus, nitrous oxide concentration in nasopharynx was found to be lower by 50% of concentration set at flowmeter. ***However, this study was carried out in adults and authors also concluded that results could not be applied to children directly due to anatomical differences between the children and adults.*** Few other interesting findings of this study which could have clinical implications are as follows:

1. Nitrous oxide could be measured in the nasopharynx only when the flowmeter setting is greater than 20%. This implies that nitrous oxide flowmeter setting should start with 20% when the administration of nitrous oxide commences.
2. There were considerable inter-individual differences in nasopharyngeal N_2O concentrations, with identical flowmeter settings. This implies that every individual will have different nasopharyngeal nitrous oxide concentration irrespective of similar flowmeter settings. Hence, even the clinical response will be different for individuals.
3. During the period of increasing nitrous oxide concentrations, expired nasopharyngeal N_2O concentration was 22% lower than the inspired concentration, and it took 2 min for both the concentrations to become equal. This implies that the concentration of nitrous oxide should be gradually increased in increments of 10% every 2 min.

In another study (Klein, Robinson, Allshouse, 2011) [12] conducted on children (6–9 year old), it was found that an expired concentration was 63% less than that dispensed by the flowmeter. However, authors concluded that patient movement did not affect the gas delivery. They also inferred that on an average 90 s are required to reach the maximum N_2O saturation after rapid induction with 50% N_2O.

Increasing the Efficacy and Potency

The efficacy of the inhaled nitrous oxide can be maximized by the following:

1. Child should not be having any nasal congestion so that the child does nasal breathing completely. Instruct the child to breathe into and out of the mask.
2. Child should be discouraged from talking. Avoid unnecessary conversation.
3. Child should not be breathing from mouth.
4. Use snugly fitting nasal hood.
5. Use rubber dam to ensure a good seal around the mouth which prevents mixing with atmospheric air. The upper border of the rubber dam should be placed over the nasal hood and not below the nasal hood.

If the above mentioned factors are taken into consideration, then the concentration of nitrous oxide required by a child can be minimized and the potency of the gas can be maximized.

Efficacy and potency of nitrous oxide being administered to a child can be maximized by preventing leakage at various sources.

Table 5.4 Table showing effect of altitude on nitrous oxide concentration to be used

	Sea level	Altitude 2000 m
Barometric pressure	760 mm	600 mm
pCO_2	40	40
Water vapor pressure	47	47
Pressure exerted by gases delivered by flowmeter	760 − 40 − 47 = 673	600 – 40 − 47 = 513
Nitrous oxide pressure at 35%	35% of 673 = 235	35% of 513 = 180 45% of 513 = 231

Sensitization

The level of nitrous oxide can be titrated down at subsequent visits due to its placebo effect.

Effect of Altitude

Higher concentration of nitrous oxide is required at a higher altitude (Table 5.4).

Thirty-five percent of nitrous oxide at sea level will have same sedative effect as 45% of nitrous oxide being administered at an altitude of 2000 m above sea level.

5.1.9 Continuous Flow Technique

The technique described so far is known as the continuous flow technique, where a continuous flow of the gases is maintained irrespective of the respiratory volume of a child. Therefore, it is beneficial for children who may not follow instructions properly or may have shallower respiration. Demand flow technique, which is obsolete now, required an inspiratory effort to activate the gas flow, which was impractical and unachievable in children.

> Continuous flow technique has improved the ease of administration of nitrous oxide to children.

5.1.10 Special Considerations during the Administration of Nitrous Oxide in Children

- ***Upper respiratory tract infection***
  Upper respiratory tract infection makes it difficult for a child to breathe through the nose, thereby reducing the efficacy of nitrous oxide sedation in children. Also, on nitrous oxide inhalation, air in the middle ear chamber gets replaced with nitrous oxide. In chronic nasal congestion, the eustachian tube also gets congested, thereby limiting the ability of air pressure to equilibrate between the middle ear and the oropharynx. This may produce bulging, fullness, tingling of the tympanic membrane, or earache. An appropriate dose of anti-histamines or nasal sprays or decongestants can be used prior to the appointment.

- **Mouth breathing**
  Child who has no obstructive cause to mouth breathing should be trained by a constant verbal reminder to breathe through the nose. A modified hand over mouth or wet towel over mouth method can be carried to ensure nasal breathing. If mouth breathing is related to anxiety, after initial euphoria and relaxation caused by nitrous oxide, nasal breathing would take over mouth breathing.

  For children with an obstructive cause, nitrous oxide is administered using a technique known as "Insufflation." [3, 4] In this technique, after the placement of rubber dam, one end of nitrous oxide tubing can pass under the rubber dam, filling oropharynx with nitrous oxide. The other tube is clamped off.
- **Obese child**
  An obese patient may feel uncomfortable breathing through the nose when positioned in a supine position, as abdominal contents press on the diaphragm. In such a scenario, the child should be positioned in an upright position and the dentist would have to compromise on his/her preferred working position [3, 4].
- **Claustrophobic patient**
  Use of nasal cannula with continuous flow system should be considered.

5.1.11 Success of Nitrous Oxide Sedation in Children

Nitrous oxide inhalation sedation should not be considered as a magical wand for behavior management of children. The children may accept nitrous oxide sedation well but may not be willing to accept the dental treatment completely. For example, the child may be putting the nasal hood or may like using the nasal hood, but when the child is asked to keep the mouth open, the child may not agree. At the same time, the child would like to continue using the mask or show unhappiness if the mask is removed.

Clinical success of nitrous oxide sedation has been reported to be in the range of 85–95% by various authors [2, 14–17]. It is dependent on previous anxiety, fear level of a child, any previous traumatic dental experience, and the ability to communicate and cooperate [18, 19].

> A major determining factor for the success of inhalation sedation in pediatric dentistry is dependent on the dentist's ability to judge the cooperative ability of a child and child's willingness to support the dentist in the dental treatment [20].

Factors such as age, sex, complexity of the dental procedure, and the type of dental procedure, do not govern the success of nitrous oxide inhalation sedation in children [13]. A wide variety of individual attributes govern the success of nitrous

oxide inhalation sedation in children. Various authors have stated that the children with difficult temperament usually result with unsuccessful inhalation sedation [21–24].

Role of the dentist is also important to govern the success of inhalation sedation in pediatric dentistry. Children who may fail to be treated using nitrous oxide inhalation sedation should be considered for oral sedation or general anesthesia rather than letting them develop negative dental experience.

A dentist should be able to determine the fear or anxiety in a child's mind, handle them with tender love and care, and also apply basic behavior management skills, which helps in handling children with difficult temperament.

Factors used to assess that nitrous oxide may be unsuccessful in a child
Child does not want to enter the clinic
Child is constantly crying
Child is less than 40 months old
Child does not communicate with the dentist
Child with special health care needs

Reasons for Failure with Nitrous Oxide

- Ineffective communication
- Ignoring or failure in recognizing anxiety in a child
- Incorrect evaluation of child's compliance
- Poor behavior management
- Excessive interference from parents
- Failure in managing pain
- Using pharmacological pain measures after the occurrence of pain
- Not practicing fragmented treatment for children with attention and cooperation deficits

5.2 Monitoring

Monitoring during nitrous oxide inhalation sedation is the key to safe and efficacious sedation appointment. The entire monitoring process of inhalation sedation in children is focused around maintaining the minimal level of sedation and preventing it from going to a moderate-deep level of sedation.

Monitoring is defined as the continuous observation of response from specific organ systems to evaluate the status of physiologic function [25].

