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clinical trial of heparin *versus* saline for intraoperative flushing of intravascular catheters, currently in progress, to determine the frequency and clinical impact of heparin sensitization resulting from this practice.

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Effects of Sevoflurane on QT Interval in a Patient with Congenital Long QT Syndrome

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THE inhaled anesthetics enflurane, halothane, and isoflurane prolong the electrocardiographic QT interval in healthy patients.¹ In patients with idiopathic long QT syndrome, however, cardiac arrest and death during halothane anesthesia,² absence of QT interval change

during enflurane administration,³ and shortening of QT interval during isoflurane anesthesia⁴ suggest that generalizations from healthy patients to patients with long QT syndromes are unjustified. Similarly, thiopental prolongs QT interval in healthy patients⁵ but had no effect in patients with long QT syndrome.⁶ We recently anesthetized a young woman with idiopathic long QT syndrome. We report the effects of sevoflurane on the QT interval in this patient.

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Case Report

A 17-yr-old, otherwise healthy, 49-kg girl presented for extraction of impacted wisdom teeth. She was receiving no medication. Preoperative examination revealed an irregular pulse and electrocardiography (ECG) was ordered. Although the initial ECG was entirely normal, with a QT interval of 362 ms (QT interval corrected for heart rate, QTc of 396 ms), recording was continued. Multifocal premature ventricular extrasystoles, and a 14-beat run of polymorphic ventricular tachycardia

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at a rate of 135 beats/min appeared shortly thereafter, associated with a prolonged QTc of 526 ms. The patient was completely unaware of the arrhythmia. Surgery was postponed and the patient was referred for electrophysiologic evaluation.

There was no family history of deafness, but careful review of family records revealed that the patient's maternal great-grandmother died suddenly at age 50 without other known medical problems. The ECG of the patient's mother showed an elevated QTc of 564 ms (QT interval, 440 ms; heart rate, 99 beats/min), but she refused further evaluation. Although our patient did not present with typical syncope precipitated by emotional or physical stress,⁷ the diagnosis of presumptive congenital long QT syndrome was made based on published probability criteria.⁸ These included a QTc of 460–470 ms on a subsequent resting ECG (2 points), T-wave alternans that was seen on Holter recording (1 point), low heart rate for age (42 beats/min; 0.5 points), and torsades-like polymorphic ventricular tachycardia (2 points). Based on scoring criteria, ≥ 4 points shows a high probability of long QT syndrome.⁸ Although QT-interval prolongation on the resting ECG is the hallmark of the long QT syndrome, as in our patient, it need not be always present, and patients can have symptomatic long QT syndrome manifested by torsades and sudden death with normal QT intervals.⁹

The transthoracic echocardiogram was entirely normal. Initial Holter study showed 337 runs of asymptomatic polymorphic ventricular tachycardia consisting of as many as 11 beats. The lack of prognostic factors to predict in which patients fatal arrhythmias will develop led to the decision to treat our patient despite the detection of only nonsustained ventricular tachycardia on Holter recordings.⁷ During 3 months of study, it was determined that intravenous lidocaine abolished extrasystoles and that nadolol was marginally beneficial. Nadolol, 80 mg orally, twice daily, reduced heart rate to 50 beats/min, while decreasing the number of runs of ventricular tachycardia to 151 per day, with a longest run of 18 beats. However, persistence of arrhythmias led to a trial of 300 mg oral labetalol twice daily. Possessing α - and β -adrenergic blocking properties, labetalol may suppress arrhythmias in long QT syndrome patients when β -blockers are not effective.¹⁰ Labetalol reduced the incidence of polymorphic ventricular tachycardia to 37 episodes/day, with a longest run of 5 beats. Surgery was rescheduled.

At arrival in our same-day surgery waiting area, the ECG showed a rate of 72 beats/min, a QT interval of 362 ms, and a QTc of 396 ms. The patient received incremental intravenous doses of midazolam totaling 4 mg. The ECG recorded at this time is displayed in figure 1. The first points in figure 2 show the heart rate and QT interval corrected for heart rate by Bazett's formula ($QT_c = QT/\sqrt{RR}$).¹¹ Lidocaine infusion of 1 mg/min followed a bolus of 1 mg/kg based on the efficacy of the drug during testing. Subsequent points in figure 2 represent heart rate and QTc after administration of lidocaine, after induction of anesthesia with 100 mg propofol intravenously and 100 μ g fentanyl intravenously, after relaxation with 30 mg rocuronium intravenously, after uneventful tracheal intubation, and after addition of 66% nitrous oxide. The ECG after addition of nitrous oxide is shown in panel B of figure 1 and reveals a single extrasystole. After intubation and during nitrous oxide administration, such single monoform extrasystoles occurred at a rate of 3/min. Blood pressure rose from 118/56 mmHg before induction to 135/75 mmHg. Sevoflurane was then added to end-tidal concentrations between 1.2 and 1.8%. Figure 1, panel C, shows an example of the ECG during sevoflurane inhalation. In this example, QTc was 467 ms. Figure 2 shows that QTc is prolonged during the period of

