TABLE 1. Morphologic and Biochemical Effects of Nitrous Oxide (N₂O) on Embryos Treated for 24 Hours on Day 9 and Examined on Day 11

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>50-75% N₂O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of embryos cultured</td>
<td>96</td>
<td>106</td>
</tr>
<tr>
<td>Number of viable embryos</td>
<td>94</td>
<td>93</td>
</tr>
<tr>
<td>Number of malformed embryos</td>
<td>6</td>
<td>60*</td>
</tr>
<tr>
<td>(Percent of viable embryos)</td>
<td>(6.3%)</td>
<td>(71.0%)</td>
</tr>
<tr>
<td>Number of embryos with left-sided tail (Percent of viable embryos)</td>
<td>2</td>
<td>14*</td>
</tr>
<tr>
<td>Number of embryos with inverted heart (Percent of viable embryos)</td>
<td>1</td>
<td>18*</td>
</tr>
<tr>
<td>Protein content (µg/embryo ± SD)</td>
<td>422 ± 80</td>
<td>183 ± 108†</td>
</tr>
<tr>
<td>(n = 36)</td>
<td>(n = 30)</td>
<td></td>
</tr>
</tbody>
</table>

* P < 0.01 versus control by chi-square analysis.
† P < 0.01 versus control by Student’s t test.

convincing evidence than in our previous report. We are now in a position to use this more robust day-9 in vitro model to establish dose-response relationships and mechanisms of N₂O teratogenicity.

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Unusual Cause of an Absent Capnogram

To the Editor—The capnogram is taken to be a valuable adjunct in identifying proper endotracheal tube placement; inability to detect exhaled CO₂ following intubation represents esophageal intubation until proven otherwise. Herein we report an unusual cause of abrupt capnography failure in a pediatric patient.

A 5-year-old ASA physical status I patient presented for elective strabismus repair. After inhalation induction with nitrous oxide and halothane in oxygen, an iv infusion was begun, vecuronium administered, and the trachea was intubated without difficulty with a 5.0-uncuffed oral RAE tube. Bilateral breath sounds were confirmed. A large leak at less then 5 cm H₂O was evident around the endotracheal tube. A 5-l fresh gas flow was used and the lungs were easily ventilated when mechanical ventilation was initiated (the bellows failed to refill fully with a lower flow). Capnography (Life Watch/Perkin-Elmer mass spectrometer, aspiration rate ~240 ml/min), however, failed to demonstrate expired CO₂ previously evident on induction. Breath sounds were confirmed bilaterally with good chest wall excision; peripheral oxyhemoglobin saturation remained at 100% on an inspired Fio₂ of 0.3. The ventilator bellows (Omeda 7000) emptied and filled appropriately with a peak inspiratory pressure of 20 cm H₂O and an end-expiratory pressure of approximately 2 cm H₂O (the lowest resting position of the aneroid manometer). The aspirating tubing of the mass spectrometer had no obvious loose connections or kinks. When tested, CO₂ was immediately evident upon exhalation into this tubing by an anesthesiologist. Suspecting the large leak to be the culprit, we briefly manually sealed the patient’s mouth and nose and a CO₂ tracing appeared on the screen. We then checked the circuit system for other obstruction to exhaled volume and found the Omeda GMS PEEP valve to be minimally engaged. Upon loosening the valve one-half turn counterclockwise, CO₂ appeared on the capnogram. Reinstating minimal PEEP again resulted in no observable CO₂ on the capnogram, despite the manometer registering only 2 cm H₂O at end-expiration.

The valve was then opened fully, with the manometer needle still resting on 2 cm H₂O, and the case proceeded uneventfully.

In this child with a large leak around the endotracheal tube, the small resistance to flow through the expiratory limb of the circuit system offered by partial engagement of the PEEP valve was enough to divert total expiratory flow around the tracheal tube. The leak, however, prevented the development of PEEP, and the manometer correctly determined end-expiratory pressure to be low. We do not believe that the Omeda GMS PEEP valve, which provides a spring-loaded obstruction to the circuit’s exhalation valve, was faulty; nonetheless it was difficult to determine by simple visual inspection if it was engaged. The mechanism consists of a knob atop a spring over the exhalation valve of the circuit system; progressive clockwise turns provides a graded obstruction to gas flow. The valve is disengaged when turned fully counterclockwise. A click-lock position when disengaged might prevent accidental turning of the knob; more importantly, its evaluation should be part of the machine check-out before each case.

Although practice differs among anesthesiologists, significant leaks around the endotracheal tube are often accepted for short cases if gas exchange appears adequate and excessive fresh gas flow (>5 l) is not needed to ensure proper bellows refillling. The maneuver of sealing the patient’s mouth and nose was merely demonstrative and is not to be condoned as an alternative to placing an appropriately larger-size tube. High fresh gas flow, particularly with small tidal volumes, may also result in significant attenuation of the capnogram. As we were unable to reduce the fresh gas flow, we do not know how a lower flow would have affected the capnography in this case.

