

Nitrous Oxide Analgesia for Minor Pediatric Surgical Procedures: An Effective Alternative to Conscious Sedation?

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Background/Purpose: Minor surgical procedures in children, while usually not requiring general anesthesia, need effective control of pain, anxiety, and motion. Certain techniques of conscious sedation may result in loss of protective airway reflexes. Nitrous oxide, however, when inhaled at levels below 50% maintains protective reflexes and does not require fasting or postprocedure monitoring. This study prospectively examines the efficacy of nitrous oxide analgesia in children undergoing outpatient surgical procedures.

Methods: Over a 2-year period (2000 to 2002), 150 consecutive children were given nitrous oxide analgesia as an alternative to a general anesthetic, sedation, or local anesthetic alone. Nitrous oxide (<50%) was administered by our practice's sedation-certified nurse practitioner without an anesthesiologist present. The children used the Wong-Baker Faces Scale (0-5) to score pain at different intervals (preprocedure, at injection, during procedure, and postprocedure) and event memories were tabulated.

Results: Of 150 children, 5 were uncooperative and could not participate. One hundred forty-five children, ages 1 to 20 years (Mean, 9.83 ± 4.92 years) successfully underwent pro-

cedures (58 cyst/nevus excisions, 49 abscess drainages, 38 other) using nitrous. Two patients were too young to score pain. Pre- and postprocedure pain scores were significantly higher in the abscess group ($P < .0001$); during the procedures, however, all groups reported pain scores less than 1, with parents citing 100% satisfaction with the technique. Of 128 children receiving local anesthesia, 107 (84%) had no recall of the injection. Complications were limited to 4 patients; 2 experienced nausea, and 2 vomited. All resolved without interrupting the procedure.

Conclusions: Nitrous oxide analgesia is a cost-effective and efficacious alternative to conscious sedation or general anesthesia for minor pediatric surgical procedures. In the office or outpatient setting, the technique provides for almost pain/anxiety-free surgery, no postoperative monitoring, and a high degree of satisfaction for patients, parents, and staff. *J Pediatr Surg* 39:495-499. © 2004 Elsevier Inc. All rights reserved.

INDEX WORDS: Nitrous oxide anesthesia, minor pediatric procedures, pain control in children.

ALTHOUGH NITROUS OXIDE analgesia had been widely used in pediatric dentistry and to a limited extent in children's emergency rooms and orthopedics departments,¹⁻⁷ there are no large studies detailing its routine integration into a pediatric surgical practice. The surgeons and parents of children needing minor procedures have long faced the well-known dilemma. Should doctors use rapid local anesthesia and accept a varying amount of acute discomfort and anxiety, with or without the risks and inconsistencies of an oral sedative? Or would a general anesthetic with its possible complications and the inconvenience of a prolonged time of no oral feeding and of operating room scheduling be better? In a pilot study of 25 children presented by our group in 2000⁸ we found that nitrous oxide inhalation was an efficacious technique that combined the best of both options. When used at low concentration, nitrous oxide allows the maintenance of the laryngeal reflex and has a well-documented record of safety.^{1,2,13,14} In addition, the technique requires minimal advance preparation of staff, equipment, and the patient. The mask-administered gas has rapid onset, is short acting, requires no empty stom-

ach, and provides for excellent control of the pain, anxiety, awareness, and motion during the uncomfortable procedure. Postoperatively, memory of the event is blunted, and no monitoring is necessary.^{2,4,5} This article reviews the experience of the subsequent 150 consecutive children undergoing painful pediatric surgical procedures with nitrous oxide analgesia at Miami Children's Hospital during a 2-year interval.

MATERIALS AND METHODS

The Miami Children's Hospital Institutional Review Board approved the study. From August 2000 to July 2002, appropriate candidates for nitrous oxide inhalation were culled from 2 main groups: (1) children undergoing minor elective procedures—such as nevus excision—for whom the guardian and surgeon during preoperative office consultation

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FACES PAIN RATING SCALE

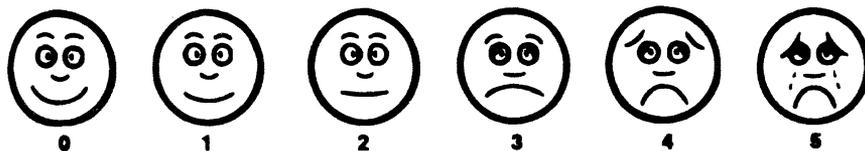


Fig 1. Wong-Baker Scale.¹⁰

agreed that local anesthetic alone would not be adequate to control pain and anxiety, and (2) children requiring emergency interventions—such as abscess drainage or foreign body extraction—who would benefit from analgesia greater than that provided by local injection alone.