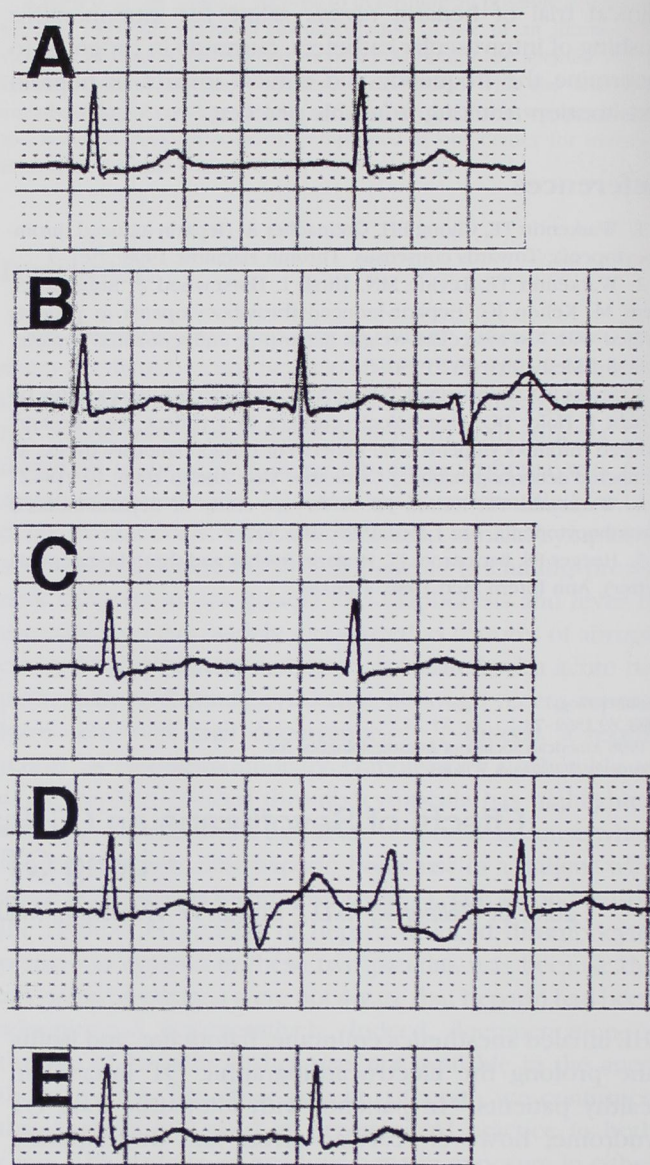


Fig. 1. Electrocardiograms (ECG) during sevoflurane anesthesia in a patient with idiopathic long QT syndrome. All recordings show lead V₅ electrocardiographic recordings at a paper speed of 25 mm/s and an amplitude of 1 mV/division. Before sedation, heart rate was 72 beats/min and QT interval was 362 ms (QTc was 396 ms). (A) The initial ECG after midazolam sedation, revealing a QT interval of 0.39 s (QTc = 0.405 s). (B) This ECG during inhalation of nitrous oxide and after tracheal intubation but before administration of sevoflurane was chosen to display occasional monoform extrasystoles. (QT = 0.38 s; QTc = 0.434 s). (C) During inhalation of sevoflurane, a QT-interval prolongation to 0.43 s and a QTc of 0.467 s. (D) One minute after extubation of the trachea, frequent multiform ventricular extrasystoles appear, despite shortening of the QTc to 0.423 s. Corrected QT for this time period was measured while extrasystoles were not present. (E) Represents therapy with intravenous labetalol. The arrhythmia is abolished, the QT interval is 0.37 s, and QTc is 0.432 s.

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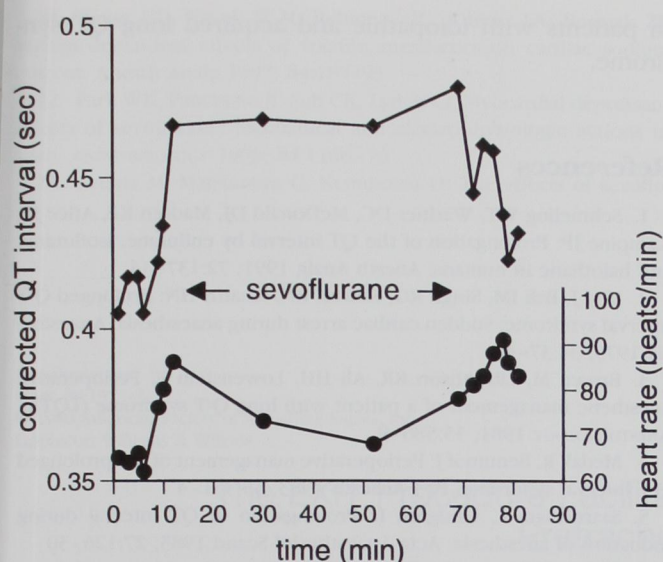


