Prehospital treatment of hyperkalaemia

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Abstract

This article explores the assessment and management considerations of patients with hyperkalaemia. Using a case study from clinical practice, the hospital treatment is reviewed with particular emphasis upon the use of calcium, insulin and dextrose. In particular, potential prehospital treatments are considered, with focus upon the use of salbutamol and furosemide. Definitions, incidence and mortality rates of hyperkalaemia are also detailed. The signs, symptoms and causes of the condition are examined, with the aim of achieving prehospital diagnosis in the absence of serum potassium levels. Hyperkalaemic electrocardiogram (ECG) changes are studied and examples are given. Conclusions are made, including a recommendation for the prehospital use of salbutamol in the treatment of hyperkalaemia.

Key words

● Electrocardiogram ● Hyperkalaemia ● Management ● Paramedic ● Prehospital ● Salbutamol

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While on placement in a large accident and emergency (A&E) department, a patient was admitted with dangerously high levels of potassium following immediate referral from their GP. Mrs Y, a 62-year-old female, displayed no signs of suffering an emergency medical condition. All observations were within normal parameters—she appeared systemically well and repeatedly stated that she felt 'absolutely fine'. Mrs Y had a minimal past medical history and was normally fit and well. A prescription of 5 mg ramipril had been started several months previously because of concerns regarding reduced kidney function.

Although no abnormalities were detected on the 3-lead or the 12-lead ECG, the patient was transferred to the resuscitation room with a serum potassium level of 7.6 mmol/L. Prompt management was initiated with intravenous 10% calcium chloride, followed by 10 units of short-acting insulin and 50% dextrose. 5 mg nebulized salbutamol was also administered. Throughout Mrs Y's treatment, the ECG had been continually examined with no changes noted. Having been in the department for approximately 1 hour, Mrs Y's serum potassium was stabilized at 5.1 mmol/L and the patient was referred to urology for further investigation and treatment.

This case study is of particular interest, not least because of the asymptomatic presentation of the patient. The aggressive treatment had also produced near-immediate, successful results and the management had been relatively uncomplicated, with the physician following straightforward management advice from the *Oxford Handbook of Emergency Care* (Wyatt et al, 2006). Of further interest was the fact that the patient had been conveyed by ambulance under normal road conditions having not received any prehospital treatment.

What is hyperkalaemia?

The definition of hyperkalaemia varies from text to text, but is generally considered to be a plasma potassium concentration of greater than 5.5 mmol/L (Guidelines and Audit Implementation Network (GAIN), 2008). This can further be divided into mild (5.5–6 mmol/L), moderate (6.1–6.9 mmol/L) or severe (>7 mmol/L) (Wyatt, 2006). Potassium is the most abundant intracellular cation and is essential for physiological processes within the body, maintaining homeostatic cell volume and sustaining cellular membrane potential (Varon and Acosta, 2009). It is obtained through diet and is secreted predominantly by the kidneys but also by the gut (Irwin and Rippe, 2008). Only 2–3% of total body potassium exists within extracellular fluid, translating to a normal value of 3.5–5.5 milliequivalents (mEq) or mmols per litre (LeFever Kee et al, 2009).

Despite many studies examining the prevalence of hyperkalaemia in specific patient groups, the total number of cases is difficult to determine. Reports of incidence in hospitalized patients ranges 1–10% (GAIN, 2008) but that number can be somewhat larger in pre-dialyzed patients, in which as many as 67% develop high potassium levels

(Khedr et al, 2009). A clear understanding of the emergency management is crucial as hyperkalaemia has lethal consequences and is associated with a mortality rate of 14–41% (Feld and Kaskel, 2010). Furthermore, severe hyperkalaemia, if not treated rapidly, carries a mortality rate of 67% (Weisberg, 2008), providing a compelling argument for treating the condition in the prehospital phase.

Diagnosis

Signs and symptoms

To carry out appropriate management of hyperkalaemic patients, an understanding of the signs and symptoms is fundamental. An increased concentration of potassium in the plasma has the effect of depolarizing cell membranes, therefore making them less excitable and in turn, resulting in neuromuscular dysfunction (Lubin et al, 2006). Patients with hyperkalaemia can display abnormal signs and symptoms specific to the renal, gastrointestinal, cardiovascular and nervous systems (LeFever Kee et al, 2009). They can present with nausea, abdominal pain and or/diarrhoea (Guy, 2009); but also muscle irritability, malaise, muscle weakness and, in patients with serum potassium levels of greater than 6.0 mEq/L, paresthesia and an increased heart rate (LeFever Kee et al, 2009).

Despite such an array of symptoms, it is commonly documented that, even with severe hyperkalaemia, patients can present with no abnormalities (Gleadle, 2007; Baltazar, 2009). This would explain Mrs Y's asymptomatic presentation, making diagnosing the condition in the prehospital environment difficult, if not impossible.

