

When the Lytes Go Out: A Case of Inpatient Cardiac Arrest

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Learning Objectives

- Discuss the risk of ventricular arrhythmia related to prolonged QTc intervals that can be affected by electrolyte derangements
- Describe some of the advantages in protocol-based management of complex and rapidly evolving care in disease states such as diabetic ketoacidosis
- Identify potential sources of error related to frequent patient handoffs and unclear roles for different care teams in the hospital
- Discuss the role of the electronic health record and auto-firing alerts to aid in the early identification of factors that can lead to complications or poor outcomes

The Case

A 44-year-old man with hypertension and diabetes mellitus complicated by diabetic retinopathy presented to the emergency department with right foot pain five days after stepping on a nail. On initial evaluation, vital signs were within normal limits, and physical exam was notable for an open, purulent, draining wound on right third metatarsal head that could be probed to the bone. Initial labs showed leukocytosis, low potassium, anion gap metabolic acidosis, and hyperglycemia, consistent with diabetic ketoacidosis. The patient was admitted to the general medicine ward and managed with antibiotics, subcutaneous insulin, and intravenous fluids and the orthopedic service was consulted. Over the subsequent six days, he had frequent nausea, ongoing poor oral intake, and was twice kept NPO (nothing by mouth) after midnight in advance of operative debridements that occurred late the following day. He had ongoing hypokalemia, as low as 2.5 mmol/L, and was repleted with low doses of oral supplements. A magnesium level was first checked on hospital day 4 and was found to be low; an electrocardiogram the same day showed a prolonged QT interval. On hospital day 7, potassium and magnesium remained low; subsequently, the patient had a cardiac arrest due to torsades de pointes and ventricular fibrillation. Luckily, the arrest occurred in front of a staff who called a code blue. He was transported to the cardiac intensive care with return of spontaneous circulation. He was discharged from the hospital a week later with an implanted cardioverter-defibrillator.

The Commentary

by Benjamin Stripe, MD, FACC, FSCAI and Dahlia Zuidema, Pharm.D, BC-ADM, CDCES

This Case represents an unfortunate and avoidable incident involving common complications related to the patient's chronic medical conditions. Torsades de pointes is a form of polymorphic ventricular tachycardia that has a characteristic appearance on electrocardiograms and is thought to be induced by early after-depolarizations in the setting of delayed repolarization with a [prolonged QT interval](#).¹ While a [prolonged QT interval](#) can be due to genetic abnormalities such as sodium channelopathies associated with the SCN5A gene, it can also occur in relation to medications, hypothermia, or electrolyte abnormalities such as hypokalemia, hypomagnesemia, and hypocalcemia.

Hypomagnesemia can be quite common in diabetics due to poor dietary intake, altered insulin metabolism, metabolic acidosis, osmotic diuresis, hypophosphatemia and hypokalemia. Hypomagnesemia can be associated with poor glycemic control and an underlying risk factor for foot ulcers.^{2,3}

Hypomagnesemia may induce altered cellular glucose transport, reduced pancreatic insulin secretion, leading to reduced insulin sensitivity. At the cellular level low magnesium levels may promote endothelial cell dysfunction and thrombogenesis via increased platelet aggregation and vascular calcifications.

Hypomagnesemia may be associated with an increased risk of diabetic foot ulcers along with cardiac arrhythmias.^{2,3}

Treatment of torsades de pointes that is not self-terminating should follow the advanced cardiac life support algorithm, with a particular emphasis placed on [early defibrillation](#). Magnesium administration is also emphasized heavily with or without sustained episodes, as correction of hypomagnesemia can stabilize torsades de pointe even before the QT interval can be shortened. Any offending medications that are thought to be the cause of or contributing to the prolongation of the QT interval should be stopped. Medications commonly used to prevent or treat nausea and vomiting like Zofran or antibiotics

like Fluorquinolones to treat infections can also cause or exacerbate QTc prolongation. Electrolytes should be corrected and optimized. This is in addition to usual post-arrest care of the patient.¹

Managing diabetic ketoacidosis in an intensive care setting with an order set during the first 24-48 hours is advisable and the standardized approach has shown to improve patient safety.⁴ The focus is on correction of fluid loss with intravenous fluids, correction of hyperglycemia with intravenous insulin and correction of electrolyte disturbances, particularly potassium loss, correction of acid-base balance and treatment of underlying cause like infection. Successful transition from intravenous to subcutaneous insulin requires overlap with basal insulin for 2-4 hours to prevent rebound hyperglycemia.

Patients who present with diabetic ketoacidosis are typically thought to have a total body deficiency of potassium even though the initial levels of potassium in the serum may not be reduced due to extracellular shifts related to acidemia and the hypertonicity of the serum. Treatment with insulin will cause a potassium shift back to the intracellular volume and can trigger a rapid and dangerous drop in serum potassium levels.⁵ Typically, if the potassium level is normal or low before starting insulin, then immediate and aggressive repletion should be undertaken.

As for the role of magnesium, it is not only useful for suppressing torsades de pointes, it is also important in the regulation of potassium in the distal nephron. When magnesium in the cells of the distal nephron is low, the renal outer medullary potassium (ROMK) channels are open allowing potassium efflux into the urine, but when magnesium levels are adequate, the channel is blocked by the divalent cation and potassium excretion is reduced.⁶ Therefore, checking the magnesium and repleting it would have improved the rate of potassium repletion as well.

