# Clinical Reports

# Succinylcholine-induced cardiac arrest in children with undiagnosed myopathy

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*Two paediatric cases are reported in which unexpected, life-threatening arrhythmias occurred. Routine induction of general anaesthesia with thiopentone, 5 mg · kg$^{-1}$, in one and with halothane in the other, and succinylcholine 1.25–1.5 mg · kg$^{-1}$ iv was followed by the development of wide complex tachyarrhythmia with hypotension in the first case and asystole in the second case despite pre-treatment with atropine in both cases. The first patient was resuscitated with tracheal intubation, 100% oxygen, manual ventilation and intravenous lidocaine and bicarbonate. The second patient required intubation, manual ventilation, 12 min of CPR and iv calcium, epinephrine and bicarbonate, as well as DC counter shock. Neither patient received dantrolene. Early recovery in both patients was uneventful with no neurological sequelae. Subsequent investigations revealed the presence of a dystrophin-deficient muscular dystrophy, Duchenne muscular dystrophy and Becker muscular dystrophy respectively, previously unsuspected, in both patients. The aetiology of the observed arrhythmias was presumably hyperkalaemia, secondary to succinylcholine-induced rhabdomyolysis. It is suggested that when faced with sudden, life-threatening arrhythmias following succinylcholine at induction of anaesthesia for paediatric patients, clinicians should include occult myopathy in the differential diagnosis, and thus consider the aggressive management of hyperkalaemia in addition to basic resuscitative efforts.*

*Cette observation décrit des arythmies potentiellement mortelles survenues chez deux enfants. L'induction de l'anesthésie générale est réalisée avec du thiopentone 5 mg · kg$^{-1}$ chez le premier et de l'halothane chez le second avec succinylcholine 1,25 et 1,50 mg · kg$^{-1}$ respectivement. Par la suite, apparaissent des tachyarythmies complexes avec hypotension dans le premier cas et de l'asystolie dans le deuxième malgré un traitement préalable à l'atropine dans les deux cas. Le premier patient est réanimé par intubation trachéale, oxygène à 100%, ventilation manuelle, administration de lidocaïne et de bicarbonate iv. Le second est intubé, ventilé manuellement, reçoit la réanimation cardiopulmonaire pendant 12 minutes et par la voie veineuse, du calcium, de l'épinéphrine et du bicarbonate en plus d'une défibrillation électrique. On n'administre pas de dantrolène aux patients. La récupération immédiate se produit sans incidents ni séquelles. L'investigation subséquente révèle dans les deux cas une dystrophie musculaire insoupçonnée de Duchenne chez le premier patient, et de Becker chez le second. On présume que les arrythmies observées sont causées par l'hyperkaliémie secondaire à la rhabdomyolyse induite par la succinylcholine. Après l'induction avec de la succinylcholine, si des arythmies menaçantes pour le vie des patients pédiatriques surviennent, le clinicien doit inclure dans le diagnostic différentiel une myopathie cachée et entreprendre, en plus des manoeuves de réanimation, un traitement agressif de l'hyperkaliémie.*

**Key words**
COMPLICATIONS: arrest, cardiac;
IONS: potassium;
NEUROMUSCULAR RELAXANTS: succinylcholine.

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Rosenberg and Gronert[1] have recently described four cases of sudden cardiac arrest following the induction of anaesthesia with succinylcholine. They postulated that these arrhythmias were caused by succinylcholine-induced rhabdomyolysis and hyperkalaemia in the presence of an undiagnosed myopathy. We wish to report two cases which we believe represent the same phenomenon.

**Case #1**

A three-year-old white boy, with a history of delayed developmental milestones, small stature and speech dis-

order, was admitted to the Surgical Day Care Unit for division of tongue-tie. Past medical history was otherwise unremarkable: there was no previous anaesthetic exposure, or family history of anaesthetic complications. Physical examination revealed no gross abnormalities apart from his small stature; his weight was 12.8 kg. His complete blood count and urinalysis were normal.

