# Case-Series of Nurse-Administered Nitrous Oxide for Urinary Catheterization in Children

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**BACKGROUND:** Children undergoing urologic imaging studies requiring urethral catheterization experience considerable discomfort and psychological distress. Nitrous oxide sedation may mitigate these detriments but the requirement for physician administration has limited the applicability of this technique.

**METHODS:** Registered nurses underwent the nitrous oxide training requirements prescribed for state licensure of dentists and dental hygienists, with special emphasis on pediatric sedation principles. To evaluate the safety of nurse-administered nitrous oxide, we consecutively enrolled all children (ASA PS I–II) sedated for urethral catheterization for urologic imaging in an observational trial designed to identify sedation-related adverse events.

**RESULTS:** Nitrous oxide was administered on 1018 occasions. There were no major adverse events (apnea, oxygen saturation <92%). Minor adverse events (diaphoresis, nausea, vomiting) occurred in 4% of patients. Eight patients (1%) were described as over-sedated. In 11 (1%) patients, nitrous oxide provided insufficient sedation for completion of urologic imaging.

**CONCLUSIONS:** Nitrous oxide sedation can be provided by a nurse-administered program in pediatric radiology. Administration of nitrous oxide for pediatric procedures by adequately trained nursing staff with appropriate multidisciplinary oversight may increase children's access to this sedative/analgesic drug.

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Considerable and well-warranted attention has been focused recently on the issue of pediatric pain management (1,2) and procedural sedation (3). Pain and distress experienced by children during medical procedures increases distress and anxiety during subsequent procedures (4). Urethral catheterization, although not particularly traumatic from an adult perspective, can be especially troublesome and painful in children who lack the emotional or cognitive maturity to cooperate or to understand the reasons for the procedure (5,6). Urethral catheterization is required for urologic imaging with voiding cystourethrography (VCUG) and radionucleide cystography (RNC). As many children with urologic abnormalities will require testing at regular intervals, it is particularly important to use strategies that minimize distress and discomfort. Oral midazolam effectively mitigates the anxiety and distress associated with these procedures, but has a half-life which significantly exceeds the time required for imaging, and often results in unwanted behavioral side effects (7). Recent data suggest that nitrous oxide ($N_2O$) is as effective a sedative drug as oral midazolam for VCUG (8). Given the cost and workforce requirements of anesthesiologist or intensivist-administered $N_2O$ sedation, Children's Hospitals and Clinics of Minnesota developed a nurse-administered $N_2O$ program to facilitate procurement of VCUG and RNC studies. If both safe and effective, nurse-administered $N_2O$ procedural sedation is likely to be less costly and more readily available than the traditional anesthesiologist-led procedure. The present study was undertaken to evaluate the safety and efficacy of the program by determining the incidence of adverse events and the ability to successfully complete the imaging using $N_2O$ sedation administered by registered nurses.

## METHODS

This study was approved by the IRB of Children's Hospitals and Clinics of MN. Given the observational study design, written informed consent was not required.

### Nurse-administered $N_2O$ Program

Registered nurses trained and experienced in monitoring deeply sedated pediatric patients underwent the training requirements prescribed for state licensure of dentists and dental hygienists for $N_2O$ administration. Accreditation entailed attendance at an 8-h course designed to address the pharmacology, toxicity, and environmental safety of $N_2O$ as well as the

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equipment used for its delivery. After successful completion of this course, the clinical competency of each qualified nurse was assessed during four additional hours of observation and mentored administration of $N_2O$. The program met the guidelines of the American Nurses' Association for registered nurses charged with the management of patients receiving IV medication for short-term diagnostic procedures (9).

### $N_2O$ Administration

A standard dental flowmeter and rubber goods were used for $N_2O$ administration and scavenging. Inhaled $N_2O$ was administered via a continuous flow device (Porter Instrument Company, Hatfield, PA) which allows titration of $N_2O$ concentration from zero to a maximum of 70%, with oxygen as the remaining gas. Unlike the commercially available fixed 50:50 $N_2O$:$O_2$ mixture, there was no need for the patient to overcome a demand valve to maintain $N_2O$ delivery. The equipment incorporates built-in safety features, including a non-rebreathing valve, emergency air intake valve, and fail-safe device that automatically terminates the flow of $N_2O$ in the event of an interruption in oxygen flow. The equipment includes an apparatus for exhaled gas scavenging and evacuation. An adequate seal could be comfortably maintained using the nasal hood over the nose of the older child or over the nose and mouth of a toddler. Before clinical use, the equipment was assembled and tested for $N_2O$ leakage by the hospital's biomedical department. Badge dosimetry monitoring was performed periodically to ensure compliance with National Institute of Occupational Safety and Health $N_2O$ occupational exposure limit of less than 25 ppm time-weighted average.