Approach to Improving Safety & Patient Safety Target

Protocol-based management of medical problems such as diabetic ketoacidosis, a condition that requires rapidly shifting priorities and goals, should be a backbone of therapy. Fluid resuscitation, management of hyperglycemia, and electrolyte repletion often require close attention and rapid titration of therapy; therefore, a nurse-led protocol can aid in making quick changes and prevent the need for multiple communication sessions with the physician team. Many such protocols exist and there is little in the way of evidence to support the use of one protocol over another, so the details can be tailored to a specific institution and/or patient.⁷

In any hospital in which medical trainees are caring for patients, inexperience and supervision are key points of potential intervention for ensuring patient safety. In many cases, medical trainees underestimate the challenge of knowing the different formulations of medications, and how to order potassium and magnesium repletion is not always clear. Inpatient pharmacists may be helpful in educating physicians about the advantages and disadvantages of alternative formulations and can advise on replacement strategies for electrolyte abnormalities. Most hospitals have 24/7 access to inpatient pharmacist help.

Additionally, there was clearly more than one team involved in the care of the patient in this case, with Orthopedics managing the foot wound and Internal Medicine managing the medical issues. This situation can lead to important abnormalities going untreated if clear lines of team communication are

lacking. Due to the shift work nature of medicine, it is not always clearly handed off that electrolytes need to be checked and repleted through the night. While handoffs have certainly been shown to be a source of error, interventions aimed at improving sign out have not definitively shown to improve patient outcomes such as electrolyte repletion and avoidable death.⁸

[Electronic health record \(EHR\) alerts](#) for factors that can lead to complications are another potential target for intervention. In one study of risk factors for QT prolongation, EHR alerts were shown to increase assessment for QT prolongation in patients at risk. However, the overall increase in any action taken after instituting the alert was modest at best and only 21% of EHR alerts led to physician action.⁹

Systems Change Needed/Quality Improvement Approach

In response to the Case above, several systems issues can be addressed. First, it was not clearly stated in this Case whether an Internal Medicine team or an Orthopedics team was primarily responsible for the patient. This should clearly be defined when there is shared responsibility. It would be unlikely that the orthopedics team would be managing the DKA, so it would be important to drill down on the processes to determine what barriers there were in carrying out the internal medicine team's intent. For example, were there communication gaps or problems with order transcription between the frequent trips to the operating room and periods when the patient was NPO? In academic settings, orthopedic surgery residents may primarily manage many patients that do not have medically complex issues; however, this patient would be better served on an internal medicine team with the orthopedics team serving as a consulting service. This will likely streamline the treatment of the medical problems.

Second, protocol-based electrolyte repletion is helpful in reducing the time from when an abnormal laboratory test value is reported to the administration of a repletion dose of potassium.¹⁰ The same systems intervention has been accomplished with improvement in the satisfaction of both the physicians and the nurses, with no increase in the number of laboratory tests or increased rates of over-repletion to a state of hyperkalemia. While only potassium was tracked in this study, other electrolytes, such as calcium and magnesium, are likely to respond similarly to protocol-based management. In this specific case of a patient who was repeatedly NPO for surgery, the protocol can provide important flexibility to switch between intravenous and oral repletion routes. A dietary consultation may have also been helpful to provide an assessment of the patient's nutritional status and fluid and electrolyte balance.

Third, for a patient coming in with DKA and a foot infection it is very important to pursue good glycemic control to improve wound healing. Insulin is the agent of choice. A multidisciplinary approach with a physician, dietary consultation, pharmacist and bedside nurse for diabetes education can achieve blood glucose goals much faster while the patient is being treated for a foot infection and to prevent damage to limb.^{11,12}

Fourth, good communication is key to good outcomes. While multidisciplinary rounds will often facilitate this communication, more frequent brief communications between the bedside nurse, pharmacy team, and the primary physician team are crucial. Empowering the bedside nurse to reach out to the physicians with some suggestions to expedite electrolyte repletion may have been helpful here.

Lastly, the experience and competence of the primary resident should be considered. Early in the career of the freshly graduated physician, there are many things to learn and many mistakes that will be made but helping to prevent them is the job of the senior residents and the attending physician on service. Timely bedside teaching via direct intervention by one of these more experienced physicians may have prevented this outcome and helped to reinforce important learning points for the new physician.

Take Home Points

- Patients with a history of poor glycemic control can be at higher risk for electrolyte disturbances exacerbated by DKA, infection and the patient's NPO status that is often ordered in preparation for procedures; clinicians must recognize the importance of glycemic control in relationship to potential electrolyte disturbances.
- Protocolized repletion of electrolytes can help to prevent prolonged hypokalemia by empowering the bedside nurse, leading to shorter time from when an abnormal laboratory value is reported to administration of a dose for repletion.
- Physician shift-to-shift handoff has been shown to be a potential source of missed communication or miscommunication thus leading to error, but interventions have not yet been demonstrated to improve patient outcomes such as electrolyte repletion.
- Recognition of medications that can cause QTc prolongation (like anti-emetics and antibiotics) is essential.
- EHR alerts may stimulate action by physicians in response to early signals of potential problems, but they have limited ability to induce action and may lead to "alert fatigue."
- Inclusion of an interprofessional team (medicine, nursing, pharmacy, dietary) to coordinate management and ensure inter-team communication (between medical/surgical services as well as with ancillary services) is an important mechanism to identify issues and prevent poor outcomes from conditions that are usually easily reversed.

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