Hypokalemia is generally well tolerated in otherwise healthy people, but it can be life threatening when severe. Hypokalemia results from decreased oral intake, gastrointestinal losses caused by repeated vomiting or diarrhea, urinary losses through increased potassium secretion or decreased reabsorption, and processes that shift potassium into the intracellular compartment [5-7]. Severe hypokalemia (<2.5 mEq/L) can cause rhabdomyolysis, and values less than 2.0 mEq/L can cause ascending paralysis with eventual respiratory arrest [8].

Hypokalemia in critically ill adults is well described, as is the management of potassium abnormalities in children, and although hypokalemia is one of the most common electrolyte disturbances in sick children [9,10], the magnitude of the problem in current pediatric practice remains unknown. The present study compares the frequency, interventions and outcomes of moderate (2.5-2.9 mEq/L) and severe (<2.5 mEq/L) hypokalemia in children presenting to the pediatric emergency department versus those developing the condition subsequently during hospitalization in the pediatric wards of a large tertiary care pediatric hospital.

Methods

This was a retrospective case series of children aged <16 years with moderate (2.5-2.9 mEq/L) and severe (<2.5 mEq/L) hypokalemia in the six years between March 1\textsuperscript{st} 2008 - March 31\textsuperscript{st} 2014 in the pediatric emergency department (PED) or pediatric wards of the Dana-Dwek Children's Hospital. We excluded cases diagnosed primarily in the intensive care unit (that's mean that they didn't present to the PED). Results were compared between patients diagnosed during admission in the PED and those that developed hypokalemia in the hospital wards of the same institution. The study excluded patients diagnosed in the intensive care unit or any of the three adult intensive care units at the hospital.

References:

1. Source 1
2. Source 2
3. Source 3
4. Source 4
5. Source 5
6. Source 6
7. Source 7
8. Source 8
9. Source 9
10. Source 10
was seen at the PED). The hospital serves a catchment area of approximately 800,000 people and the PED seen approximately 35,000 patients per year, of whom 10% are admitted. All patients who are admitted to the hospital for several reasons have blood work performed: Renal function and electrolyte levels at least in the PED. All patients are admitted though the emergency department, including those needing intensive care.

**Definitions**

1. Moderate hypokalemia: potassium concentration between 2.5-2.9 mEq/L [11].
2. Severe hypokalemia: serum potassium concentration <2.5 mEq/L [11].
3. Pseudohypokalemia is a decrease in the amount of potassium that occurs due to excessive uptake of potassium by metabolically active cells in a blood sample after it has been drawn. It is a laboratory artifact that may occur when blood samples remain in warm conditions for several hours before processing [12].
4. The following diseases were considered predisposing/risk factors to developing hypokalemia: drugs like beta adrenergic agonist (albuterol, insulin), metabolic alkalosis, diabetic ketoacidosis, Bartter/Gittelman, anorexia, renal disease, malnutrition, hepatic disease, steroid use, neurological disease, and chronic respiratory disease.
5. Intravenous replacement therapy was categorized as slow if the patient received 4-6 mEq potassium per 100 mL of intravenous fluids and rapid if the concentration was greater.
6. Maintenance potassium requirement: 3 mEq/100 mL water × 1,000 mL/day = 30 mEq/day 30 mEq/L, 800 mL = 15-20 mEq/L.
7. Indication for rapid replacement: for severe hypokalemia, as the potassium concentration falls to less than 2.5 mEq/L with clinical manifestation of weakness prominent, areflexic paralysis (respiratory failure may occur) or significant changes in the electrocardiogram.

Data on all patients who experienced hypokalemia on at least one occasion during their PED or ward stay in our institution were analyzed; the patients were identified from laboratory records. Details regarding age, sex, diagnoses, predisposing factors, clinical course, outcomes including biochemical parameters such as serum electrolyte levels, acid-base status and renal function, electrocardiograms and treatment were extracted from hospital charts; (is the policy of our institution that every patient who gets admitted must get a basic electrolyte panel. Electrocardiographs (ECG) were analyzed for changes characteristics of hypokalemia. For symptomatic patients we used in the intensive care setting the rapid infusion:

That required intravenously (IV) administration of potassium chloride, particularly in those who are unable to take oral medications. In this setting, an infusion with a potassium concentration of no more than 40 mEq/L was given at a rate not to exceed 0.5 to 1 mEq/kg of body weight per hour. The rapid replacement was given in intravenous access or central vein and when the peripheral vein were given were well tolerable because were given with normal saline.