The patient received no preoperative medication. On admission to the operating room, routine monitors were applied; heart rate was 100 beats · $min^{-1}$, BP 90 mmHg systolic, axillary temperature was 36.9°C, oxygen saturation was 97% and the ECG revealed normal sinus rhythm. Anaesthesia was induced with atropine 0.02 mg · $kg^{-1}$, thiopentone 5 mg · $kg^{-1}$, and muscle relaxation was produced with succinylcholine 1.5 mg · $kg^{-1}$ *iv*. The lungs were ventilated manually with oxygen ($FIO_2$ 1.0); transient generalized muscle rigidity was observed, followed immediately by complete relaxation. There was no clinical evidence of masseter spasm. The trachea was intubated easily with a 4.5 mm uncuffed orotracheal tube. Auscultation of the chest revealed good air entry bilaterally and satisfactory placement of the endotracheal tube was confirmed by capnography.

Immediately after intubation the patient developed a bizarre, wide-complex tachyarrhythmia, at times resembling ventricular tachycardia. He became ashen and hypotensive (systolic BP 40 mmHg). Apical heart sounds remained audible and pulses palpable. Axillary temperature was 37°C. No further anaesthetic agents were administered and manual ventilation with oxygen ($FIO_2$) was continued. He received boluses of xylocaine (20 and 10 mg), and sodium bicarbonate 5mEq *iv*, and a 150 ml bolus of crystalloid fluid.

Within a few minutes the patient converted to sinus tachycardia with normal blood pressure. His temperature remained normal and unchanged. Throughout the episode the patient's oxygen saturation remained at 98–100%; $PETCO_2$ decreased from 44 to 36 mmHg. Five minutes after restoration of blood pressure and sinus rhythm, arterial blood gases and chemistry were obtained: pH 7.34, $PaCO_2$ 45 mmHg, $PaO_2$ 632 mmHg; serum electrolytes Na 136 mmol · $L^{-1}$, K 4.9 mmol · $L^{-1}$, Cl 100 mmol · $L^{-1}$ and $HCO_3^-$ 24 mmol · $L^{-1}$; random blood sugar was 4 mmol · $L^{-1}$ and blood urea 1.8 mmol · $L^{-1}$. The entire episode lasted approximately ten minutes.

The surgery was aborted. The patient emerged from anaesthesia uneventfully, the trachea was extubated, and he was transferred to the Recovery Room for further observation, including pulse oximetry and ECG monitoring. His vital signs remained stable; heart rate 140 beats · $min^{-1}$, BP 90 mmHg systolic, temperature 36.5°C, and ECG revealed sinus tachycardia. The patient remained drowsy, but could be roused easily. Subsequently, he was admitted to the Paediatric Acute Care Unit for further monitoring. His vital signs remained stable and unchanged. The first two urine samples in the post-anaesthetic period were "tea coloured" and were confirmed to contain myoglobin. His course in hospital was unremarkable. Follow-up haematology and blood chemistry, including serum creatinine and urea were normal; chest *x*-ray and ECG were normal; CPK was not measured. The myoglobinuria resolved spontaneously, and the patient was discharged home the following day in good condition.

Subsequently, the patient underwent neurological investigation at a paediatric tertiary care centre. Physical examination revealed mild delay in language and motor milestones. His neurological examination was characterized by a positive Gower sign, a tendency to slip through the examiner's hands indicating shoulder girdle weakness, and enlarged calf muscles. Studies during hospitalization showed an elevated creatinine phosphokinase, and the electromyogram showed polyphasic units indicative of a myopathy.

The patient had a muscle biopsy performed under local anaesthesia. The histological findings, in addition to a diminution of dystrophin staining, were felt to be diagnostic of Duchenne's muscular dystrophy (DMD). A contracture test was not performed.

**Case #2**

A three-month-old, 8.3 kg boy presented to the Surgical Day Care Unit for cystoscopy and hydrocoele repair. Perinatal history had been unremarkable, development to the present time had seemed normal, and currently he was in good health. He had no previous anaesthetic exposure, and there was no family history of anaesthetic complications. The patient was not receiving medications and had no known allergies. Physical examination was normal. Preoperative investigations included: haemoglobin 190 g · $L^{-1}$, and normal urinalysis.