5.2.1 Purpose of Monitoring

1. Clinically determine the level of sedation
2. To promptly recognize deviation from normal
3. To determine the level of consciousness
4. Establish verbal communication with the child at regular intervals
5. Clinically determine oversedation, if present
6. Monitor respiration

Respiratory system is considered to be the most important system for monitoring of pediatric patient sedation other than cardiovascular and central nervous system.

5.2.2 Types of Monitoring

1. Clinical observation
2. Electronic devices

Electronic devices used for monitoring should ideally be continuous or "real time," accurate, dependable, convenient, affordable, rapidly responsive, and noninvasive.

Proper monitoring helps to maintain the child in a minimal level of sedation.

Clinical Observation

(a) *Establishing communication with the child* (Fig. 5.18)
- Purposeful response is a clear indicator of minimal sedation
- There should be minimal time lag between the operator's questions and the child's response.
- In pediatric dentistry, the operator cannot allow the child to talk while carrying out dental procedures. Therefore, the operator should ask questions which just need a nod. For example, "are you ok?"; "are you doing fine?"; "can you raise your left hand?

(b) *Observing facial and eye response* (Fig. 5.19)
- Repeated mouth closing is a sign that the child is going towards moderate sedation. This sign can be missed if a mouth gag is being used. The jaw appears more rigid because of muscular contractions.
- The eye response is not very definite in children. Usually in adolescents, a slight drooping of upper eye lid may be seen. In younger children, this may not be very evident.

Fig. 5.18 Establishing communication with the child by asking the child to raise left hand

Fig. 5.19 Operator checking the child's facial expressions during the procedure

- Eye ball movements are reduced in minimal sedation. Fixed eye balls or a stare-like appearance or dazed look is an indication of moderate level of sedation.
- Closing eye lids is also an indication for moderate sedation
- Flushing on face is an indication of oversedation
- Sweating on forehead, neck creases, or scalp is also a sign of oversedation

(c) *Observing movement of reservoir bag* (Fig. 5.20)

- It is best to have an assistant who has been assigned to observe the movement of reservoir bag intermittently, while carrying out his/her work. Movement of reservoir bag monitors the respiration of a child.
- Reservoir bag should always be two-thirds fill so as to visualize its movements clearly.
- If the movement of reservoir bag is not appreciated well, it is best to verify by checking the placement of nasal mask, pressing the nasal mask gently over the nose to reduce any leakage. This will usually make movement of reservoir bag more noticeable.

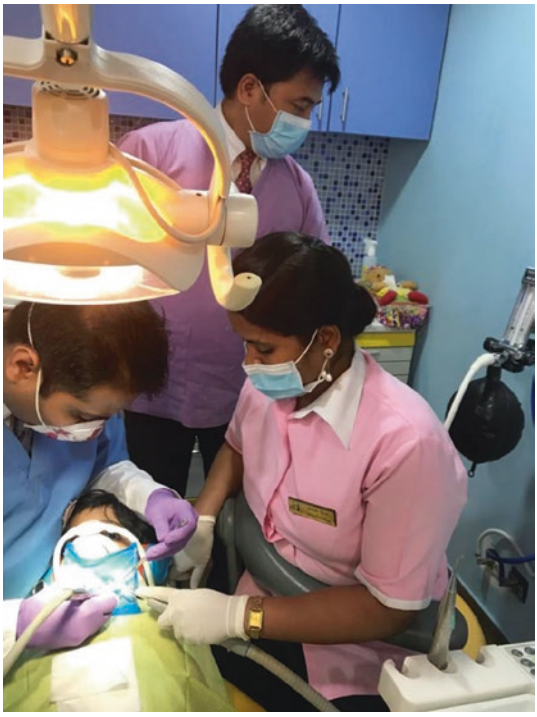

Fig. 5.20 Dental assistant intermittently checks for movement of reservoir bag, during the procedure

(d) *Observing thoracic or abdominal movement* (Fig. 5.21)

- In case, the movement of the reservoir bag is not noticeable due to shallow respiration, then the abdominal movement or chest raises help in confirming the respiratory movements.
- Visual observation of respiratory excursions needs continuous and close attention, which is not practical for the operator. Also, shallow respirations in children are sometimes difficult to be appreciated because of clothing or drapes.
- Sudden and exaggerated movement of thorax or abdomen is usually a sign of adverse event—vomiting. This is usually seen before a child has regurgitation or vomiting.

Establishing communication with the child at regular intervals is the key to a successful monitoring.

Fig. 5.21 Operator looking for chest raises during the procedure by movement of the patient drape

Signs of Oversedation

To summarize signs of over sedation are as follows:

1. Fixed eyes—no eye ball movement is seen or is minimal (Fig. 5.22).
2. Flushing of face—face appears stern and red in color.
3. Sweating on scalp, neck, back, and palm (Fig. 5.23).
4. Abnormal breathing pattern or abnormal breath sounds.

Electronic Devices

One of the simplest and useful monitoring tools is pulse oximetry. It is a non-invasive instrument whose probe is attached to the child's finger/big toe or ear (Fig. 5.24a, b). This device helps to determine the oxygen saturation and the cardiac rhythm during the procedure.

Fig. 5.22 Fixed eyes with no eye ball movement

Fig. 5.23 Sweating on forehead is a sign of oversedation

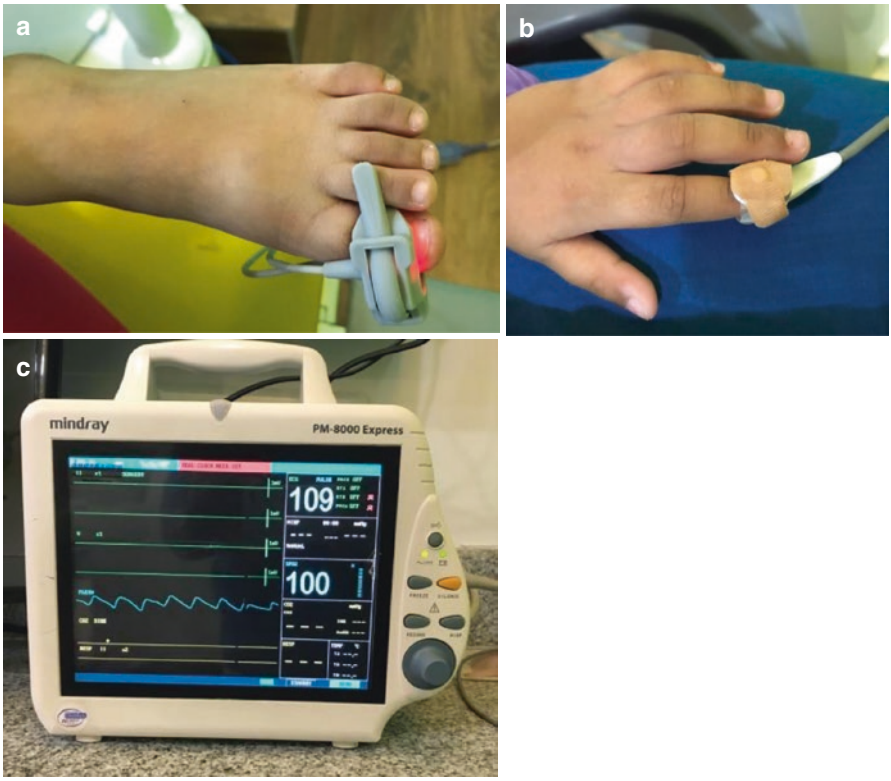

Fig. 5.24 (**a**) Pulse oximeter sensor attached to big toe. (**b**) Pulse oximeter Nellcor sensor attached to index finger. (**c**) Multiparameter monitor showing oxygen saturation in numerical and graphic form

Pulse oximeter is a valuable monitor because it is very accurate and rapidly responsive. It requires no calibration, warm up time, or tissue preparation. It can detect hypoxemia much before the clinical signs and symptoms of it are manifested.