Capnography is currently felt to be the most reliable means of detecting esophageal intubation, and there have been no documented failures of the technique, i.e., the false-negative rate is zero. The converse is not true, however, and this event represents the equivalent of a false-positive; the lack of end-tidal CO₂ does not necessarily imply

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esophageal intubation. Capnography may also be impaired by obstruction or disconnection of the pathway (breathing circuit, endotracheal tube, or aspirating tubing) between the trachea and the CO₂ sensor. This case presents a previously undescribed variant of the circuit obstruction scenario, with partial expiratory limb obstruction caused by a minimally engaged PEEP valve. Capnography identifies proper endotracheal tube position by detection of exhaled CO₂. However, we are primarily concerned with appropriate delivery of gas during inspiration. Under most circumstances, gas enters and exits via the same route. In this case, we determined that inhalation of delivered gases was indeed occurring appropriately; that exhaled gas did not enter the endotracheal tube did not signify improper placement.

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REFERENCES
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Immediate Respiratory Arrest after Caudal Epidural Sufentanil

To the Editor:—Life-threatening early respiratory depression requiring treatment has been reported after the epidural administration of sufentanil, but only after repeated injections containing 50–75 μg. A case is presented in which respiratory arrest occurred within 3 min after single caudal epidural administration of 50 μg of sufentanil.

A 34-yr-old female, ASA physical status 1, 56 kg, was scheduled for elective surgical repair of a perineal fistula in outpatient surgery under caudal epidural anesthesia. The solution for caudal epidural administration was prepared by adding 1 ml containing 50 μg of sufentanil to 20 ml bupivacaine 0.25% with epinephrine 1:200,000. Caudal epidural block was performed with the patient in the prone position. ECG, pulse rate, blood pressure, and oxygen saturation were monitored by automatic devices throughout the procedure.

Entry of the sacral canal was easily established using a 25-G short-bevelled caudal needle. No blood or cerebrospinal fluid could be aspirated and the solution of bupivacaine, epinephrine, and sufentanil was slowly injected over a 60-s period. After every 5 ml an attempt for aspiration was made, which proved negative at all times. Heart rate remained constant between 70–75 beats per min throughout the procedure. Immediately after injection the patient was turned into the supine horizontal position. At that time she complained of a light-headed feeling and became drowsy. It was noted that she had pinpoint pupils and during the next minute her respiratory rate decreased to a complete respiratory arrest.

During the next minute the patient remained apneic and did not respond to verbal commands to take a deep breath; peripheral cyanosis became apparent, oxygen saturation decreased from 97 to 85% and ventilation via face mask was instituted with a mixture of 35% oxygen and 65% nitrous oxide, leading to an immediate increase in oxygen saturation to 99%. Blood pressure decreased slightly from 120/80 to 110/75 mmHg, heart rate remaining constant at all times. The operation was commenced with the patient in the lithotomy position. Fifteen minutes after completion of the caudal epidural injection, two increments of 0.1 mg of naloxone were given intravenously, spontaneous respiration returning after the second dose. Nitrous oxide was discontinued after which the patient regained full consciousness. She experienced no pain and the operation was completed with the patient awake and breathing room air.

Upon arrival at the recovery, the level of sensory blockade as measured by temperature discrimination was at the twelfth thoracic dermatome. Motor blockade of the lower limbs for both legs was grade 1 on the 0–5 scale as described by Bromage. Two hours after the caudal epidural injection the patient was able to raise the extended leg on both sides. Four hours after the caudal epidural injection sensation in both legs was restored, a tingling feeling in the perineum the only remaining sign of a preceding caudal block.

The patient was observed until 8 h after the caudal epidural administration of the sufentanil/bupivacaine solution. Although she experienced no pain, all signs of the caudal block had worn off and she was discharged from the hospital.

Although the rapid onset of respiratory arrest in combination with the observation of pinpoint pupils after caudal epidural injection of a solution containing 50 μg of sufentanil suggests iv injection, this is not likely for the following reasons. First, before, during, and after caudal epidural injection aspiration was negative for blood. Second, when using a solution containing epinephrine 1:200,000, iv injection of as much as 3 ml should result in an increase in heart rate, and the heart rate in our patient remained constant. Moreover, no central nervous system or cardiac symptoms related to iv injection of bupivacaine were observed. Third, the patient developed a symmetrical block with a sensory level of blockade reaching the twelfth thoracic dermatome and bilateral partial motor blockade of the lower limbs, as would be expected after the caudal epidural administration of 21 ml of a solution containing 50 mg of bupivacaine. The only possible explanation remaining therefore must be an immediate, massive, selective vascular absorption of sufentanil from the site of injection, despite the fact that the solution employed by us did contain epinephrine.

In a study comparing arterial plasma concentrations of meperidine 1 or 2% with or without epinephrine 1:200,000 after intercostal, brachial plexus, sciatic femoral, lumbar epidural, and caudal epidural block,