Fig. 2. Corrected QT interval and heart rate during sevoflurane anesthesia in a patient with idiopathic long QT syndrome. The left axis and diamonds represent QTc interval. The right axis and circles show heart rate at various times during the reported case. Administration of sevoflurane, 1.2% to 1.8%, is shown by the arrows and parallels an increase in QTc. The data points before sevoflurane inhalation represent, sequentially, administration of midazolam, institution of the lidocaine infusion, induction with propofol and fentanyl, relaxation with rocuronium, intubation, and inhalation of nitrous oxide.

sevoflurane administration. Despite this, no extrasystoles appeared during sevoflurane administration. Blood pressure was stable at 100/50 mmHg throughout. Discontinuation of sevoflurane was followed by a return to shorter QTc intervals. A total of 6 ml bupivacaine, 0.25%, without epinephrine was injected into the extraction sites to provide analgesia. Emergence, including the effects of reversal of neuromuscular blockade with 2 mg intravenous neostigmine 0.3 mg intravenous glycopyrrolate, awakening, and extubation was associated with tachycardia and a rise in blood pressure to 130/75 mmHg, but no increase in QTc. As the patient awakened, single monoform extrasystoles appeared at the rate of 12/min. After extubation, multiform ventricular extrasystoles, as shown in panel D of figure 2 appeared at a rate of 39/min. Labetalol, 5 mg intravenously, was administered and the arrhythmia resolved. The labetalol effect probably reflects its antiadrenergic activity rather than a specific effect on QT prolongation. The heart rate and QTc after labetalol are shown by the last points in figure 2. In the postanesthetic care unit, the lidocaine infusion was continued, but, 1 h later, multiform ventricular extrasystoles identical to those shown in panel D of figure 1 recurred. These responded to 5 mg intravenous labetalol and did not recur. Lidocaine was discontinued. After several hours of monitoring without further arrhythmias, the patient was discharged home where she continues to do well.

Discussion

The long QT syndrome is a cardiovascular disorder that causes syncope, seizures, and sudden death from

cardiac arrhythmias, typically polymorphic ventricular tachycardia (torsades de pointes), and ventricular fibrillation.¹² Although medications such as quinidine or terfenadine may produce an acquired form of the disease, the inherited long QT syndrome encompasses two variants. The autosomal recessive form (Jervell-Lange-Nielsen) is associated with congenital deafness, and the autosomal dominant form (Romano-Ward) is more common.¹² More than 35 mutations have been identified in four cardiac ion-channel genes that encode channels responsible for three fundamental ion currents in cardiac cells.¹³ Mutations causing loss of function of the rapidly activating (*LQT2*) and slowly activating (*LQT1*) delayed rectifier potassium channels delay repolarization, increasing QT interval. In *LQT3*, partial disruption of inactivation of the inward sodium current (I_{Na}) prolongs repolarization.¹² Recent recognition of a mutation of the potassium channel subunit, *IsK*, identifies a new genotype (*LQT5*).¹⁴ The mechanisms responsible for torsades de pointes and polymorphic VT in patients with QT-interval prolongation are poorly understood. Reentry or triggered activity caused by early after depolarizations, or both mechanisms, may be responsible.¹⁵

Anesthetic management of patients with long QT syndrome has changed little during the last decade.¹⁶ Continuation of preoperative antiarrhythmic medications and adequate premedication to provide a calm, placid patient are desired. Intraoperative arrhythmias follow catecholamine release and sympathetic nervous system stimulation, reflected in our patient by the appearance of arrhythmias after intubation and emergence. To preclude such sympathetic outflow increases, avoidance of ketamine, halothane, and pancuronium has been suggested.¹⁶

Several aspects of our treatment of the patient reflect published observations. Induction of polymorphic ventricular tachycardia by hemostatic infiltration of a local anesthetic solution containing epinephrine¹⁷ led us to avoid such an intervention. Observation that propofol did not prolong QT interval in a patient with Jervell-Lange-Nielsen syndrome¹⁸ and a desire for rapid awakening and discharge to home led us to induce anesthesia with propofol. Sevoflurane was similarly chosen to speed emergence and because it had been reported to decrease action-potential duration.¹⁹

The electrophysiologic effects of sevoflurane have not been described completely. Compared to isoflurane or desflurane, sevoflurane has minimal effects on heart rate or sympathetic nerve activity, both of which increase during isoflurane or desflurane inhalation.²⁰ Sevoflurane