### $N_2O$ Sedation for Urologic Imaging

All patients underwent a presedation assessment before sedation administration to identify potential contraindications to sedation (e.g., gastroesophageal reflux, craniofacial abnormalities) and inhaled $N_2O$ (e.g., pneumothorax, bowel obstruction). A set of vital signs, including temperature, respiratory rate, heart rate, arterial blood pressure, and baseline pulse oximetry reading, were obtained during the presedation assessment. By hospital policy, all patients with ASA classification >II were ineligible to receive nurse-administered $N_2O$ and did not participate in this study. During the initial 4 mo of the study, patients were kept fasting for a minimum of 4 h before sedation. On the basis of further literature review (10,11) and interim analysis of the study data, subsequent patients were instructed to restrict intake to at most a light meal for 4 h before the procedure. $N_2O$ was administered at 70% $N_2O$/30% $O_2$ until completion of urethral catheterization. After catheterization, 100% oxygen was administered for 2–5 min. Throughout the $N_2O$ administration, and until the child returned to the presedation level of alertness, the patient was monitored with continuous pulse oximetry and direct nursing observation. No additional arterial blood pressure recordings were obtained. VCUG or RNC was then performed as determined by radiology protocol. Venous access was not obtained in any child, either for the imaging study or, per policy, for $N_2O$ sedation.

**Table 1.** Adverse Effects of Nitrous Oxide for Urologic Imaging in 1018 Children

| | *N* | % |
|---|---|---|
| Apnea (>15 s) | 0 | 0 |
| $O_2$ saturation <92% (>1 s) | 0 | 0 |
| Diaphoresis | 7 | 1 |
| Nausea | 9 | 1 |
| Vomiting | 21 | 2 |
| Other (crying, pallor, agitation) | 8 | 1 |
| Total unique cases with any side effect | 36 | 4 |

### Data Collection

From September, 2004 through April, 2006, all children receiving $N_2O$ sedation for urethral catheterization for VCUG or RNC in the radiology department of the St. Paul campus of Children's Hospitals and Clinics of MN were enrolled consecutively in the study. Data collection sheets were attached to each $N_2O$ sedation order to ensure compliance with data collection for each patient. Data collected for this study included presence or absence of the side effects listed in the Table 1, duration of $N_2O$ administration (<15, 15–30, >30 min), and whether the level of sedation was sufficient to allow successful completion of the procedure. Level of sedation was assessed as presence or absence of over-sedation, defined as sedation deeper than a drug-induced state during which patients respond normally to verbal commands.

## RESULTS

$N_2O$ was administered on 1018 occasions for urethral catheterization for either VCUG or RNC during the 20-mo study period. Review of departmental scheduling records revealed that there were 3398 VCUGs and RNCs scheduled during that time. One thousand ninety-three procedures were scheduled with sedation, representing data collection on a minimum of 93% of possible sedation encounters. The actual percentage may be higher, as last minute cancellations were not removed from the records. Patients ranged in age from 11 mo to 17 yr, with a mean age of 5.4 yr and median of 4.8 yr. Almost all (94%, $n = 952$) received $N_2O$ for <15 min. Sixty-three patients (6%) received $N_2O$ between 15 and 30 min and three patients (0.3%) received $N_2O$ for longer than 30 min. No patient developed apnea (>15 s) or oxygen saturation below 92% (>1 s) at any time during $N_2O$ administration or recovery. Thirty-six patients (4%) had minor adverse effects, including nausea, diaphoresis, and/or vomiting (Table 1). Eleven procedures (1%) were unsuccessful due to sedation failure.