Oxygen desaturation rarely occurs during inhalation sedation with nitrous oxide. In fact, there is always a good concentration of oxygen being received by the child (usually 65–50% if the child is receiving 35–50% nitrous oxide). It has been stated that the maximum concentration of nitrous oxide recommended for dental operations is 55% in which there is no chance of hypoxemia [26–28].

It is very sensitive in detecting hypoxemia than visual assessment. Oxygen desaturation can only occur in cases of airway obstruction, which is rare during minimal sedation. Even a slight decrease in oxygen saturation based on pulse oximeter needs attention and prompt action. This is more important in children due to their high basal oxygen consumption and less oxygen reserve, owing to their small size. As a result, desaturations occur more rapidly in children. Saturation levels above 95% are preferable for a child and anything below 90 should be a cause of definite concern.

In a study carried out in adults, it was found that 96.88% of patients did not experience arterial blood oxygen desaturation [29].

Limitations of using pulse oximeter in children
- A child tends to move his/her finger or toe which may displace the sensor thereby giving false reading.
- A child, at times, may not allow the operator to put the sensor on finger or toe.
- It may increase anxiety in a child or even parents.

Some dentists consider the use of pulse oximeter as absolute necessary during inhalation sedation using nitrous oxide [28]; others do not find it necessary but only prefer to use it [30] while some dentists do not prefer to use it at all because of its limitations mentioned above [31]. **However, according to the guidelines by the American Academy of Pediatric Dentistry, use of pulse oximetry is not required when nitrous oxide is used alone for sedation in pediatric patients. Authors would recommend, recording of baseline oxygen saturation levels in case of children with prexisting systemic diseases such as congenital heart disease, obstructive pulmonary diseases, sickle cell disease etc. In cases where nitrous oxide inhalation sedation is being used for children in ASA III or IV, pulse oximeter may be used during the procedure.**

Bispectral Index System

This monitoring technique is best suited for non-anesthesiologists. It is used to measure the level of sedation following the use of anesthetic or sedative agent. It is electroencephalogram-based cerebral activity measurement, which is computer processed. The score ranges from 0 to 100, with 0 representing the state of no brain activity and 100 representing an awake state (Fig. 5.25).

40–60 general anesthesia
61–70 deep sedation
71–90 moderate sedation
>90 awake

It represents a noninvasive and continuous method for assessment of the level of sedation [32]. It also increases clinicians comfort and improves safety. It may allow a clinician to objectively determine deepening of sedation and take appropriate steps to reverse that.

Use of Bispectral index is not of significance when the nitrous oxide is used alone as it is meant to bring about minimal sedation. It will be of importance when nitrous oxide is combined with other drugs such as midazolam to produce moderate sedation.

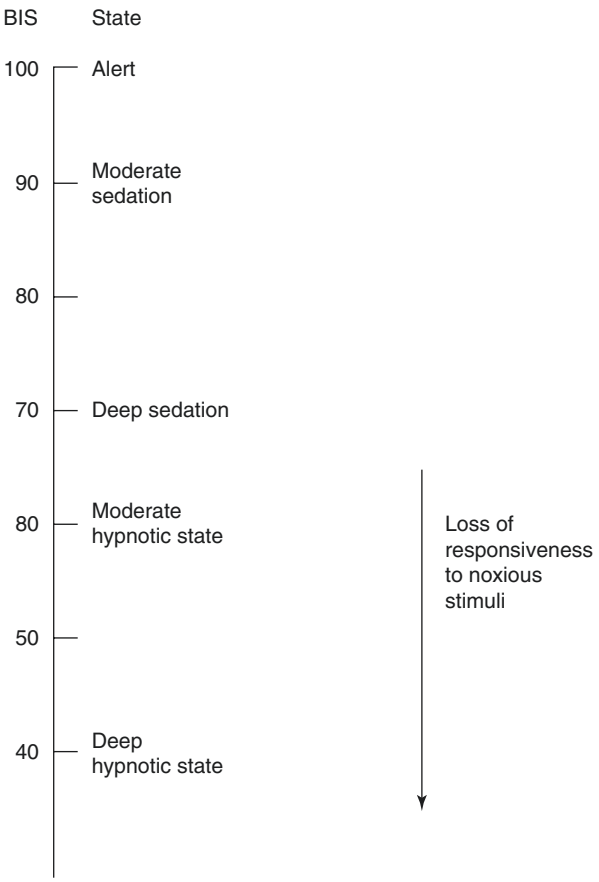

Fig. 5.25 Bispectral index

It has been found that BIS did not change with inspired nitrous oxide concentrations up to 50% [33]. Two researches showed that no change in BIS value was seen even up to 70% nitrous oxide concentration even though the patients lost consciousness clinically [33].

Also, in children, it is difficult to perform bispectral index system.

> Electronic monitoring may not be very accurate in children.

Capnography

Capnography is the measurement of carbon dioxide in the patient's exhaled air over time. It measures end-tidal carbon dioxide which is the amount of carbon dioxide released at the end of expiration. This is essential for assessing proper oxygenation and metabolism in the body. High $eTCO_2$ is indicative of hypoventilation and increased metabolic activity. On the other hand, low $eTCO_2$ is indicative of hyperventilation and decreased metabolic activity. Hence, purpose of capnography is to detect the presence or absence of ventilation and the depth of respiration.

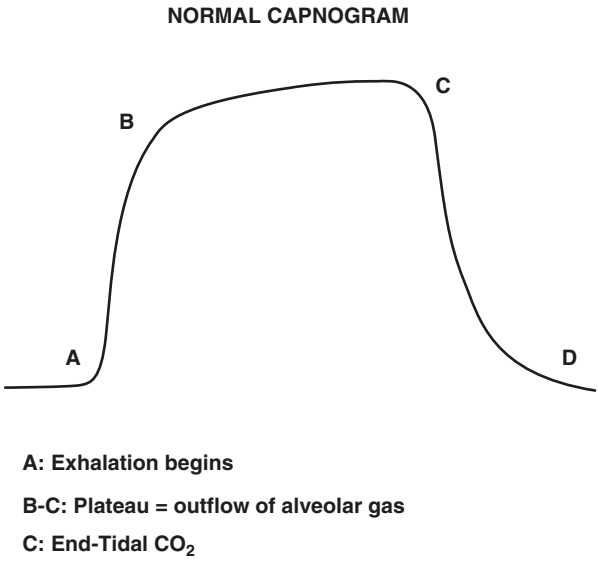

Fig. 5.26 Normal capnograph

Capnography has a role to play during moderate sedation and therefore is not of significance when nitrous oxide is used alone [34] (Fig. 5.26).

Sedation Scales

Sedation scales are quantitative and subjective indication of the level of sedation. The most popular one for pediatric patients is the Houpt Sedation scale (Appendix IX). It measures different parameters such as sleep, movement, crying, and behavior.

Another one is the Observer's Assessment of Alertness and Sedation scale (OAA/S) (Appendix X). It measures the level of alertness in sedated subjects based on the assessment of four categories: responsiveness, speech, facial expression, and ocular appearance.