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depresses the inward sodium and calcium currents and markedly suppresses the delayed outward rectifier K^+ current.^{21,22} During the experimental conditions of the study that showed K^+ current inhibition, the slowly activating component (I_{Ks}) was predominantly expressed.²² The inwardly rectifying K^+ current was, in contrast, only slightly reduced by sevoflurane.²² Prolongation and reduction of action-potential duration both have been observed by different investigators.^{19,22,23} In any event, the QT-interval prolongation noted in our patient throughout sevoflurane inhalation does not necessarily imply an increased risk of polymorphic VT. Amiodarone, for example, prolongs the QT interval but rarely produces torsades de pointes.^{24,25}

Despite the relatively uneventful course of our patient and the favorable response of potentially dangerous arrhythmias to intravenous labetalol boluses, we were prepared to provide a variety of other therapeutic interventions. A transcutaneous pacemaker/defibrillator was present in the room, and conductive pads were placed on the patient. Had bradycardia, which increases the risk of malignant arrhythmias in patients with long QT syndrome, occurred, pacing was instantly available.¹⁵ Intravenous magnesium was readily accessible, and intravenous amiodarone was contemplated as pharmacologic therapy if malignant arrhythmias became incessant.¹⁵ However, the role of magnesium and amiodarone therapy in idiopathic long QT syndrome is not as well defined as it is in cases of drug-induced acquired long QT syndrome.

In our patient, the diagnosis of long QT syndrome was established based on published probability criteria.⁸ In the absence of syncope or classic torsades de pointes, however, our diagnosis must be considered presumptive. Certainly, if the diagnosis of long QT syndrome was incorrect, the clinical implications of QT-interval prolongation by sevoflurane would be altered. Only when other patients with long QT syndromes are anesthetized with sevoflurane will confirmation of our findings be possible.

In summary, sevoflurane administered at concentrations ranging from 1.2 to 1.8% prolonged QT interval in a patient with long QT syndrome. Despite this prolongation, ventricular arrhythmias never occurred during inhalation of sevoflurane and only appeared during periods of intense stimulation and enhanced sympathetic tone. The prolongation of QTc by sevoflurane, however, is disturbing and suggests that, until further data are available, the drug should be administered with caution

in patients with idiopathic and acquired long QT syndrome.

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The EXIT Procedure Facilitates Delivery of an Infant with a Pretracheal Teratoma

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THE *ex utero* intrapartum technique (EXIT) procedure allows for the continuance of fetoplacental circulation during cesarean section. Initially, only the infant's head and shoulders (but not the placenta) are delivered, thus maintaining uteroplacental blood flow. After the infant's airway is secured, the umbilical cord is clamped and delivery of the infant is completed. It has proven useful in cases of anticipated difficult airway instrumentation of the neonate (e.g., large fetal neck masses causing airway obstruction).¹ The authors report a case of an antenatally diagnosed, large pretracheal teratoma, wherein the EXIT procedure was used to secure the infant's airway during cesarean section performed during general anesthesia.

Case Report

During a routine ultrasonographic examination, a 29-yr-old woman, gravida 3, para 2, weighing 84 kg, with no significant medical history was noted at 24 weeks' gestation to have a fetus with a cystic structure on the anterior neck. The mass was consistent with teratoma. No other fetal anomalies were noted. Increasing hydramnios was noted between 26 and 32 weeks' gestation. Consequently, preterm contractions developed, which were treated successfully with terbutaline subcutaneously. Ultrasonography at 31 weeks' gestation showed that the mass increased in size to 8.6 × 7.8 cm. In anticipation of difficulty with securing the infant's airway, the decision was made to perform the EXIT procedure when delivery became imminent.

The patient was admitted at 32^{6/7} weeks' gestation with increased preterm contractions. Expectant management with terbutaline subcutaneously and nonstress testing, in addition to two doses of betamethasone intramuscularly, was continued until 33^{3/7} weeks' gestation at which time cervical dilation was 5 cm. The decision was made to proceed with delivery.

Preoperatively, 20 mg famotidine and 10 mg metaclopramide were administered intravenously and 30 ml sodium citrate was administered orally. At arrival in the operating room, the mother was positioned supine with left-sided uterine displacement. Standard noninvasive monitors were applied.

After preoxygenation and abdominal preparation, rapid-sequence induction of anesthesia was performed with 300 mg thiopental and 120 mg succinylcholine intravenously. A 6.5-mm endotracheal tube was placed without difficulty *via* direct laryngoscopy. Isoflurane in 100% oxygen was administered (~2.8% end-expired concentration). A second 18-g intravenous catheter was placed in the right upper extremity after induction of anesthesia. An intravenous infusion of angiotensin II (2.5 µg/ml in saline) was started immediately after induction

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Key words: Airway obstruction; intrapartum airway management.