Bloods

In Mrs Y's case, the diagnosis had been made on the basis of blood results and a history of reduced renal function—a well recognized cause of hyperkalaemia (Irwin and Rippe, 2008). In the presence of normal renal function, the attending doctor would suspect 'pseudohyperkalaemia', a condition in which abnormal potassium levels are the result of haemolysis in-vitro (Irwin and Rippe, 2008). However, such factors are not of concern to UK paramedics as, despite evidence-based approval (Prause et al, 1997), blood gas and electrolyte testing is currently unavailable in the prehospital stage.

The ECG

Without the help of serum potassium results and without the benefit of specific signs and symptoms, diagnosing hyperkalaemia in the prehospital environment could pose difficulties for the paramedic. However, the role of the electrocardiogram in recognizing the condition is well-documented in literature and discussed in ECG and medical textbooks alike (Irwin and Rippe, 2008; Baltazar, 2009; Jevon, 2009). ECG changes frequently parallel the severity of the electrolyte disorder (Baltazar, 2009) and, crucially, allow diagnosis of hyperkalaemia—giving rise to emergency treatment even before the results of serum potassium levels are available (Baltazar, 2009).

Serum potassium	Typical ECG appearance	Possible ECG abnormalities
Mild (5.5–6.5 mEq/L)		Peaked T waves Prolonged PR segment
Moderate (6.5–8.0 mEq/L)		Loss of P wave Prolonged QRS complex ST-segment elevation Ectopic beats and escape rhythms
Severe (>8.0 mEq/L)		Progressive widening of QRS complex Sine wave Ventricular fibrillation Asystole Axis deviations Bundle branch blocks Fascicular blocks

Figure 1. Illustration showing progressive ECG changes.

ECG changes are varied. Potassium and sodium play an essential electrophysiological function within the myocardium, maintaining concentration gradients across the cell membranes with the use of the sodium-potassium pump. An increase in extracellular potassium has the effect of reducing the membrane potential. This in turn slows myocardial conduction, resulting in prolongation of the P wave, the PR interval and the QRS complex (Parham et al, 2006). These changes (*Figure 1*) can progress to ventricular fibrillation and asystole without prompt treatment (Barash et al, 2009), making prehospital management even more challenging.

Earlier changes (*Figure 3*) include tall 'peaky' T waves and QT shortening (Lubin et al, 2006). The peaked T wave, caused by rapid repolarization, is best seen in leads ll, lll, and V2—V4 (Parham et al, 2006). This draws similarities with the hyperacute changes of myocardial infarction, but can be distinguished as the T waves are relatively shorter in duration (<250 m sec) than those seen in myocardial infarction (MI) (Dananberg, 1999).

Unfortunately, there is no widely excepted definition of a peaked T wave, but some have suggested envisaging it as a seat—if it is too uncomfortable to sit on, then it is likely to be peaked (Toy et al, 2009).

Interestingly, despite extensive descriptions in the literature, recent research suggests ECG

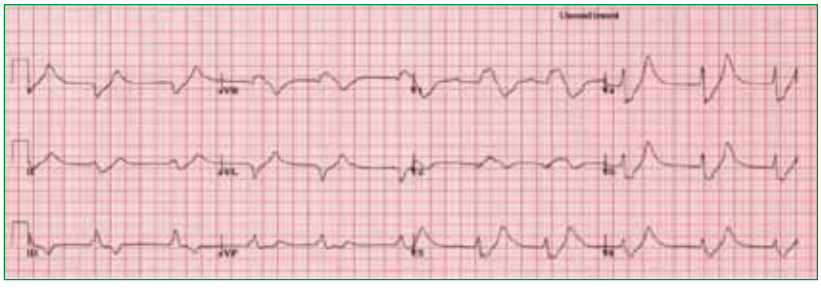

Figure 2. Prolonged QRS associated with hyperkalaemia.

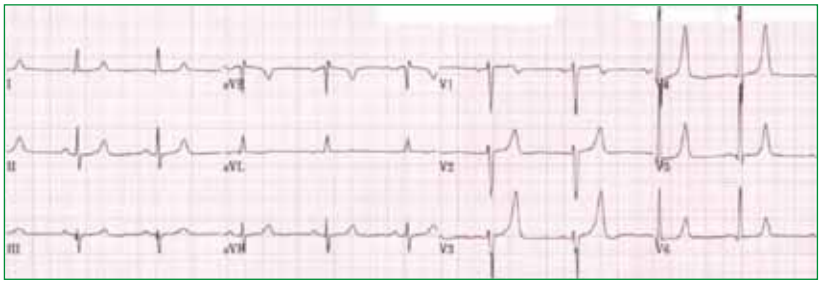

Figure 3. Peaked T waves associated with hyperkalaemia.

abnormalities have a poor sensitivity and specificity for identifying hyperkalaemia in stable patients (Montague, 2008). This is something recognized by Barash et al (2009), who state that the ECG should provide a suggestion of hyperkalaemia but that the focus be upon the medical history (with emphasis on drug history) and assessment of renal function. This certainly seems a sensible approach. Nevertheless, Montague's article does acknowledge that 80% of the patients studied had only mild or moderate hyperkalaemia and that the likelihood of ECG changes increased with rising levels of potassium.