Ramsay Sedation scale (RSS) is a well-established tool for the evaluation of sedation which is easy and inexpensive to perform (Appendix XI). However, sedation scales are not objective methods.

5.2.3 Operator's Response to Monitoring

During the process of monitoring, if the operator feels that the child is proceeding towards a moderate level of sedation, then he/she should reduce the concentration of nitrous oxide by 5–10% and observe for a decrease in signs of oversedation. If not then, the nitrous oxide concentration should be decreased further by 5–10% (Fig. 5.27). This process of gradual reduction in the concentration of nitrous oxide should be carried on till the desirable clinical signs are achieved.

> If the child goes into a moderate level of sedation, then the nitrous oxide concentration should be reduced by 5–10% till the child is in level of minimal sedation.

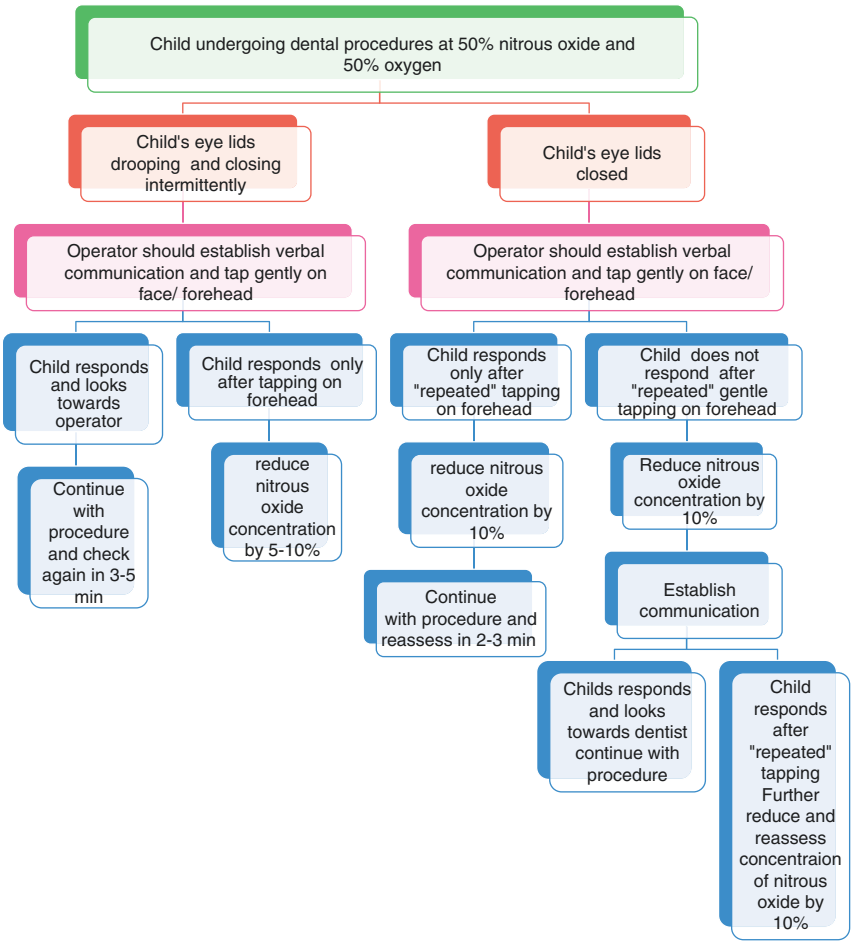

Fig. 5.27 Operator's response during monitoring

5.3 Adverse Events

Nitrous oxide is a commonly used agent for minimal sedation in pediatric dentistry. Nitrous oxide is easy to administer and produces predictable and desirable clinical effects, namely anxiolysis, analgesia, and amnesia. Its effects are completely reversed prior to discharging the patient by flushing with 100% oxygen for 5 min. Due to its high safety profile, ease of use, and acceptance, nitrous oxide remains an important adjunct to behavior guidance for pediatric patients. However, no procedure is free of side effects or complications. There are risks and adverse events that necessitate practitioner's vigilance when considering the use of nitrous oxide.

An adverse event can be defined as any untoward medical occurrence in a patient which does not have a causal relationship with the drug being used.

The adverse events related to the use of nitrous oxide are not serious or life threatening if treated promptly [35]. Most common "intra-administration" adverse events can be hallucinations, dreams, or development of nausea and vomiting.

Broadly, adverse events related to nitrous oxide sedation may be categorized as minor and major adverse events. The classic minor adverse events discussed in literature include dizziness, headache, perioperative/postoperative nausea and vomiting, diffusion hypoxia, and expansion of gas-filled spaces (causing flatulence, stomach ache, or earache). However, current literature reports elucidate major adverse events such as laryngospasm, cardiovascular morbidity and mortality, impaired wound healing, and acute and chronic pain [13]. It is important to keep in mind that most major adverse events associated with nitrous oxide have been reported when nitrous oxide is used at high concentrations for the administration of general anesthesia or during pediatric medical sedation in an emergency room, and not at low concentrations for anxiolysis used in a dental office.

An observational study on 1- to 17-year-old children reported 8.3% minor and self-resolving adverse events in children inhaling 50% nitrous oxide in oxygen and found no significant difference in adverse events between nitrous oxide of 50 and 70% [36, 37]. However, adverse events are higher in children <3 years old when a higher concentration of nitrous oxide is used.

Another report in children between 33 days and 18 years with a median age of 5.0 years reported minor adverse events including nausea (1.2–1.6%), vomiting (2.2%), and diaphoresis (0.4%). A total of 0.14% reported serious adverse events including oxygen desaturation and generalized seizures which were resolved promptly with an increase in oxygen [38, 39].

A systematic review on use of nitrous oxide in minor pediatric medical procedures reported minor adverse events of 4–8% and major adverse events of less than 0.5% in children aged 0–19 years.

American Academy of Pediatric Dentistry has recommended 50% as maximum concentration of nitrous oxide to minimize adverse events.

Reasons for Precipitation of Side Effects

- Side effects observed during nitrous oxide administration are relatively uncommon. Their incidence can be further minimized by certain precautions during its administration. These are as follows:

  (a) Restricting administration of nitrous oxide/oxygen to 30–45 min.
  (b) Avoiding fluctuations in nitrous oxide concentrations.
  (c) Using nitrous oxide at a concentration >50% for a longer duration.
  (d) Mechanical or equipment failure (though rare).

5.3.1 Diffusion Hypoxia

When nitrous oxide is administered to a child, there is a rapid uptake of the gas into the blood stream through the alveoli, due to the concentration gradient and low

solubility of nitrous oxide in blood. Nitrous oxide is transported in blood as free gas. It does not combine with hemoglobin and does not undergo biotransformation. When the administration of nitrous oxide is discontinued, the gas is eliminated by expiration in precisely the reverse manner. Again, due to low solubility, nitrous oxide is eliminated rapidly.

However, when the administration of nitrous oxide is discontinued, a high concentration of the gas rapidly builds up in the alveoli. This dilutes the partial pressure of oxygen in the alveoli and leads to hypoxia. This phenomenon is called diffusion hypoxia. The hypoxia is transient, yet should not be taken lightly.

If a child gets up from a dental chair, soon after cessation of nitrous oxide administration, he/she may fall down due to the imbalance caused by diffusion hypoxia. The clinical sequelae related to diffusion hypoxia are headache, disorientation and nausea/vomiting, and lethargy after the treatment. Some children may sleep in the car while returning from the clinic or at home, after the treatment, which may result in parents getting worried. Prior information to parents or reassurance will be helpful in reducing parents distress, if any.