These patients required continuous electrocardiographic (ECG) monitoring to detect changes due to hypokalemia, and also possibly rebound hyperkalemia during replacement therapy. All the ECG was interpreted by the physician who treated. Categorical and continuous variables were analyzed using Fisher’s exact and the Mann-Whitney U test respectively. A p value of <0.05 was considered statically significant. Statistical analysis was performed using SAS for Windows Version 9.4.

The study was approved by the Institutional Ethics Committee.

**Results**

There were 24 episodes of hypokalemia during the study period; nine moderate and fifteen severe. Fourteen (58%) were diagnosed in the PED and 10 (42%) developed later on the ward. There were no significant differences in age or primary diagnosis between patients with hypokalemia on initial presentation in the PED versus those who developed the condition subsequently on the ward (Table I). Hypokalemia was more severe in the PED group (p=0.05), but those developing hypokalemia only later, on the ward, experienced longer admissions (62.5 days versus 5.5 days; p<0.005). In both groups, most patients belonged to the diagnostic categories of diarrhea-induced dehydration (50%); other causes included respiratory conditions, diabetic ketoacidosis, neurological causes (epilepsy disorder), primary hyperaldosteronism, sepsis and intoxications (beta adrenergic agonist accidental ingestion).

There were no significant differences in predisposing factors to the development of hypokalemia; Eight patients (61%) with clinical dehydration during severe diarrhea condition was the most important diagnostic in PED patients. Eight episodes of hypokalemia were associated with ECG changes, consisting of flat or absent T waves [6] and prominent U-waves [2].

Correction of severe and moderate hypokalemia was accomplished in a mean of 10.5 and 14.2 hours respectively. Two patients in each group received rapid IV correction under continuous ECG monitoring for pre-infusion serum potassium levels ranging from 1.8-2.8 mEq/L (Table II). The one patient who died developed hypokalemia during hospitalization in association with septicemia and disseminated intravascular coagulation.

**Discussion**

Moderate and Severe hypokalemia is not a common problem among pediatric patients in our institution. But sometime can have serious consequences and may require prompt intervention [11]. In our institution we found 24 patients cases over a six-year period, excluding cases diagnosed primarily in the intensive care unit.
Although eight had ECG changes only four required rapid intravenous potassium replacement. Absence of ECG changes should never be used to exclude significant hypokalemia [10].

Common ECG findings of hypokalemia include depression of the ST segment, decreased T-wave amplitude and increased U-wave amplitude [13].

Fifty eight percent of patients presented with hypokalemia in the PED and the remainder developed the electrolyte disturbance on the ward, stressing the importance of monitoring for this abnormality in admitted patients [14]. Four (16.6%) of our patients required rapid intravenous replacement under ECG monitoring. The maximum safe infusion rate for IV potassium is summarized elsewhere [15-16]. Based on experience with a large number of infusions, Weiner et al concluded, that under intensive care monitoring, IV administration of 20 mEq potassium/hour (central or peripheral vein) were well tolerated [13]. There are studies that have documented the use of doses up to 100 mEq/hour in life threatening circumstances [17]. The goal of therapy is to correct potassium deficit without provoking hyperkalemia. The choice of oral or intravenous replacement depends on the severity of the disorder and the patient's ability to tolerate enteral salts. Oral replacement is preferred, except when there is no functioning bowel or in the setting of ECG changes, neurological symptoms, cardiac ischemia, or digitalis therapy. The main concern about the use of IV potassium supplementation is the inadvertent administration of a large amount of potassium in a short period.
of time, resulting in hyperkalemia. Safety measures to prevent this complication include limiting the absolute amount of potassium in any single container or bag of fluid, and using an infusion pump. IV potassium administration is also associated with pain and phlebitis when administered through a peripheral vein, which can be minimized if the potassium content of the infusion is less than 20 mEq/L. Central venous access is needed if the potassium concentration exceeds 40 mEq/L.