On the day of the intervention, EMLA (AstraZeneca, Wilmington, DE) or ELA-max (Ferndale Labs, Ferndale, MI) is liberally applied to the pertinent skin site according to the surgeon’s prior instructions. On arrival, vital signs are taken, and a short history and physical are done by our practice’s sedation-certified nurse practitioner to exclude contraindications to the technique. These include otitis media, bowel obstruction, altered mental status from drugs or injury, hemodynamic instability, pneumothorax or American Society of Anesthesia risk score greater than 3.^{2,4} The nurse has a short educational session (about 5 minutes) with the parent and the child. The parent assists the child in practicing to breath through the brightly colored, pleasantly scented (vanilla, orange, or bubblegum) occlusive nasal hood (nose mask; Accutron, Inc, Phoenix, AZ).

All procedures are performed by the surgeon in the minor operating room of the Outpatient Center at Miami Children’s Hospital while the nurse practitioner titrates the nitrous oxide, from 20% to 50%, with oxygen according to our previously described protocol.⁸ We do not routinely restrain the children nor do we force the mask on them, because breathing through the mouth—when crying, for example—rapidly negates the effect of any inhaled nitrous. If the patient is old enough (usually older than 3 years) and can cooperate, he may himself hold the mask during induction; frequently, the accompanying parent takes over when this ability is lost as the gas concentration increases. Heart and respiratory rates and oxygen saturation are monitored. When the heart rate returns to a baseline value and the analgesia is assessed as adequate, the surgeon begins, in most cases by injecting lidocaine, 1%, with epinephrine buffered with sodium bicarbonate at the site. The level of sedation and other symptoms, such as pain, nausea, or vomiting, are noted throughout the procedure.

Upon completion of the operation, oxygen is administered for at least

5 minutes to wash out all remaining nitrous, preventing a phenomenon called diffusion hypoxia, which can cause headache, lethargy, and nausea.⁴ The child is shown the Wong-Baker Faces Pain Scale¹⁰ depicted in Fig 1 and asked to score pain from 0 to 5 at 4 points during the procedure: (1) preoperatively, (2) at injection, (3) during the operation, and (4) postprocedure. Parents are questioned about whether the child had more or less pain than expected and about their satisfaction with the technique. The children are allowed to eat and can be discharged immediately without any postprocedure monitoring. Statistical analysis was done using an analysis of variance with a least significant difference post-hoc test.

RESULTS

Nitrous oxide was offered to and accepted for 150 children over the 2-year period. This represents 11% of the total minor procedures our practice did in the Outpatient Center over the same period (n = 1,348). Five of the 150 children (3%) were unable to cooperate, refusing to put on the mask or to breath exclusively through the nose. Statistical analysis was conducted on the remaining 145 patients. Children in all age groups were well represented, as depicted in Fig 2, ranging in age from 1 to 20 years (mean, = 9.83 ± 4.93). Eighty-three (57%) were girls, and 62 (43%) were boys. Minor excisions of nevi or cysts were undertaken in 58 (40%), drainage of abscess in 49 (34%), and other procedures in 38 (26%, Table 1).

Two of the patients were too young (1 and 2.5 years) to participate in the Wong-Baker scoring. Pre- and postoperative pain scores in the remaining children were

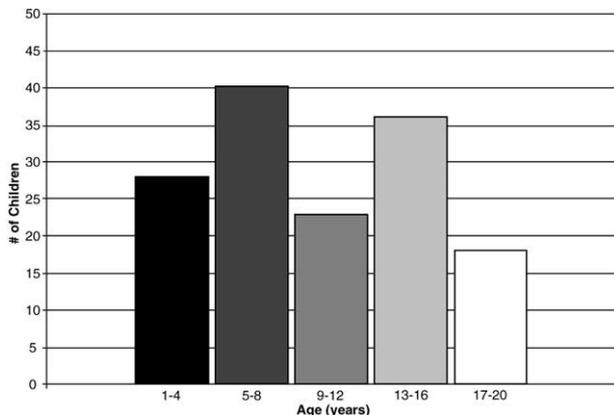


Fig 2. Age distribution (n = 146).

Table 1. Procedures Undertaken (n = 145)

Procedure		
Cyst/mole excision (%)	58	40
Abscess drainage (%)	49	34
Other procedures (%)	38	26
FB removal	14	
Penile manipulation	5	
Port/CVL removal	4	
Vaginal dilatation	4	
Drain place/remove	3	
Debridement	3	
Burn/wound		
Frenulectomy	2	
Labial adhesions	1	
GT granulomas	1	
Needle aspirations	1	

Table 2. Wong-Baker Pain Scale (0-5), Mean Scores

	Preprocedure	At Injection	During Procedure	Postprocedure
Mole/cyst (n = 58)	0.1	0.3‡	0.5‡	0
Abscess (n = 49)	2.1*	0.5†‡	0.8†‡	0.9*
Other (n = 38)	0.8	0.3‡	0.9‡	0.3
Total (n = 145)	1.0	0.4	0.7	0.5

* $P \leq .01$ compared with pre- and postprocedure pain in other groups.