Following the application of routine monitors, anaesthesia was induced by inhalation of halothane in 50% nitrous oxide and oxygen. Upon loss of consciousness intravenous access was established and a mixture of atropine 0.15 mg with succinylcholine 10 mg was administered. The lungs were manually ventilated with oxygen ($FIO_2$ 1.0). During laryngoscopy, and prior to intubation, sinus bradycardia developed, and oximetry indicated progressive desaturation ($SpO_2$ 100% to 74%) and a slowing of the heart rate. The laryngoscope was removed and manual ventilation with oxygen was continued. The patient's rhythm deteriorated from a sinus bradycardia of 50 beats · $min^{-1}$ to asystole. Atropine 0.4 mg *iv* was given, the trachea was intubated, manual ventilation with oxygen continued, and CPR commenced.

Over the course of the resuscitation the patient received epinephrine 300 μg, bicarbonate 10 mEq, and calcium chloride 1 g, all in divided doses. Approximately 12 min after induction there was a return of circulation with sinus tachycardia. Several episodes of ventricular tachycardia and fibrillation were successfully treated with defibrillation and boluses of xylocaine. The post-resuscitation rectal temperature was 35.7°.

At the initial return of circulation, laboratory values were as follows: arterial blood gases, pH 7.16, $PaCO_2$ 36 mmHg, $PaO_2$ 401 mmHg, $HCO_3^-$ 12 mmol · $L^{-1}$; Na 132 mmol · $L^{-1}$, K 7.7 mmol · $L^{-1}$, Cl 100 mmol · $L^{-1}$, HC3 13 mmol · $L^{-1}$; CPK 12,713 UI (normal 0–200). An additional 5 mEq of sodium bicarbonate was given. Repeat data following stabilization, breathing spontaneously ($FiO_2$ 1.0) approximately 40 min after induction, revealed: pH 7.35, $PaCO_2$ 32 mmHg, $PaO_2$ 306 mmHg, $HCO_3^-$ 16 mmol · $L^{-1}$; Na 136 mmol · $L^{-1}$, K 6.0 mmol · $L^{-1}$, Cl 101 mmol · $L^{-1}$, $HCO_3^-$ 16 mmol · $L^{-1}$; and CPK > 20,000 U · $L^{-1}$.

The trachea was extubated one hour after induction and he was transferred to a paediatric tertiary care centre for further management and investigation. Early recovery was uneventful. No hyperthermia is noted in the ICU records and no myoglobinuria was detected despite a CPK measurement of 90,000 at 24 hours post event. Cardiology consultation, electrocardiogram and 2-D echocardiogram did not suggest a primary cardiac cause.

Follow-up by the neurology service eight weeks after the event revealed an elevated resting CPK (4512 U · $L^{-1}$). Muscle biopsy was performed under general anaesthesia with propofol, $N_2O/O_2$, and fentanyl. Pathology showed a dystrophin deficient muscular dystrophy – Becker's type; curiously, no samples were sent for contracture testing.

**Discusson**

These two cases illustrate life-threatening arrhythmias and cardiac arrest associated with succinylcholine during induction of anaesthesia in paediatric patients with undiagnosed myopathic disorders.

Duchenne muscular dystrophy is the commonest form of muscular dystrophy, with an incidence of 1 in 3,300 male births. Diagnosis is often not made until the age of two to six years.[2] Becker muscular dystrophy is also an X-linked dystrophin-deficient muscular dystrophy. It is less common (1 in 33,000), has a more benign clinical course, and a later onset with a mean age of diagnosis of 12 yr.[2] Therefore, it can be anticipated that, of the paediatric population presenting for surgery, a small number will have an occult myopathy.

Two early reviews, now more than 20 yr old, of anaesthetic experience in patients with known DMD did not report complications attributable to the use of succinylcholine.[3,4] Since that time a case report literature has emerged, linking succinylcholine with rhabdomyolysis, myoglobinuria, arrhythmia and cardiac arrest.[1,5-11] The majority of these cases has involved patients with previously unrecognized DMD. There is one case report of cardiac arrest on induction of anaesthesia in a patient with Becker muscular dystrophy: this is a second-hand report and succinylcholine is not mentioned.[12] Rosenberg and Gronert[1] suggested that the mechanism for cardiac arrest in their patients was acute hyperkalaemia, with either wide-complex tachyarrhythmia or bradycardia/asystole. They further postulated an annual incidence of six cases per annum in the United States with a predicted 60% mortality rate.