Maximum excretion of nitrous oxide gas takes place in the first 3–5 min after discontinuing its administration. A clinical study has mentioned that 99% of nitrous oxide is excreted during the first 5 min [40], and diffusion hypoxia occurs during the first 4 min in the majority of cases [41, 42]. Hence, it is the standard of care and conventional practice to provide 100% oxygen to a pediatric patient for at least 5 min after the administration of nitrous oxide in a dental practice [43]. In pediatric patients, the lingering effects of nitrous oxide should be assessed and further oxygenation should be provided if the child has had a long dental appointment under nitrous oxide [44]. Oxygenating the patient in this manner reduces diffusion hypoxia and related clinical manifestations. It provides an opportunity for a waning placebo effect. It also enables expiration of nitrous oxide into the scavenging system and, hence, minimizes the escape of nitrous oxide into the clinical environment [43].

Diffusion hypoxia is not of much clinical significance in healthy child patients. Significance increases in medically compromised children, children suffering from bronchitis, or when a high concentration of nitrous oxide has been used for a long time.

Certain studies have questioned the clinical significance of diffusion hypoxia [45]. It has been reported that diffusion hypoxia is not clinically significant in healthy pediatric dental patients [40]. This is because arterial oxygen pressure remains higher than usual during the administration of nitrous oxide [46] (e.g., even if a child is inhaling nitrous oxide at a concentration of 50%, he/she is also inhaling 50% oxygen which is much higher than the oxygen available in the atmospheric air). A child patient allowed to breathe atmospheric air (having 21% oxygen) under careful observation on a dental chair for 5 min will not develop diffusion hypoxia [40, 47]. It has been reported in a clinical study that only 2–3% drop in alveolar oxygen tension occurs during washout period in spontaneously breathing patients who had inhaled 50% N_2O and 5 L/min flow rate [48].

The clinical significance gains magnitude when the respiratory ventilation gets compromised (like in bronchitis) [40, 49] or a higher concentration of nitrous oxide (meaning lesser concentration of oxygen has been used for a longer time). Also, in children who are medically compromised it becomes essential to administer 100% for 5 min after the cessation of nitrous oxide.

5.3.2 Nausea and Vomiting

Nausea and vomiting are the most common adverse events associated with the use of nitrous oxide [50]. There are different mechanisms for nausea and vomiting associated with the inhalation of nitrous oxide. These include

(a) Action on central opioid and dopaminergic receptors.
(b) Diffusion of nitrous oxide into the middle ear cavity which may cause barometric changes within middle ear, thereby stimulating vomiting center [51, 52].
(c) Bowel distension [53, 54].
(d) Children who suffer from motion sickness are more likely to develop nausea.
(e) Pre-existing gastrointestinal disease.

Clinical signs which may suggest that nausea is precipitating are perspiration on scalp or neck/palm creases, excessive swallowing, change in thoracic and abdominal movement, sudden movement of a child who was otherwise calm and still, coughing, and a child trying to remove the nasal mask. Adolescents may express verbally by saying that "I feel sick" or "I don't want to use this mask anymore."

The emetogenic effect of nitrous oxide is significantly related to the duration of administration and a higher concentration of nitrous oxide [50, 53]. A report mentions increased chances of nausea and vomiting when nitrous oxide is administered at a concentration of 50% for more than 2 h [55]. It is also related to the titration method. If nitrous oxide is titrated very quickly, then it can cause nausea (e.g., in rapid titration method, instead of increasing nitrous oxide concentration by 10% every 2–3 minutes, it is increased by 10% every 30 s). Also, younger age group has been reported to have an increased incidence of vomiting [56]. An inexperienced operator can alter the concentrations of nitrous oxide very frequently. This causes a "Roller Coaster effect" precipitating nausea.

Nausea and vomiting are distressing perioperative events for the child, parents, as well as for the practitioner. If vomiting occurs, primary action should be to prevent aspiration of vomitus. Further, a supine child on a dental chair may aspirate gastric contents if emesis occurs, which increases the risk of aspiration pneumonia.

Hence, it is prudent to institute a 2-h fasting period prior to the administration of nitrous oxide to minimize emesis and aspiration [50]. It was found that chances of vomiting increased when fasting was less than 2 h [57]. However, a prospective case series on 220 children concluded that there was no association between pre-procedural fasting and emesis [58].

Nausea and vomiting can be minimized by administering a minimum effective concentration of nitrous oxide for the shortest duration required.

Efficacy of Laryngeal Reflex

It has been found that the laryngeal reflex is not depressed during nitrous oxide inhalation sedation, if nitrous oxide concentration is kept less than 50% [59]. An experimental clinical study conducted on 50 anxious and fearful children found no aspiration into larynx or chest [59].

A contradictory report mentioned aspiration in 20% of adult patients on using a fixed concentration of 50% nitrous oxide in oxygen [60].

Handling Situation with Vomiting

If a child vomits, immediately use high vacuum suction and keep telling the child to spit out. Check for the alertness of the child and then administer 100% oxygen. Lift the chin upwards to maintain the airway.

In the event of any emergency, follow certain steps to assess proper functioning of the above mentioned systems.

1. Maintain patency of airway why head-tilt/chin-lift maneuver.
2. Scan the child's chest for rise and fall for no more than 10 s to assess breathing.
   (a) If there is normal breathing and pulse, activate emergency response system.
3. Palpate the pulse (carotid and femoral pulse in a child). Signs of poor perfusion are cool extremities, decline in responsiveness, weak pulse, and pale mottled skin which may turn to cyanosis.
   (a) If there is no normal breathing but presence of pulse, then provide rescue breathing (1 breathe every 3–5 s or 12–20 breaths/min).

If there is no breathing and only gasping or no pulse, then activate CPR (cycle of 30 compressions and 2 breaths for single rescuer or 15 compressions and 2 breaths for 2 rescuers).

5.3.3 Pain in Ears

Seldom, children may complain of pain in the ears due to the pressure changes in middle ear. This may progress to rare (mostly seen during use of nitrous oxide as a general anesthetic, meaning use of nitrous oxide gas at a higher concentration for a longer duration) but more serious events such as tympanic membrane rupture or blood in ear [52, 61]. This is due to an increased pressure in the middle ear. Mechanism of increased middle ear pressure is because of the blood gas partition coefficient being 30 times greater than nitrogen (gas predominantly present in air). As a result of this, nitrous oxide fills in air-filled cavity more rapidly than nitrogen is removed from those cavities, thereby increasing middle ear pressure. This gets reduced by passive venting of nitrogen gas from the eustachian tube [52].

Also, after the discontinuation of nitrous oxide, development of negative pressure may occur in the middle ear. This can be explained by rapid outward movement of nitrous oxide from the middle ear at a rate much higher than the movement of nitrogen gas replacing it. Consequently, flexible walls of the eustachian tube tend to collapse inwards which prevents equilibration of sub-atmospheric pressure. This may lead to earache or in rare instances, rupture of the tympanic membrane [52].

Pain in ears and stomach is due to the difference in the rate of entry of nitrous oxide into closed air spaces and the rate of exit of nitrogen gas from these spaces.

This is a common occurrence in children following the use of nitrous oxide as a general anesthetic agent [52] though not so common with its use for inhalation sedation in a dental setting. Its clinical significance increases in children with respiratory tract infection or history of ear problems such as eustachian tube dysfunction. Also, in children with anatomic variations in the ear such as in Crouzon's syndrome (acoustic nerve compression from skull base and cartilage anomalies causes narrowing in internal acoustic meatus), increased middle ear pressure following the use of nitrous oxide can cause postoperative hearing loss [62].

