Tetany During Intravenous Conscious Sedation in Dentistry Resulting From Hyperventilation-Induced Hypocapnia

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Hyperventilation can be a manifestation of anxiety that involves abnormally fast breathing (tachypnea) and an elevated minute ventilation that exceeds metabolic demand. This report describes a case of hyperventilation-induced hypocapnia resulting in tetany in a 16-year-old girl undergoing orthodontic extractions under intravenous conscious sedation. Pulse oximetry is the gold standard respiratory-related index in conscious sedation. Although the parameter has great utility in determining oxygen desaturation, it provides no additional information on respiratory function, including, for example, respiratory rate. In this case, we found capnography to be a very useful aid to monitor respiration in this patient and also to treat the hypocapnia.

Key Words: Tetany; Conscious sedation; Hyperventilation; Hypocapnia.

This report describes a case of hyperventilation-induced hypocapnia resulting in tetany in a 16-year-old girl undergoing orthodontic extractions under intravenous (IV) conscious sedation.

Hyperventilation can be a manifestation of anxiety and involves abnormally fast breathing (tachypnea) and an elevated minute ventilation that exceeds metabolic demand.¹ This can lead to hypocapnia, a state of abnormally low levels of carbon dioxide in the blood that results from excessive amounts of carbon dioxide being exhaled. Hyperventilation with resultant hypocapnia can result in a reduction in calcium ions, which can lead to tetany, an involuntary contraction of the skeletal muscles.

Pulse oximetry is the gold standard respiratory-related index in conscious sedation. Although the parameter has

great utility in determining oxygen desaturation, it provides no specific information on ventilatory function, including, for example, respiratory rate or expired carbon dioxide.

For many people, a visit to the dentist is synonymous with fear and anxiety. Extraction of teeth and dental surgery has been shown to be extremely anxiety provoking.² To combat such anxiety, conscious sedation is now a fundamental part of the pain and anxiety management of patients who require oral surgery procedures in many countries. Despite this, anxiety can progress to panic during sedation, making it more challenging to regain control of the patient's emotions.

CASE REPORT

A 16-year-old female patient was referred to the oral surgery department at the Cork University Dental School and Hospital for orthodontic extractions under IV sedation. The patient's general dental practitioner

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Figure 1. Trousseau sign demonstrating flexure of the fingers and thumb.

attempted the extractions under local anesthetic, but was forced to abandon treatment because of the patient's escalating anxiety and panic. The patient also complained of a sensation of "pins and needles" in her hands at that time.

The patient was seen initially in the Cork University Dental School and Hospital for a sedation assessment and dental consultation. The sedation assessment revealed a low body mass index (BMI) of 15.3. Both patient and mother reported a healthy appetite and moderate level of exercise. Otherwise, the patient's sedation assessment and medical history were unremarkable. She was considered American Society of Anesthesiology grade 2 for sedation in this setting based on her low BMI. She required extraction of 2 maxillary premolar teeth and 1 mandibular deciduous molar. She had not had any previous extractions, but had restorative treatment carried out under local anesthetic.

Because of the patient's heightened anxiety in relation to her anticipated treatment, she was informed by her mother only on the morning of surgery that she was to have the teeth extracted under sedation that afternoon.

The patient was accompanied by her mother to our department. With local ethical approval and informed consent, the patient was enrolled in a clinical trial assessing the impact of Microstream capnography via an oral-nasal cannula during otherwise standard clinical care including pulse oximetry. This investigator-sponsored research was supported by Covidien, manufacturer of the Microstream capnography system. Capnography is not routinely used in sedation in this setting.

Baseline observations recorded were:

- Pulse rate: 72 beats per minute
- Blood pressure: 99/55 mm Hg
- Respiratory rate: 18 breaths per minute
- Oxygen saturation (SpO_2): 100%
- End-tidal carbon dioxide (ETCO_2): 36 mm Hg

The patient's mother subsequently left the surgery before IV cannulation. The cannula was successfully inserted into a vein on the right dorsal hand on the first attempt. Following insertion, the patient appeared to relax marginally.

In accordance with the recognized standard sedation technique for dentistry, midazolam was titrated at a rate of 1 mg per minute to an endpoint where the patient appeared drowsy, but verbal contact was maintained. A total of 4 mg midazolam was administered.