Most of our patients presenting in the PED suffered acute gastroenteritis. Diarrhea in children can cause electrolyte abnormalities such as hyponatremia, hypokalemia and metabolic acidosis with normal anion gap [18]. The concentration of potassium in normal stool is 80-90 mMol/L, but because of the low volume of water in normal stool, only about 10 mMol of potassium is normally lost each day [19]. In diarrheal states, although the potassium concentration in stool decreases, large quantities of potassium can be lost as the volume of stool increases [20]. Thus conditions, such as infectious diarrhea, that increase stool volume can result in clinically significant potassium depletion and hypokalemia.

Children with mild hypokalemia are often asymptomatic. More significant potassium deficits (serum concentrations 2-3 mEq/L) cause generalized malaise and weakness. As the concentration of potassium falls to <2 mEq/L, weakness becomes prominent, and areflexic paralysis and respiratory failure may occur. Rhabdomyolysis is also likely [21]. In all cases of significant hypokalemia, monitoring for ECG changes and muscle strength is imperative, and if abnormalities are present immediate replacement is warranted.

Potassium is a predominantly intracellular ion and an understanding of the relationship between intra- and extra-cellular fluid milieu and potassium handling by the kidneys, is important in the diagnosis and treatment of potassium disorders [3]. Metabolic acidosis with a random urine potassium-creatinine ratio <1.5 suggests excessive gastrointestinal losses due to diarrhea, or a shift of potassium into cells [21]. Measurement of blood pressure, blood pH, renin and aldosterone levels, stool and urine volumes and the concentration of potassium in each patient would have helped clarify potassium homeostasis in our patients.

For successful potassium replacement, the optimal potassium preparation, route, and speed of administration, as well as severity, acuity, associated clinical signs, comorbid conditions, and the expectation for ongoing loss should be considered [16]. In general, potassium replacement is indicated when there has been potassium loss. In clinical scenarios when potassium loss is accompanied by acid-base disturbance, a redistribution effect should be factored in when losses are estimated. Supplementation during a redistributive process should proceed with close monitoring, given the risk of rebound hyperkalemia [22]. In cases when potassium has been lost, there is no direct correlation between serum level and total body stores, and potassium deficit can only be approximated [9]. If the child is clinically well, oral therapy is preferable and can be provided 2-4 times per day as potassium chloride [22]. Dosing should start at 2-5 mEq/kg per day and be adjusted on the basis of serial laboratory assessment. Oral supplements should be used in patients predisposed to hypokalemia, such as those on diuretic therapy. If there is concurrent metabolic acidosis, potassium citrate or bicarbonate can be provided. If the child is unable to take oral medications or is symptomatic, intravenous potassium should be provided as an intermittent infusion beginning with an intravenous dose of 0.5-1 mEq/kg (typical maximum 30-40 mEq/dose). If the child is not symptomatic, potassium can be added to the maintenance fluids (20-40 mEq/L) via a peripheral vein. Some patients with severe hypokalemia do not manifest ECG changes, and even in the absence of ECG abnormalities, rapid corrections have been shown to be safe and useful [19]. In order to avoid insulin secretion, which promotes trans cellular shift of potassium into the intracellular space, potassium should be provided in a dextrose-free solution. Magnesium supplementation is indicated in hypokalemia associated with hypomagnesemia[13]. Potassium chloride or potassium phosphate may be used, although the use of phosphate salt is typically limited to the treatment of diabetic ketoacidosis or documented severe hypophosphatemia.

Although our study covered a six year period in a busy tertiary care pediatric hospital, the number of patients found to have moderate to severe hypokalemia was relatively low, limiting the strength of conclusions that can be drawn. Urine electrolytes were not assessed in many of our patients, particularly those in the PED; knowledge of these measurements would have helped elucidate causes of hypokalemia.

**Conclusion**

Potassium deficiency alters the function of several organs, most prominently the cardiovascular and neurologic systems, muscles, and kidneys. These effects ultimately determine the morbidity and mortality related to this condition. Children and young adults tolerate greater degrees of hypokalemia with less risk than the elderly. Although significant hypokalemia is relatively uncommon in pediatric emergency patients.

**References**