5.3.4 Sexual Phenomenon

Although this phenomenon may not be an adverse event in true sense, it may present an embarrassing moment for the parents and the dentist. This phenomenon is of greater significance in adolescents and dental staff of both the sexes should be present in the dental operatory, while treating adolescents.

During this phenomenon, children may move their hands towards their genitals (Fig. 5.28). Some children may even touch dentist's face with affection.

This phenomenon usually occurs because of transition into a state of light sleep or dreamy state which may become erotic or sexual in nature [63]. It may also be because of a hypnotic state which may occur spontaneously or unintentionally [64].

5.3.5 Laryngospasm

Laryngospasm has been reported in a child during procedural sedation in medical emergency and analgesia using nitrous oxide alone at a high concentration (70%

Fig. 5.28 Child putting hands near genitals during nitrous oxide sedation

induced deep sedation, close to GA) [65]. High concentrations of nitrous oxide may cause laryngospasm due to variability in patient responses [50]. The oral cavity provides access to the airway, and dental treatment may produce aerosols or pooling of saliva, which in conjunction with sedation can predispose to a laryngospasm [50]. Careful monitoring of the patient and use of saliva ejectors and rubber dam isolation can help minimize the likelihood of this serious adverse event. Also, laryngospasm cannot occur in minimal or moderate sedation.

5.3.6 Malignant Hyperthermia

This is a very rare adverse event (one in 15,000 anesthetic procedures) [66] and can occur in patients who are sensitive to general anesthetics and depolarizing muscle relaxants because of an autosomal recessive trait. This can result in muscle contracture, acidosis, hyperkalemia, and hyperthermia. Occurrence of this adverse event in a dental setting has not been reported ever. The child must get unconscious before malignant hyperthermia due to nitrous oxide can occur [46], and hence it cannot happen in a dental setting. However, it is mentioned here for knowledge of readers.

5.3.7 Head Trauma and Nitrous Oxide

Nitrous oxide can increase cerebral blood flow and intracranial pressure. In animal models, this increase in oxygen consumption seems to exacerbate ischemic neurologic injuries. In light of this information, intracranial injuries and head concussion should be ruled out in children who have sustained dental trauma before administration of inhalational nitrous oxide.

5.3.8 Fire

Nitrous oxide is capable of supporting combustion. A report mentioned fire in the mouth of a 54-year-old patient undergoing removal of leukoplakia patches from posterior part of tongue using electrocautery. It was believed that combination of electrocautery, dry gauze, and nitrous oxide caused combustion [46].

5.3.9 Accidents with Nitrous Oxide

Nitrous oxide in dentistry has a safety record of more than 150 years. There have been sporadic incidents of nitrous oxide-mediated complications due to technical problems. In these incidents, cross-connections of central nitrous oxide and oxygen lines during construction lead to nitrous oxide asphyxiation-related deaths [67]. Another reason was failure of mechanical interlocking between oxygen and nitrous

oxide flowmeter controls. This leads to severe hypoxia due to inhalation of 100% nitrous oxide [67].

A complication due to wrong gas tank connection was reported in 1977 [68]. The event occurred during the recovery period after nitrous oxide sedation in a US dental school oral surgery clinic. Pins were dislodged from the machine, compromising the pin index system, which lead to wrong connection of the gas tank. As a result, during the recovery period, patient inhaled 100% nitrous oxide instead of 100% oxygen resulting in cyanosis and loss of consciousness.

5.3.10 Asphyxiation Related to Impurities in Nitrous Oxide Cylinder

This adverse event is not of significance now but is being mentioned here for knowledge of readers. Before 1970s, there were higher chances of contamination of nitrous oxide cylinders with nitrogen in concentration of 0.5–2.0%. Inhalation of contaminated nitrous oxide has potential of triggering a rapid methemoglobinemia, chemical pneumonitis, and acidosis causing intense cyanosis, respiratory distress, and loss of consciousness [69] which is incapable of being managed by administering 100% oxygen. In scientific literature, two fatalities have been reported as a consequence of nitrogen contamination [49].

5.4 Documentation

5.4.1 Medical History

Prior to using nitrous oxide–oxygen minimal sedation, it is essential to review the patient's medical history and make a note of any changes to the medical status of the patient, any medications being taken by the child (including dose, time, route, and site of administration), and allergies. It is important to also have a record of any previous hospitalizations or surgeries and any complications during the same (Fig. 5.29).

Parents must be instructed to update the office if the child had any recent illness, a cold or congestion, for instance, which may compromise the airway. In case of any such changes to medical history, the procedure may need to be rescheduled.

5.4.2 Informed Consent

A written informed consent must be obtained from the parent or the legal guardian of the child and documented in the dental record prior to the use of nitrous oxide (Fig. 5.30). The informed consent should explain the indication and rationale for the use of inhalational nitrous oxide, all the risks and benefits associated with its use, and alternatives, if applicable. Prior to the procedure, all questions from the parents/legal guardians should be encouraged and answered by the dentist.

Documentation of using nitrous oxide in child patients involves recording of the medical history, taking informed consent from parents, providing preoperative and postoperative instructions, and recording per-operative notes including any adverse events.

MEDICAL HISTORY

□ Yes	□ No	Is Your child in good health? Date of last medical exam _____
□ Yes	□ No	Has your child ever had a health problem _____
□ Yes	□ No	Is your child allergic to anything? _____
□ Yes	□ No	Is your child currently taking any medications? If yes, please provide medication, Dose and reason: _____
□ Yes	□ No	Are your child's immunizations current? _____
□ Yes	□ No	Have you ever been told that your child needs to take antibiotics before dental treatment?
□ Yes	□ No	Has your child ever been hospitalized, had general anesthesia, or emergency room visits?
□ Yes	□ No	Were there any difficulties at birth or pre-mature? _____

Please check if your child has been treated for any of the following

□ Heart disease	□ Heart murmur	□ Bleeding/transfusions	□ Asthma/breathing
□ Anemia	□ Blood disorders	□ Tonsil/abenoid problems	□ Tuberculosis
□ Liver Disease	□ Sickle cell disease/trait	□ Diabetes	□ AIDS
□ Kidney disease	□ Rheumatic fever	□ Hepatitis	□ Mental delays
□ Speach/hearing	□ Seizures	□ Cleft lip/palate	□ Physical delays
□ Eyesight	□ Congenital birth defects	□ Gastric disease/reflux	□ Cancer/tumors
□ Recurrent headaches	□ Frequent infections	□ Adverse drug reactions	□ Cerebral/tumors
□ Significant injuries	□ Endocrine/growth	□ Autism	□ Arthritis
□ ADHD	□ Spina bifida	□ Snoring	□ Abuse

Other: _____

Fig. 5.29 Medical history form

5.4.3 Preoperative Instructions

The dentist should provide the parents/legal guardians written preoperative instructions on how to prepare the child for the dental appointment with nitrous oxide–oxygen inhalation sedation. Pretreatment dietary precautions should be discussed with the parent. The parent should be instructed to keep the child NPO for 2 h prior to the scheduled dental appointment. The parent should be advised on ensuring that the child arrives in a loose, comfortable clothing on the day of the appointment (Fig. 5.31).