Eight patients (1%) were described as over-sedated. Charts of all eight patients were reviewed. One patient was described as "snoring," with rapid response to discontinuation of $N_2O$ and initiation of 100% oxygen. None required airway intervention.

## DISCUSSION

Dentists have been administering $N_2O$ alone or combined with other sedatives and analgesics since the 1800s (12). Eighty-five percent of pediatric dentists use $N_2O$ for patient sedation (13). Although an article published in the Journal of the American Medical Association more than 20 yr ago described the use of $N_2O$ for more than 3000 patients in a general pediatric office in UT, (14) the use of $N_2O$ for pediatric procedural sedation in the United States likely remains sporadic. Use of $N_2O$ outside of the operating room or dental clinic has been reported primarily in the pediatric emergency department for laceration repair (15,16) or fracture reduction (17,18).

$N_2O$ administration by non-physician providers is routine. Either dentists or dental hygienists can deliver $N_2O$ in much of the United States. Advanced practice nurses deliver $N_2O$ to pediatric patients for minor surgical procedures in the United States (19). Registered nurses deliver $N_2O$ in the emergency department and outpatient setting in Australia and England (20,21). The safety of $N_2O$ administration to children by pre-hospital providers, including lay responders, has been documented (22).

A recent article (23) addressed the efficacy of a tiered approach to pediatric sedation including nurse-administered protocols. The authors stressed the importance of accurately matching the pharmacologic approach to appropriately trained personnel. The present report provides data that supports the notion that inhaled $N_2O$ can be used by registered nurses for specific urologic procedures. While several articles have addressed the safety of $N_2O$ sedation for a variety of pediatric procedures (24–31), the current study adds to this body of knowledge by reporting the largest series of patients sedated with $N_2O$ using a nurse-administered protocol. In the present series, the use of $N_2O$ to expedite the performance of urologic imaging studies in more than 1000 children did not result in a single major adverse event (apnea or arterial oxygen saturation <92%). Despite using $N_2O$ at a concentration of 70%, the incidence of minor adverse effects of $N_2O$ (nausea, vomiting, diaphoresis) in the present study was less than previously reported (20,24). The difference may derive from the relatively short duration of administration of $N_2O$ required to expedite urethral catheterization.

Restriction of $N_2O$ administration privileges to physicians or nurse anesthetists may not only considerably limit the use of $N_2O$ as a sedative/analgesic drug due to workforce requirements, but also increase the cost of the procedure. An editorial (32) critical of $N_2O$ use for laceration repair in a pediatric emergency department cited the labor-intensive need for a physician to administer the $N_2O$ in addition to the physician performing the procedure and asked the question, "can the substantial logistical hurdle of a separate sedating physician be overcome through special nurse training in this technique?" The current study seems to answer that question in the affirmative.

The present study does not address the quality of sedation for urethral catheterization. Rather the study end-point was the successful completion of the imaging study. Similarly, the study does not address discomfort that may have been encountered during the remainder of the urologic imaging (bladder filling, voiding). Nevertheless, our experience mirrors the report of Keidan et al. (8) wherein $N_2O$ provided a reduction in anxiety and distress associated with urologic imaging comparable to oral midazolam, but with a shorter recovery time.

$N_2O$ administered at <50% concentration in oxygen with no other sedative or analgesic medications is recognized as minimal sedation (33). For this study, patients characterized as "over-sedated" correspond to a level of sedation deeper than minimal sedation, as outlined in the ASA Continuum of Depth of Sedation (33). Even though $N_2O$ was administered at a concentration of 70%, more than 99% of the study patients remained at the level of minimal sedation, as judged by responsiveness to verbal stimulation. The fact that eight patients reached a level of moderate sedation nevertheless reinforces the importance of preparation to appropriately manage patients at the level of moderate sedation when $N_2O$ is used at this concentration. Measurement of patient sedation level during $N_2O$ administration using a validated sedation scale is important information for future study. Rates of dysphoria should also be measured in future studies with larger sample sizes to better estimate rates of adverse events.

In conclusion, the present data support the notion that $N_2O$ sedation can be safely and effectively provided using a nurse-administered program in a hospital-based radiology department. Administration of $N_2O$ for pediatric procedures by adequately trained nursing staff with appropriate multidisciplinary oversight may increase children's access to this sedative/analgesic drug.


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