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Renal Replacement Therapy (2021) 7:66
https://doi.org/10.1186/s41100-021-00381-5

Renal Replacement Therapy

CASE REPORT

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Reverse pseudohyperkalemia in a newly diagnosed pediatric patient with acute T-cell leukemia and hyperleukocytosis: a case report and literature review

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Abstract

Background: Hyperkalemia is a serious medical condition that requires immediate intervention. However, pseudohyperkalemia and reverse pseudohyperkalemia are misleading clinical manifestations that can result in incorrect diagnosis and consequent harmful intervention.

Case presentation: An 11-year-old girl manifested an incidental finding of hyperleukocytosis (WBC > 400 × 10^9/L), with 90% blast cells during routine pre-operative investigations for adenotonsillectomy. Initial investigations demonstrated elevated serum potassium levels (7.5 mmol/L), despite concomitantly normal levels in venous blood gas samples (3.9–4.4 mmol/L) and being clinically stable with normal 12-lead ECG. Surprisingly, plasma potassium level was exacerbated, in comparison to the serum level by > 1 mmol/L. This finding is consistent with reverse pseudohyperkalemia that is associated with hyperleukocytosis in acute leukemia that does not require any active intervention.

Conclusion: This case report emphasizes the significance of interpreting potassium levels accurately, preferably utilizing whole-blood potassium level over serum and plasma level in newly diagnosed leukemia cases with hyperleukocytosis. Additionally, having a high index for the possibility of reverse pseudohyperkalemia, secondary to leakage from fragile leukocytes, avoids unnecessary treatment that might cause harm to the patient.

Keywords: Hyperkalemia, Pseudohyperkalemia, Hyperleukocytosis, Leukemia

Introduction

Hyperkalemia is a potentially life-threatening condition that requires immediate medical intervention. However, pseudohyperkalemia and reverse hyperkalemia are misleading clinical manifestations that might result in inappropriate patient management. Pseudohyperkalemia (PHK) has been defined as a false increase in serum potassium level, in comparison to a normal plasma level of ≥ 0.4 mmol/L [1]. This is commonly encountered within settings of high leukocyte or platelet-counts, secondary to the release of intracellular potassium during the process of specimen collection and clot formation [2–6]. Singh and colleagues first-described reverse pseudohyperkalemia (rPHK), wherein plasma potassium concentrations were exacerbated in comparison to serum potassium levels. This study proposed that the underlying mechanism was an increased sensitivity to heparin-induced membrane damage during cases of hematological malignancy [1].

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Identifying PHK and rPHK in patients with leukemia and hyperleukocytosis carries a significant clinical implication in patient monitoring and management, by avoiding unnecessary interventions that might actually cause harm to such patients. This case report discusses a child with acute leukemia that presented with hyperleukocytosis and hyperkalemia. Such a case emphasized the significance of differentiation between true hyperkalemia, PHK, and rPHK in guiding the appropriate patient management and addressing all possible causes for such clinical manifestations.

Patient and methods

Previously reported cases were identified by performing a MEDLINE and PubMed review of clinical literature, using the keywords 'reverse pseudohyperkalemia' and'leukemia' (English language) for the time frame of 1964–2020. Any case report with tumor lysis syndrome or true hyperkalemia (secondary to another cause, other than acute leukemia) was excluded, together with animal studies (Table 1). This study identified 14 reported cases, which were similar to the case described in this article (Tables 1, 2).

Case report

An 11-year-old girl with unremarkable medical history was incidentally found to manifest a white blood cell-count (WBC > 400×10^9/L) with 90% blasts and hyperkalemia, during pre-operative investigations for adenotonsillectomy. The patient was referred to pediatric oncology in our hospital for further management. Initial assessment within the pediatric intensive care unit (PICU) revealed a clinically and hemodynamically stable patient with tonsillar hypertrophy, multiple enlarged cervical lymph nodes, and hepatosplenomegaly. Complete blood count (CBC) of the patient revealed WBC of 440×10^9/L with 92% blasts, hemoglobin count of (Hgb) 8.3 g/dL, and a platelet count 90×10^9/L. Her initial biochemical (serum) profile revealed a potassium level of 7.5 mmol/L, sodium level of 139 mmol/L, phosphate level of 1.27 mmol/L, calcium level of 2.4 mmol/L, uric acid level of 0.01 mg/dL, lactate dehydrogenase (LDH) level of 1434 u/L, creatinine level of 0.53 mg/dL, together with a blood urea nitrogen level of 4.48 mg/dL. In addition, venous blood gas sample revealed a potassium level of 3.9 mmol/L. There was a noticeable discrepancy between potassium levels in serum and venous blood gas samples (7.5 mmol/L and 3.9 mmol/L, respectively). However, the presence of an equivocal, prominent T wave in the 12-lead Electrocardiography (ECG) investigation triggered the medical team to manage this case as true hyperkalemia, consequently considering the deployment of calcium chloride, sodium bicarbonate bolus infusions and urgent dialysis. Following medical treatment, serum potassium level was 6.8 mmol/L, while the venous blood gas sample exhibited hypokalemia, with a potassium level of 2.5 mmol/L. Serum specimens were transported by pneumatic tube, and the time from phlebotomy to analysis was approximately 30 min using [Abbott Machine] following a five-minute centrifugation step. No hemolysis was observed, while a whole blood samples was collected in a blood-gas syringe (Q-cork, with 25-u balanced heparin) and immediately analyzed through a blood-gas analyzer machine [GEM premium 4000®] that is located within PICU.