Clearly, the lack of ECG changes in the case of Mrs Y demonstrates that not all hyperkalaemic patients present with ECG changes. Indeed, the ECG is not sensitive enough to rule out hyperkalaemia, but should instead be used as an indicator for aggressive management where hyperkalaemic ECG changes exist (Wolfson et al, 2009).

Causes

Given the diagnostic abilities of the ECG, identifying hyperkalaemia in the prehospital environment is possible, enabling active management. Any doubt in the clinician's mind could be further affirmed by recognition of an obvious cause of the electrolyte imbalance. Hyperkalaemia occurs as a result of excessive potassium production, cellular shifts and/or inadequate elimination. Decreased renal excretion (as seen in renal failure, hyporeninemic hypoaldosteronism, renal tubular disease and the use of ACE-inhibitors and NSAIDs) is the most common cause of hyperkalaemia (Lee, 2009).

This is particularly relevant to the case study, as Mrs Y was suffering a degree of renal dysfunction and had been prescribed the ACE-inhibitor ramipril. Other causes include potassium-sparing diuretics (e.g. spiralactone), tumour cell necrosis, metabolic acidosis and Addison's disease (Rastergar and Soleimani, 2001). Of further relevance to the prehospital environment are burns, rhabdomyolysis and the use of suxamethonium (a paralytic drug used in rapid sequence induction), which can also be attributed to hyperkalaemia (Wilson et al, 2007).

Management

With ECG changes indicative of hyperkalaemia and the presence of an obvious cause (determined by a thorough health history), prehospital treatment could be initiated. In fact, Guy (2009) advocates paramedic involvement in the treatment of hyperkalaemia, in the form of calcium gluconate, sodium bicarbonate, dextrose and insulin. In the case study, the doctor began with intravenous 10% calcium chloride. This should indeed be a priority, as calcium antagonizes the action of potassium on the cell membrane, reducing myocyte excitability and improving cardiac conduction (Sirvent et al, 2008). This has the effect of reversing electrocardiographic changes and stabilizing the myocardium but, notably, has no effect on lowering serum potassium (Hollander-Rodriquez and Calvert, 2006).

It is for this reason that other, more definitive treatment needs to be initiated subsequently. In Mrs Y's case, insulin and dextrose had been given concurrently. Insulin is indicated for the treatment of hyperkalaemia that requires emergency intervention and is recognized as the benchmark against which newer treatments are compared (Ahee and Crowe, 2000).

Short-acting insulin

Short-acting insulin is administered as a firstline treatment. It works by stimulating the sodium/potassium pump, an action that shifts potassium into the intracellular environment (Parham et al, 2006). Studies have demonstrated insulin's ability to lower potassium by 0.45 and 1.35 mEq/l (Ngugi, 1997; Mahajan et al, 2001), with effect being taken within 15 minutes of administration (Allon and Copkney, 1990). Dextrose is administered to counteract the hypoglycaemic effects of insulin, meaning treatment should be followed by close monitoring of blood sugar levels (Parham et al, 2006).

Despite clear evidence of insulin and dextrose's success, this treatment is essentially temporary until removal of potassium from the body is

possible. Haemodialysis is the fastest and most efficient way to do this (Blumberg et al, 1988); but because of the time, expense and invasiveness involved, it is rarely used as a firstline treatment—instead exchange resins such as sodium polystyrene sulfonate are preferable (Parham et al, 2006).

Furosemide

Similarly, consideration could be given to furosemide—a non-potassium sparing diuretic and something already available to the UK paramedic (Joint Royal Colleges Ambulance Liaison Committee (JRCALC), 2006). Furosemide acts by preventing the tubular reabsorption of sodium at the loop of Henle and early distal tubule. This increases sodium delivery to the distal tubule, stimulating potassium excretion (Carvalhana et al, 2006). For this reason, like resins, it is also recommended in the removal of potassium in a dose of 40–80 mg (American Heart Association, 2005). However, the guidelines only suggest furosemide for the treatment of mild hyperkalaemia, something unlikely to be identified in the prehospital stage. Furthermore, a Cochrane review could not identify any studies that examined the role of loop diuretics in the treatment of high potassium (Mahoney et al, 2005) and, with a lack of a solid evidence base, it is doubtful whether there is any benefit to initiating this treatment in the prehospital phase.