The anticipated effects of nitrous oxide should be explained well to the parents, with an emphasis that the desired effect is anxiolysis only. The parent should be informed that their child will maintain all protective reflexes and will be awake during the procedure. Parents should ensure that reliable transportation is available after the completion of the procedure to transport the child home on completion of the procedure.

NITROUS OXIDE INFORMED CONSENT

I hereby authorize **Dr.**_____
to give nitrous oxide/oxygen (laughing gas) for my child/ward:

_____

1. I accept and understand that Nitrous Oxide is commonly called laughing gas and provides relaxation. I understand that my child will be awake, conscious, aware of what is happening, and able to respond to questions and instructions.

2. I have provided to the doctor and the dental clinic staff:

    a. a complete medical history for my child
    b. list of all prescription and over-the-counter medications he/ she is taking
    c. known food and drug allergies
    d. history of emergency room visits
    e. history of past surgeries
    f. history of anycomplications with anesthesia for my child or in the immediate family
    g. any known genetic mutations in my child or in the immediate family, including MTHFR gene mutation

3. I will let the doctor and the staff know if my child falls ill or develops a cold, runny nose, respiratory infection, ear infection, asthma, or difficulty breathing.This will make it difficult for my child to breath in the nitrous oxide gasor have complications.

4. Nitrous oxide sedation has been recommended for my child to help him/ her feel more relaxed during the dental treatment. Local anesthesia in the form of an injection inside the mouth may also be required to numb the teeth and/or gums for the dental treatment.

5. The doctor has discussed with me the possible complications associated with Nitrous Oxide. They include, but are not limited to:

    a) Nausea and vomiting: This is the most frequent of the side effects of breathing nitrous oxide. In order to avoid this, your child must not have eaten or drank anything for the 2 hours prior to the appointment time.

    b) Temporary tingling in the fingers, toes, cheeks, lips, tongue and head or neck area

    c) Temporary warm feeling throughout the body with accompanying flushing/ blushing

    d) Temporary detachment or “out of body” sensation

    e) Temporary “floaty” feeling

    f) Temporary sluggishness in motion and/or speech

    g) Shivering –usually at the end of the procedure

Fig. 5.30 Informed consent for nitrous oxide sedation in children

5.4.4 Dental Chart Notations

The child’s dental chart should provide the indications for utilization of nitrous oxide/oxygen inhalation. This may entail a description of the child’s behavior, anxiety, and/or past dental experiences as well as the extent of dental treatment needs. Scales used to assess fear, anxiety, or phobia of children have been described in Appendix XII and XIII.

6. Nitrous oxide sedation iseffective for most children if they breathe it. However,some children may not like the feeling it produces, or it may produce increased activity in some children. If the dentist notices these effects, nitrous oxide will be discontinued for my child, and my child will receive 100% oxygen for at least 5 minutes.

7. Some children may not calm down enough with only nitrous oxide. If this happens, the dentist may stop the procedure at a safe stopping point and discuss other options such as moderate sedation or general anesthesia to safely complete the treatment for my child.

I hereby certify that I understand this authorization and the reasons for the above named sedative procedure and its associated risks. I am aware that the practice of dentistry is not an exact science. I acknowledge that every effort will be made for my child to have a positive outcome, but no guarantees have been made as to the result of the procedure authorized above.

_____ _____

Date Parent or Guardian's Signature

_____ _____

Date Dentist's Signature

Parent Instructions for Children having Dental Treatment with Inhalational Nitrous Oxide

It is essential to follow these instructions for the safety of your child. Failure to follow instructions may lead to cancellation of your child's dental appointment.

Before your child's appointment:

1. Your child should not eat or drink in the two hours before the appointment.

2. Before the two-hour fasting period your child may have a light meal. Examples include toast, small fruit, small sandwich, crackers, water. Avoid greasy or fried foods.

3. Please do not bring any other children or individuals who need supervision to the dental appointment. This will allow the dental team to focus on your child who is going to receive dental treatment with nitrous oxide.

4. If your child takes any daily medication(s), the dentist would have advised you about whether your child should or should not take them. Please follow the dentist's recommendation for medication(s).

5. If your child develops anyillness, such as fever, runny nose, respiratory infection,asthma,ear infectionor stomach illness, you should let us know immediately as we may have to reschedule your child's appointment.

6. Have your child wear loose, comfortable clothes for the appointment.

7. If your child has finger nail polishor false nails, please remove them before the appointment.

After your child's appointment:

1. You should make arrangements to travel home by car rather than by public transport.

2. Observe your child, and if he/ she shows any behavior that is unusual for him/ her, please call the dental office.

3. After the effects of the local anesthetic (numbness medicine) wears off, your child can eat. Give your child something light to eat at first. Make sure that he/ she does not feel nauseated before giving more food.

The effects of inhalational nitrous oxide generally wear off within minutes of the treatment being completed. It is still important to follow the instructions above.

Your child's care will be provided by: **Dr.** _____

Clinic telephone number: _____

Fig. 5.31 Preoperative instructions for nitrous oxide sedation in children

No. 8, First Floor, MGF Megacity Mall, MG Road, Gurgaon - 122002

SEDATION RECORD SHEET

Name of the child: Age/ Gender :

Last meal : Last meal time:

Any significant medical history: Cold/ cough/ runny nose:

ASA Classification: I / II / III / IV Consent form Signed : Yes/ No

Pre operative levels (for ASA II /III): SpO_2: Blood pressure: Pulse rate:

Primary assessment of anxiety: Crying aloud/ Struggling/ Quiet/ Shy or withdrawn/ Talkative or friendly

Method of Titration : Slow/Rapid

	Nitrous Oxide Concentration	Oxygen concentration	Flow rate	Time
Oxygenation phase				
Induction phase				
Injection phase				
Maintenance phase				
Recovery phase				
Total Time				
Procedures performed				

Intra operative behavior: Quiet throughout/ Mostly quiet but responded to few procedures/ Cried/ Procedure aborted

Sedation outcome: Minimal sedation throughout/ minimal sedation with periods moderate sedation

Adverse events

Perioperative: Nausea/vomiting
Post operative: Nausea/ Vomiting/ Headache/ Dizziness/ Sleepy/Drowsy

Name of operator: Signature of operator:
Date :

Fig. 5.32 Sedation record sheet

Evaluate the child's airway prior to the procedure and document the clearance. Preoperative blood pressure and pulse must be recorded on the chart as well (for ASA II/III).

Other records for the sedation procedure must include the following (Fig. 5.32):

- Outcome of sedation may be described based on "Sedation outcome assessment scale" (Appendix XIV).
- Total flow rate of nitrous oxide and oxygen
- Percentage and duration of administration of nitrous oxide
- Duration of administration of 100% oxygen at the end of the sedation procedure
- Notation regarding the patient's tolerance of the sedation procedure (any use of additional behavior guidance techniques to augment should be mentioned).
- The occurrence of any minor or major adverse events (with complete details of management done)
- Recovery status at the end of procedure (stable vital signs, orientation, ambulation)

Dentist should make a note of the parental presence (or lack of it) within the dental operatory during the procedure. Mentioning the presence of dental team members and parents is particularly important if nitrous oxide is being administered to adolescent patients.

It is a good idea to mention the effect of nitrous oxide/oxygen administration on the behavior of the child as a part of the clinical note too. The patient should be discharged only when the preoperative level of ambulation and cognition are achieved.

5.5 Personnel and Team Building

Nitrous oxide sedation in a child patient requires concomitant efforts by the dentist and dental assistants. Effective teamwork ensures a successful nitrous oxide sedation. Effective teamwork has certain components such as well-designated roles and effective communication.