The differential diagnosis of severe cardiac arrhythmias or cardiac arrest in children in the peri-induction period broadly includes failure to ventilate the lungs, adverse medication effects including anaphylaxis and malignant hyperthermia, and unrecognized congenital disease. Both of these children were adequately oxygenated and their lungs were easy to ventilate prior to the onset of the arrhythmia. A medication error is always possible; however, a careful review in both cases did not detect one, nor would this account for the myoglobinuria in the first case and the elevated CPK in the second case. DC cardioversion does cause an increase in CPK but normal values for the elevation of CPK after cardioversion in adults are less than one order of magnitude.[13,14] Malignant hyperthermia must be part of the differential; however, the instantaneous onset of the arrhythmia and the lack of any evidence of a hypermetabolic state as well as a rapid recovery in the absence of dantrolene therapy all argue against MH as an aetiology.

The pathophysiology of hyperkalaemia is well described,[15] and it is likely that bradycardia/asystole represents higher serum potassium concentrations than wide-complex rhythm disturbances. Our first patient developed a haemodynamically unstable, wide-complex tachyarrhythmia, which responded to bicarbonate, lidocaine and basic resuscitative measures. We were unable to demonstrate hyperkalaemia; however, the child clearly had rhabdomyolysis with subsequent myoglobinuria. Our second patient suffered cardiac arrest with circulatory collapse secondary to bradycardia/asystole, and required calcium, epinephrine and sodium bicarbonate, in addition to basic resuscitative therapy, to lower serum potassium concentrations and achieve a successful outcome. Why the second patient developed a more profound increase in serum potassium, with more severe clinical consequences, is open to speculation. Differences in the underlying myopathies or the induction sequence of halothane inhalation, followed by intravenous succinylcholine,

sensitizing the abnormal musculature of this patient, with greater potassium release, are possible explanations.

Treatment of hyperkalaemia is directed at re-establishing an electrical gradient at the level of the cardiac myocyte by the use of calcium, and reversing the outward movement of potassium from the cell, with the administration of beta agonists, bicarbonate/hyperventilation and insulin/glucose. In retrospect, we could have been more aggressive with bicarbonate therapy, particularly in the second case. Recently, bicarbonate has fallen out of favour in cardiac arrest protocols because of its lack of proven efficacy and its deleterious effects (myocardial depression, hyperosmolality, decreased vascular resistance). The previously recommended dose of 0.5–1 $mg \cdot kg^{-1}$ was designed to restore acid base balance toward normal. In the setting of succinylcholine-induced hyperkalaemia one uses bicarbonate to treat a suspected metabolic acidosis (a mixed organic and inorganic metabolic acidosis is reported to accompany potassium release in these cases[1]). Acknowledging a lack of scientific support we suggest consideration of doubling the recommended dose of bicarbonate (to 1–2 $mg \cdot kg^{-1}$) if hyperkalaemia is suspected as the cause of cardiac arrest. We want to emphasize that this is less important than the early use of calcium. The use of glucose solutions in the setting of cardiac arrest has been shown to worsen neurological outcome.[16,17] We were reluctant to use glucose or insulin in our arrest situation because of the potential for hypo- or hyperglycaemia. This concern is echoed by Berry in a recent letter[18] regarding the subject of succinylcholine and Duchenne muscular dystrophy.

The relationship of myopathies to malignant hyperthermia is unclear, but recent opinion suggests that, except for central core disease, there is no proved relationship between MH and muscular dystrophy.[19] We disagree with Rosenberg and Gronert that dantrolene should be given to these patients, "because it is not acutely toxic and the clinical differentiations from malignant hyperthermia susceptibility have not been clarified."[1] The clinical presentation is distinct from MH and there appears to be no reason to believe that these events were secondary to MH. A reasonable hypothesis exists which explains all of the events in our two cases, and it is therefore unnecessary to invoke another mechanism. If dantrolene is to be given in this clinical scenario, it should not distract the clinician from appropriate basic resuscitation and therapy for hyperkalaemia.