† $P \leq .01$ compared with the preprocedure level of pain.

‡All groups had good analgesia during the injection and procedure with no significant differences in pain among the groups.

significantly higher in the abscess group compared with the other groups ($P < .01$). At the time of injection and during the procedure under control of nitrous oxide analgesia, however, there were no significant differences between the groups with all groups averaging a pain score of less than 1 on the 0 to 5 scale (Table 2). Although there was a significant drop in reported discomfort during the operation in the abscess group (mean pain scores dropped from 2.1 to 0.8), there were no significant changes in the mole/cyst or the other procedure groups during the intervention. This is most likely because the preoperative pain scores started low (means below 1 in both these groups) and remained there throughout the operation. If anything, the pain scores tended to rise during the procedure in these 2 groups, although not significantly, probably because many were completely pain free at the onset.

No procedure, once started, was aborted because of uncontrollable discomfort, motion, or anxiety. It was not uncommon for the child to flinch or show a mild, transient tachycardia during the injection phase, but most were amnesic to the event. In fact, 123 (95%) of the 129 patients receiving injections of local anesthesia denied getting a shot. No patient required an intravenous line or resuscitation of any kind.

There were no serious complications during the study and 4 minor ones for a rate of 3%. Two children became nauseated, and another 2 vomited. In each case, the problem resolved, and the procedure was successfully completed. These complications occurred early in the study period and always in patients who had empty stomachs. Later on in our series, we requested that children who had not eaten recently ingest a few crackers or half a single-serving box of cereal before the procedure began. This eliminated the problem with nausea and vomiting.

Parental satisfaction was 100%. Comments such as "That was remarkable!" and "I cannot believe it was so easy!" and "This was so much better than the other times she has had to have this done" were common. Almost every parent felt that the pain the child experienced was minimal and less than expected. No parents expressed regrets at the decision to use the technique or felt the

child would have been better served by a general anesthetic. The adolescents tend to report feeling "happy" or "giddy" or "pleasantly light headed" from nitrous oxide. Many of the younger children keep their "noses" pressed on their faces long after the nitrous has been turned off in an attempt, we assume, to recreate the euphoric feeling they must have gotten from the agent.

DISCUSSION

Experience with nitrous oxide in pediatric dentistry, orthopedics, and emergency rooms¹⁻⁷ provides good precedence for use in the scope of a pediatric surgical practice. This study is the first to detail the routine integration of inhaled nitrous for outpatient procedures on a busy pediatric surgery service. Nitrous oxide analgesia satisfies several goals that make it ideal for use in both elective and emergency minor procedures that children in our practice setting face every day. The technique is (1) safe; (2) effective in the relief of pain (alone or with local anesthesia), anxiety, and unpleasant memories; (3) easily utilized in the emergency setting when operating room scheduling is difficult or the patient has a full stomach; (4) both time and cost efficient, being rapid in onset and requiring minimal preparation of equipment and personnel and no intravenous line or postprocedure monitoring; and (5) highly satisfactory to children, their families, and the medical staff.

Although our study is too small to be a "safety study," it adds to the many reports that have already shown the wide margin of safety using inhaled nitrous oxide in the pediatric population.^{1,5,11} Although the favorable effects of nitrous have been lauded for over 150 years, Griffin's landmark 1983 study of over 3,000 procedures first outlined the technique for children treated as outpatients.¹² In this report, we show its usefulness in a novel setting, for inpatients and outpatients on a pediatric surgical service. Serious complications such as respiratory depression and aspiration are rare, because there is no loss of reflexes as long as the concentration of the gas is kept below 50% and hypnotic sedatives are not simultaneously administered.^{13,14} The agent is exquisitely titratable. Simply lowering the concentration reverses the oversedation within seconds. The most common compli-

cations are mild and preventable. Headache and lethargy can result from an effect called diffusion hypoxia, which stems from a rapid washout of the nitrous⁵ and which is avoided by at least 5 minutes of postprocedure oxygen administration. Nausea and vomiting, which in our study stemmed from nitrous administration on an *empty* stomach, are prevented by feeding the children immediately before beginning.