The patient remained in a relaxed state until local anesthetic administration commenced. Following completion of local anesthetic administration, the patient began to hyperventilate, with a rise in blood pressure to 139/94 mm Hg and a gradual reduction in ETCO_2 . Respiratory rate increased to ~ 87 and the respiratory wave form showed rapid, shallow breathing (tachypnea). The patient began to complain of stiffness and an inability to close her hands—the Trousseau sign.

The Trousseau sign is a characteristic spasm of the muscles of the forearm that causes flexion of the wrist and thumb and extension of the fingers (Figure 1). It may occur spontaneously or can be elicited by inflation of a blood pressure cuff placed on the upper arm. In this case, muscular spasm began in the contralateral hand to that with the blood pressure cuff attached, but soon after involved both hands. The Chvostek sign, a unilateral spasm of the facial muscles that can be elicited by tapping the facial nerve at the point at which it crosses the angle of the jaw, was not witnessed during this case.

A diagnosis of hyperventilation-induced tetany was reached, and the patient was reassured it would resolve once normal breathing was reestablished. It was decided reversal of the sedation would not resolve the panic attack. Further sedation was considered unwise because of the risk of a paradoxical effect. The teeth were ultimately extracted despite the patient's state of anxiety. The extractions were swift and uneventful.

The patient continued to hyperventilate for a further 6 minutes, with ETCO_2 values remaining at ~ 11 mm Hg (Figure 2). A polystyrene cup was held over the patient's mouth to facilitate rebreathing of exhaled air to increase carbon dioxide retention. Her respiratory rate gradually reduced as she more readily engaged in conversation. As respiratory rate reduced, ETCO_2 increased and the tetany reduced, which further relaxed the patient. When ETCO_2 levels returned to within the normal range (35–45 mm Hg), the patient was brought to the recovery

Figure 2. Capnography monitor demonstrating respiratory waveform (upper panel) and rate (89 breaths/min), oxygen saturation (SpO_2 ; 98%), end-tidal carbon dioxide (ETCO_2 ; 11), and pulse rate (129 beats/min). This illustrates hyperventilation with resultant low ETCO_2 ; SpO_2 is normal and alone would not serve as an index of respiratory disturbance.

room, where she made an uneventful recovery (Figure 3). She was discharged to her mother's care and traveled home by private car.

DISCUSSION

A BMI of 15.3, according to the Royal College of Paediatrics and Child Health, is below the second percentile, indicating the degree of thinness of the patient.³ It was decided before sedation commenced that a minimum amount of midazolam would be administered, with each increment administered slowly because of possible decreased plasma proteins and likely decreased tissue redistribution space. A state of conscious sedation was reached at 4 mg midazolam, where the patient appeared drowsy, but verbal contact was maintained. Paradoxical reactions can be witnessed in response to the administration of benzodiazepines such as midazolam. Paradoxical reaction may present as increased talkativeness, emotional release, excitement, excessive movement, and even hostility and rage.⁴ Ensuring a sufficient level of sedation without instigating a paradoxical reaction can be a delicate balance. In this case we felt administration of additional sedative could have potentially made the case more difficult. Abandoning sedation has been found to be more distressing for children and young people.⁵

Capnography is the monitoring of the concentration of partial pressure of CO_2 in exhaled air. It is a noninvasive procedure in the nonintubated patient generally involving placement of a nasal cannula with

or without an oral extension that captures exhaled air from the nose and/or mouth (see Figure 4). Although it might seem that the oral extension may interfere with dental treatment, we do not find that it compromises our ability to carry out the planned surgeries. The majority of cases performed have been surgical and nonsurgical extractions, but it has also been used to carry out routine restorative work. Surgeons experienced in operating with the capnography apparatus have carried out periradicular and implant surgery in the maxillary anterior segment. There is, however, a learning curve associated with its use.

Although the National Institute for Health Care Excellence in the United Kingdom recommends capnography only for deep sedation,⁵ capnography used in this case greatly aided the management of this patient. Monitoring of SpO_2 is an essential requirement of conscious sedation. This patient's SpO_2 did not drop below 97%. In this case, owing to hyperventilation, ETCO_2 was a better reflection of the patient's abnormal breathing pattern than SpO_2 . The ETCO_2 readings available throughout the procedure facilitated continual monitoring, and offered assurance that if we could reestablish regular breathing, ETCO_2 would also improve. This in turn would restore the acid-base disturbance related to hypocapnia and hence resolve the muscle spasm.