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**References**

1 *Rosenberg H, Gronert G.* Intractable cardiac arrest in children given succinylcholine (Letter). Anesthesiology 1992; 77: 1054

2 *Miller JD, Lee C.* Muscle diseases. *In:* Katz J, Benumof JL, Kadis LB (Eds.). Anesthesia and Uncommon Diseases, 3rd ed., Philadelphia: WB Saunders 1990; 590–6.

3 *Cobham IG, Davis HS.* Anesthesia for muscular dystrophy patients. Anesth Analg 1964; 43: 22–9.

4 *Richards WC.* Anaesthesia and serum creatine phosphokinase levels in patients with Duchenne's pseudohypertrophic muscular dystrophy. Anaesth Intensive Care 1972; 1: 150–3.

5 *Genever EE.* Suxamethonium-induced cardiac arrest in unsuspected pseudohypertrophic muscular dystrophy. Br J Anaesth 1971; 43: 984–6.

6 *Watters G, Karpati G, Kaplan B.* Post-anaesthetic augmentation of muscle damage as a presenting sign in three patients with Duchenne's muscular dystrophy. Can J Neurol Sci 1977; 4: 228.

7 *Seay AR, Ziter FA, Thompson JA.* Cardiac arrest during induction of anesthesia in Duchenne's muscular dystrophy. J Pediatr 1978; 93: 88–90.

8 *Smith CL, Bush GH.* Anaesthesia and progressive muscular dystrophy. Br J Anaesth 1985; 57: 1113–8.

9 *Kepes ER, Martinez LR, Andrews IC, et al.* Anesthetic problems in hereditary muscular abnormalities. N Y State J Med 1972; 72: 1051–3.

10 *Miller Ed Jr., Saunders DB, Rowlingson JC, Berry FA Jr., Sussman MD, Epstein RM.* Anesthesia-induced rhabdomyolysis in a patient with Duchenne's muscular dystrophy. Anesthesiology 1978; 48: 146–8.

11 *Linter SPK, Thomas PR, Withington PS, Hall MG.* Suxamethonium associated hypertoxicity and cardiac arrest in unsuspected pseudohypertrophic muscular dystrophy. Br J Anaesth 1982; 54: 1331–2.

12 *Marks WA, Bodensteiner JB, Reitz RD.* Cardiac arrest during anesthetic induction in a child with Becker type muscular dystrophy (Letter). J Child Neurol 1987; 2: 160–1.

13 *Reiffel JA, Gambino SR, McCarthy DM, Leahey EB Jr..* Direct current cardioversion. Effect on creatine kinase, lactic dehydrogenase and myocardial isoenzymes. JAMA 1978; 239: 122–4.

14 *Ehsani A, Ewy GA, Sobel BE.* Effects of electrical countershock on serum creatine phosphokinase (CPK) isoenzyme activity. Am J Cardiol 1976; 37: 12–8.

15 *Tetzlaff JE, O'Hara JF Jr., Walsh MT.* Potassium and anaesthesia. Can J Anaesth 1993; 40: 227–46.

16 *Lundy EF, Kuhn JE, Kwon JM, Zelenock GB, D'Alecy LG.* Infusion of five percent dextrose increases mortality and morbidity following six minutes of cardiac arrest in resuscitated dogs. Journal of Critical Care 1987; 2: 4–14.

17 *Nakakimura K, Fleischer JE, Drummond JC, et al.* Glucose administration before cardiac arrest worsens neurologic outcome in cats. Anesthesiology 1990; 72: 1005–11.
18 *Berry FA.* Succinylcholine and Duchenne muscular dystrophy (Letter). Anesthesiology 1993; 79: 401.
19 *Allen GC.* VIth international workshop on malignant hyperthermia (MH). Can J Anaesth 1993; 40: 284–5.