5.5.1 Components of a Team

Three key members of nitrous oxide sedation team are regulator, facilitator, and surveillant. In nitrous oxide sedation team, the dentist is a regulator, dental chair side assistant is a facilitator, and another dental assistant is a surveillant (Fig. 5.33).

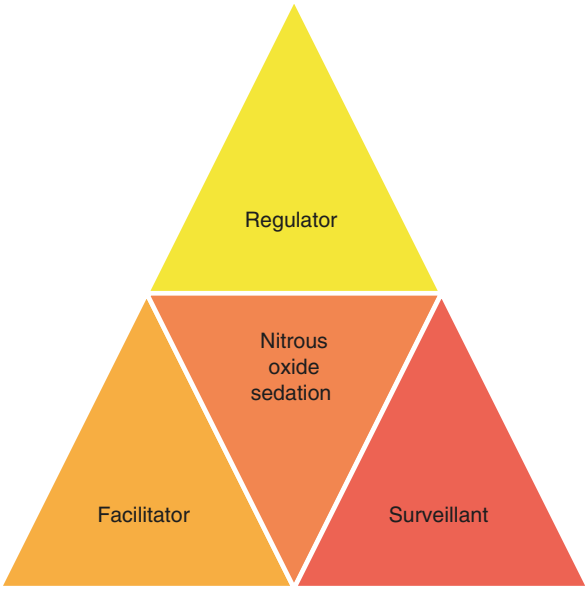

Fig. 5.33 Team members for nitrous oxide sedation in children

Well-Designated Roles

Understanding roles and responsibilities will help in the clear demarcation of actions, adequate monitoring during sedation, prevention of adverse events, and successful seeing off/discharge of patient.

Roles of a Regulator

1. Regulator/dentist serves as a team leader.
2. Regulator organizes the team, provides education/training to team members.
3. Regulator sets expectations for facilitator and surveillant.
4. Gives clear instructions to facilitator regarding the size of nasal mask to be used, titration technique to be followed (standard or rapid), adjustments in concentration of nitrous oxide, and cessation of use of nitrous oxide.
5. Regulator observes for any sudden thoracic or abdominal movement.
6. Maintains verbal contact with the child intermittently during the procedure.
7. Regulator records the details of sedation procedure in the sedation record sheet.
8. Regulator should not leave the dental operatory while nitrous oxide is being administered. This is based on the regulations of a country or state.

> Success of using nitrous oxide in child patients is dependent on a well-coordinated team with each member having clear designated roles and the ability to communicate effectively with each other.

Roles of a Facilitator

1. *Facilitator, if required, should be able to introduce the use of nitrous oxide to parents with assurance and sincerity.*
2. Facilitator/dental chair side assistant facilitates the use of nitrous oxide in a child based on clear instructions given by a regulator.
3. Facilitator changes the nasal mask after every patient.
4. Facilitator checks with the parents regarding pre-appointment, fasting, or upper respiratory tract infection.
5. Facilitator introduces nitrous oxide mask to a child.
6. Facilitator adjusts the nasal mask on a child's nose.
7. Facilitator titrates nitrous oxide gas and keeps reminding the child to take deep slow breaths from the nose and not to breathe from the mouth.
8. Facilitator verbally repeats the concentration of nitrous oxide after the regulator advises for any adjustment (e.g., regulator says increase nitrous oxide concentration to 50%, facilitator says nitrous 50).
9. Facilitator ensures that 100% oxygen is delivered to a child after the procedure is over.
10. Facilitator checks for signs of diffusion hypoxia or other minor adverse symptoms before seeing off or discharging the child from the dental operatory.

Roles of a Surveillant

1. Surveillant serves as a monitor during the nitrous oxide sedation.
2. Surveillant checks for any leakages from cylinders or cuts in tubings.
3. Surveillant checks for adequate pressure in cylinders and also checks for depleting oxygen flow rate on flowmeter during procedure indicating emptying of cylinders.
4. Surveillant ensures nasal breathing pattern by observing the movement of reservoir bag.
5. Surveillant looks for any signs of adverse events such as sweating on the scalp and sudden movement in thorax or abdomen
6. Surveillant also observes the eye responses and informs the regulator in case the eye lids are closing indicating deepening of the level of sedation.
7. Surveillant checks for any kinks in the tubing.
8. Surveillant changes the oxygen and nitrous oxide cylinders.

Each team member must be proficient in performing their roles. They should be having adequate knowledge about their roles and know how to act in a particular situation. Each member should be observant and concentrate on their roles to ensure the success of nitrous oxide sedation in a child.

When the roles are unclear, the efficiency of nitrous oxide sedation decreases (due to improper placement of mask or lack of adequate nasal breathing). It may also lead to an increase in the number of adverse events.

If each member of the team follows their roles to the best of their abilities, then the dentist can concentrate on the procedure with minimum distraction from a clinical procedure. This not only improves their efficiency but also reduces any stress on their mind (some dentists may be stressed during the use of nitrous oxide sedation).

5.5.2 Communication

Each team member should be well aware and cautious about what to communicate, how to communicate, when to communicate, and whom to communicate.

Incorrect communications may create stressful environment and also convey wrong message to the parents present in the operatory (Table 5.5).

Table 5.5 Examples of the correct way of communicating amongst team members

Communicating team member	Incorrect	Correct
Surveillant	Child is not breathing	Child is not breathing well through his/her nose
Surveillant	Reduce the oxygen	Decrease flow rate of oxygen
Surveillant	Child is getting oversedated	Nitrous oxide concentration can be reduced now
Regulator	Child will vomit	Can you please keep a vomiting bag handy

Good Communication Skills

Messages should be communicated in a calm and direct manner. Yelling or shouting should be avoided. Communications which are not loud and clear can be missed by the recipient and cause unwanted events during the sedation procedure.

Mutual Respect

Regulator, facilitator, and surveillant should have respect for each other and not criticize any mistake committed by a team member during the process of sedation. Regulator should play a key role in rectifying any faults on part of the facilitator and surveillant (e.g., facilitator increases the concentration of nitrous oxide too rapidly).

Any wrong action taken by the facilitator or surveillant should be pointed out by regulator in a respectful and tactful manner (e.g., instead of saying "why did you increase the concentration of nitrous oxide so rapidly," a better manner of communicating is "for this patient it is better if you increase the concentration of nitrous oxide at a rate of 10% every 2 min).

Another example is "why aren't you observing the movement of reservoir bag properly to ensure that the child is breathing through the nose" is an incorrect and authoritative way of communicating. A more polite way would be "I need your help in carefully observing the movement of reservoir bag so that we ensure that the child is not breathing through his/her mouth."

Using Closed End Commands

Regulator should deliver messages which are short, concise, clear, and loud to ensure that it is well received by the facilitator. For example, during the administration of local anesthesia, if the regulator wants to increase the concentration of nitrous oxide to 60%, then it can be communicated as "nitrous 60%." The recipient team member should perform the task and confirm that the action has been taken. For example, after increasing the concentration to 60%, the facilitator says "nitrous 60%." Regulator can then say "Thanks."

Analyzing the Sedation Procedure

It is important that the regulator conducts a short debriefing session, if required, after the sedation procedure to discuss any mistakes committed by the facilitator or the surveillant. This will help in understanding the mistakes and its implications. It will also help in preventing such mistakes in future. It will also help in reinforcing the team spirit and strengthening the bond as well as the respect amongst team members. Such debriefing sessions also act as short education sessions for the team members.

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