Salbutamol

The same cannot be said for salbutamol. Like insulin, salbutamol has the effect of shifting potassium back into the intracellular environment. As a #2 agonist, it binds to #2 receptors in the liver and muscle cells creating a chain reaction, which results in stimulation of the sodium-potassium pump (Ahee and Crowe, 2000). A decrease in potassium levels occurs within 1–2 minutes, with the peak effect being reached after 40–80 minutes (Mandelberg et al, 1999)—a faster effect than that of insulin.

Salbutamol is effective in treating hyperkalaemia. In fact, salbutamol has been shown to be more effective than insulin for the treatment of hyperkalaemia (Mushtaq and Masood, 2006), reducing serum potassium levels by 0.4–1.5 mEq/L (Mahoney et al, 2005). Results have also been shown to be dose dependent. Allon et al (1989) studied two groups of patients given 10 mg and 20 mg salbutamol. Those receiving dosages of 10 mg were reported as having 0.62 mmol/L less serum potassium, while those given 20 mg averaged a 0.98 mmol/L reduction. Furthermore, McClure et al (1994) found nebulized salbutamol

Figure 4. Short-acting insulin is administered as a firstline treatment.

more effective than that of the intravenous route, with reductions of 1.19 mmol/L and 0.7 mmol/L respectively. This is something supported by recent national guidelines (GAIN, 2008), which recommend 10 mg nebulized salbutamol as a treatment for hyperkalaemia.

The use of salbutamol has a number of theoretical advantages. In a best evidence topic report (BETs) review, Bentley (2007) summarizes positive features—including easy administration, minimal side-effects, low cost and its ability to reduce potassium without affecting the patient's glucose balance. Moreover, salbutamol is already carried by all 12 UK ambulance NHS trusts and is well-established in prehospital clinical guidelines (JRCALC, 2006). Anecdotally, staff have a good grasp of its use in treating breathing difficulties and no further training would be required in the drug's administration.

However, it is not without its pitfalls. Weisberg et al (2008) strongly state that salbutamol should never be used as a single treatment for hyperkalaemia, citing that 40% of patients seem resistant to its hypokalaemic effect. While this is something to consider, salbutamol administration in the prehospital setting would not act as a single treatment, but as an interim measure until definitive care could be reached and the treatment continued.

Further consideration must be given to the adverse affects from salbutamol administration and prudence has been advised in patients with ischaemic heart disease (Ahee and Crowe, 2000), with cautions varying from hypertension to hyperthyroidism (Joint Formulary Committee, 2010). Mild tachycardia is the most commonly

reported side-effect of high-dose salbutamol (Weisberg et al, 2008).

Despite such minor disadvantages, the use of salbutamol has been demonstrated to be safe and effective by a Cochrane review (Mahoney et al, 2005) and is accompanied by national clinical guidelines (GAIN, 2008) recommending that salbutamol be a firstline treatment for the management of hyperkalaemia. The guidelines state that in the presence of ECG changes, urgent treatment is required to reduce potassium.

Conclusions

Having reviewed the signs and symptoms, ECG changes and causes of hyperkalaemia, it seems there is a clear opportunity for treatment to be considered in the prehospital environment. Certain ECG changes are diagnostic in the identification of hyperkalaemia, giving rise to treatment in the absence of blood results. This diagnosis is further affirmed in the presence of signs and symptoms and an identifiable cause, most commonly renal dysfunction.

Patients with ECG changes are likely to have high levels of potassium and are at risk of developing life-threatening arrhythmias within a short period of time. Therefore, if treatment could be initiated earlier, then the patient's chance of recovery would perhaps be enhanced. Calcium chloride, insulin and salbutamol are widely discussed in the literature and are supported by a strong evidence base in the treatment of hyperkalaemia. Of these, only nebulized salbutamol is available to the UK ambulance services, a treatment which could be started by paramedics and technicians alike; 10 mg is recommended by clinical guidelines and this could be repeated on arrival at A&E, depending on the patient's condition.

Caution should be applied in line with JRCALC's guidance on salbutamol since, especially in high doses, side-effects may develop. Furosemide is most likely an inappropriate treatment for hyperkalaemia in the prehospital arena, but may well be used as part of a management plan in hospital.

Key points

- Hyperkalaemia is a potentially lethal condition which can lead to life-threatening cardiac arrhythmias and is associated with a high mortality rate.
- In severe hyperkalaemia and/or the presence of hyperkalaemic ECG changes, urgent intervention is required.
- Current in-hospital management consists of calcium gluconate, insulin, dextrose and salbutamol.
- Hyperkalaemia can be diagnosed using an ECG and the diagnosis affirmed with signs and symptoms of hyperkalaemia and the presence of an obvious cause.
- Prehospital salbutamol administration should be considered in patients with hyperkalaemia.

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