We initiated a simple rebreathing technique to help restore the patient's CO_2 levels. We found that this traditional method, in combination with SpO_2 monitoring, helped restore normal ETCO_2 (Figure 5). Rebreathing into a paper cup/bag can lead to hypoxia,⁶ a state of deprivation of oxygen to all or part of the body. SpO_2 monitoring during the rebreathing maneuver ensured safe practice. The patient at this time was encouraged to engage in simple conversation, which was also effective in regulating her respiratory rate.

PaCO_2 is normally maintained in the range of 35–45 mm Hg, which is closely regulated by central chemoreceptors in the brain and peripheral chemoreceptors in the carotid bodies. Hyperventilation can disrupt this feedback mechanism and, if persistent, can lead to hypocapnia.

Hypocapnia is a state of reduced carbon dioxide in the blood. Hypocapnia develops as a result of hyperventilation, due to either elevated respiratory rate or tidal volume or both. A low partial pressure of carbon dioxide in the blood causes alkalosis (because CO_2 is acidic in solution), which can disrupt calcium ion balance (relative amounts of free and bound) in the plasma, leading to tetany, a classical symptom of hypocalcemia. Ionized calcium binds to negatively charged sites on protein molecules, competing with hydrogen ions for the same binding sites. This binding is

Figure 3. A trend graph based on mean values for end-tidal carbon dioxide (ETCO₂) and respiratory rate calculated every 5 seconds after the first infusion. The graph shows the progressive fall in ETCO₂ from baseline, following induction of sedation, as a result of hyperventilation. Note the gradual recovery of ETCO₂ as respiratory rate returns towards normal.

pH dependent and alters the level of ionized calcium in the blood. An increase in pH, alkalosis, promotes increased protein binding, which decreases free calcium levels. Decreased extracellular calcium concentration affects the sodium permeability of nerve membranes, which influences the ease with which action potentials are triggered. Hypocalcemia can lead to the generation

of spontaneous action potentials in nerves by lowering the threshold for the production of an action potential. When motor neurons are affected, tetany of the muscles may occur—hypocalcemic tetany. Normocalcemic tetany can also present owing to hyperexcitability of axons of peripheral nerves⁶ due to alkalosis associated with hyperventilation.

Figure 4. Nasal cannula and oral extension to capture expired CO₂.

Hypocalcemic tetany can be due to low baseline serum calcium. Calcium levels in the blood are tightly regulated by the parathyroid hormone (PTH) and influenced by vitamin D and serum phosphorus.

Causes of hypocalcemia include:

- Chronic kidney disease
- Vitamin D deficiency
- Hypoparathyroidism after neck surgery; also may be autoimmune, genetic, infiltrative, postradiation, or idiopathic
- Deregulation of PTH
- Acute pancreatitis
- Severe hypomagnesemia due to suppression of PTH release
- Sepsis or severe illness

Respiratory disease, left ventricular failure, pulmonary emboli, pyrexia, and aspirin overdose have also been implicated in hyperventilation and hypocapnia.⁷

Our patient returned for review 1 week following surgery. At this visit we recommended blood tests to investigate serum calcium and PTH levels. All blood results were unremarkable. Importantly, the patient reported she remembered very little of the procedure. She recalled being upset but could not coherently

Figure 5. Method used to have patient rebreathe expired air in an effort to increase arterial CO₂.

recollect the events of the procedure. The results confirmed the initial diagnosis of hyperventilation-related hypocapnic tetany.

CONCLUSION

Dental fear is one of the most frequent common fears.⁸ Although many people associate a visit to the dentist with the onset of anxiety, a small minority suffer from dental phobia, which may present with symptoms such as hyperventilation. However, hyperventilation is not a regular occurrence under sedation. It is more common in, but not limited to, treatment under local anesthetic, or the anticipation of impending treatment.

This study illustrates the utility of capnography in a dental setting. We found capnography to be a very useful aid to monitor respiration in this patient and also to treat the hypocapnia. It is well known that some young patients can experience a paradoxical reaction with midazolam sedation. Hyperventilation is sometimes a feature of such reactions. Interestingly, this patient complained of difficulty breathing when her ETCO₂

was low, which was likely dyspnea related to anxiety and severe alkalosis.

Consequences of hyperventilation can include paresthesia of the extremities, muscle rigidity, dizziness and fainting. Cardiovascular disturbances include palpitations and chest oppression and pain can also be experienced. Although administration of benzodiazepines such as midazolam offers anterograde amnesia, stress reduction and reassurance are important for the prevention of hyperventilation. Cognitive behavioral therapy has been shown to have a longer-lasting positive effect on patient attitude to the dentist than the administration of benzodiazepines,⁹ and should be considered for such patients.

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