Good relief from discomfort and anxiety is afforded with nitrous oxide analgesia as shown by the pain scores in this report. Krauss and Green,⁹ reviewing sedation and analgesia in children for the *New England Journal of Medicine* in 2000, cited nitrous oxide as only a “weak analgesic, sedative and anxiolytic.” All groups in our study, however, reported in the exit interviews that pain had been absent during the procedure. This may largely be because of the excellent amnesic qualities of nitrous oxide. Although many of the kids flinched at the time of injection, 84% of patients treated with local anesthesia denied receiving an injection. Because fear of shots is one of the prime motivators for children and their parents to avoid techniques relying on local anesthesia, the blunted memory is a major advantage. One recalcitrant teenager suffering from stenosis of her vaginal reconstruction came in willingly for a series of dilatations, once she experienced the procedure with inhaled nitrous oxide. We strongly recommend supplementing the analgesic qualities of nitrous oxide with appropriate adjunct therapies. Topical anesthetics such as EMLA (lidocaine 2.5% and prilocaine 2.5%) or ELA-max (4% lidocaine) for skin and Hurricane (20% benzocaine, Beautlich, Waukegan, IL) or viscous lidocaine for mucous membranes should be used whenever possible. The child is placed in a relaxed position and restraints are rarely used. In addition, parental presence, reported as a mitigating factor in many pain studies,¹⁵ helps afford the child maximum comfort.

Although the high concentrations of the gas used in general anesthesia (up to 70%) may lead to suppression of the reflexes and the loss of airway control, lower concentrations used in this study do not.^{1,2,13,14} Still, the use of nitrous oxide requires sedation credentialing. As described in our initial trial,⁸ our 2 nurse practitioners attended nitrous oxide classes at the local dental school,

including 16 hours of classroom work and 8 hours of self-guided study. They passed the Pediatric Advanced Life Support Course and the hospital-required Sedation Module, a written examination followed by a practicum in airway management in the operating room under the supervision of the Department of Anesthesiology. This process took about a year.

Preparation for a given case is quick, because the extra equipment that is required (the nitrous-oxygen tanks and the oxygen saturation monitor) is kept in the minor procedure room. A case with nitrous inhalation frequently takes the surgeon less time than the same case with straight local anesthesia, as restraints are rarely utilized, motion is better controlled and no coaxing or coddling is necessary. Similarly, when compared with the same case under general anesthesia, using nitrous oxide minimizes paper work, operating room congestion, surgeon’s time, hospital costs, and patient and family inconveniences, especially for same-day referrals requiring urgent intervention.

The satisfaction quotient for all parties—children, parents, doctors, and other medical caregivers—is uniformly excellent. Although it is clear that the increased comfort of a procedure done with nitrous oxide analgesia is highly desirable to the patient and family, the stress caused to members of the medical team as they inflict pain on a youngster is frequently ignored. The nurses staffing the minor surgical unit at our facility have overwhelmingly approved our new techniques and word of our success has encouraged other departments, notably the emergency room and hematology-oncology, to apply these methods to their own specialties.

Nitrous oxide analgesia is a cost-effective and efficacious alternative to conscious sedation or general anesthesia for children undergoing minor procedures. The agent provides for almost pain- and anxiety-free surgery, requires neither an intravenous line nor postprocedure monitoring, and blunts any unpleasant memories the child might otherwise have. Our study shows a high degree of satisfaction with the technique among patients, parents, and medical staff alike. For minor surgical interventions, nitrous oxide is an excellent technique that fits seamlessly into a busy pediatric surgery practice.

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Discussion

Unidentified Speaker: I think this is fantastic. I have a question. How much approval or disapproval do you get toward a protocol like that from your anesthesia department?

J. A. Diana-Zerpa (response): That is a good question. When I first went to the department of anesthesia, I had the full backing of the 5 surgeons, and the chief of anesthesia said, "Are you nuts? A nurse giving nitrous oxide without an anesthesiologist?" So it took about a year of jumping through hoops. We went to the dental school. We took the nitrous course, sedation certified. We even went into the operating room with them and intubated children before they were satisfied, but after a year they could not say anything else, so with a push from my surgeons they finally agreed.

Unidentified Speaker: Good for you. I think it is great.

J. A. Diana-Zerpa (response): Thank you.

E. McGahren (Charlottesville, VA): Do you have all of the ancillary monitoring, suction, airway equipment, etc, that we use in the typical conscious sedation scenario?

J. A. Diana-Zerpa (response): Absolutely. This is a minor procedure room. It is equipped with a scavenging device to take the extra nitrous out of the room. It has the emergency cart right outside the room, suction, O₂, etc. It is right in the room.

S. Shochat (Memphis, TN): I am curious about the credentialing issues. I know that the pediatric dentists do use this technique. They have some very specific controls. They cannot give any more than a certain amount of nitrous oxide. How did you deal with those issues?

J. A. Diana-Zerpa: As far as our policy with anesthesia, we agreed that we would give nitrous at no greater than 50% and with no other sedatives. The children can have Tylenol, but they cannot have any other sedatives or any narcotics. Since the completion of this study, we have agreed with anesthesia that we can go as high as 55% to 60% now, but really our pain scores were so low with 50% that I do not think it is necessary to go higher.