The patient exhibited no acidosis, renal failure, or tumor lysis syndrome. Phosphate, calcium, and uric acid levels were not increased. Consequently, the patient was started on maintenance and a half IV fluid, allopurinol and dexamethasone since admission, awaiting the bone marrow biopsy result.

The wide discrepancy between serum potassium and blood-gas potassium levels raised the possibility of PHK (Table 3, Fig. 1). Additionally, the presence of hyperleukocytosis in the absence of other biochemical markers for tumor lysis in an asymptomatic and clinically stable patient with repeated normal 12 lead ECG and sinus rhythm—supported the possibility of PHK and was consequently investigated accordingly.

Additional venous blood samples were simultaneously obtained at 1 h post-potassium-lowering treatment (Table 3). These samples were heparin-containing-tube plasma sample, heparin-lacking-tube serum sample, and whole-blood-gas syringe sample. Plasma and serum specimens were immediately transported to the laboratory by hand (< 5 min transport time), promptly centrifuged, and analyzed within five minutes of centrifugation, while the whole-blood sample was analyzed immediately through a blood-gas analyzer machine in PICU. Surprisingly, the plasma level demonstrated an exacerbated potassium level of 7.4 mmol/L, in comparison to the serum potassium level (6.3 mmol/L) and whole-blood potassium level of 2.5 mmol/L in the blood-gas sample (Table 3).

Conclusively, the medical team deemed the high serum potassium level as a rPHK secondary to hyperleukocytosis. Meanwhile, the patient was monitored closely with a continuous cardiac monitor and serial 12-lead ECG readings, along with potassium level investigations from venous blood gas samples every 3–6 h, with no dialysis performed (Fig. 1). Consequently, the medical team decided not to actively intervene unless the patient became symptomatic, or her ECG demonstrated the characteristic changes of hyperkalemia. Fortunately, the patient remained asymptomatic, with normal serial

Table 1 Published case reports on rPPK and relevant patient characteristics

	Year	Author	Diagnosis	Age (year)	Causes of rPHK	Plasma K mEq/L	Serum K mEq/L	K in blood gas (whole blood)	WBC $\times 10^9$/L	Platelet $\times 10^9$/L	Creatinine mg/dL	TLS	ECG
1	1997	Singh [1]	CLL	70	NA	7	3.6		524		1.4–1.7		
2	2008	Boban [14]	CLL	49 female	heparin-mediated cell membrane damage during processing and centrifugation	10.7–11.2	2.7	2.6	369	100	No AKI	No	No abnormality
3	2011	Garwicz[23]	T cell ALL	2 year and 10 m	1-mechanical forces during sampling 2- heparin-induced membrane damage	5.6–11.6	NA	3.7	391	86	NA	NA	Normal
4	2011	Meng[15]	CLL	86 female	1-Heparin-induced cell membrane damage 2- higher consumption of metabolic fuels that lead to impaired Na/K ATPase pump activity resulting in release of potassium	7.5(lithium heparin plasma 76 units HEPARIN)	4.7	9.7 Lithium–heparin venous Whole blood (tube) 4.3 Venous whole blood (balanced lithium–heparin syringe)	374	158	84	LDH 382 U/L	Prolonged QT
5	2012	Garwicz [9]	CLL	76 male	Mechanical forces acting on the membranes of fragile leukemic cells during pneumatic tube transport of lithium heparin plasma samples Leukemic cells undergo lysis in vitro, releasing potassium and ATP to the plasma	7.3	4.8	NA	421	Normal	Normal	None	NA

Table 1 (continued)

	Year	Author	Diagnosis	Age (year)	Causes of rPHK	Plasma K mEq/L	Serum K mEq/L	K in blood gas (whole blood)	WBC × 10^9/L	Platelet × 10^9/L	Creatinine mg/dL	TLS	ECG
6	2014	Avelar [16]	CLL	78 male	Sensitivity to heparin-mediated cell membrane damage during processing and centrifugation	8.4	4.4	NA	206	158	1.4	Uric acid, 10.6 mg/dL calcium, 8.4 mg/dL phosphorus, 4.7 mg/dL	Normal
7	2015	Mansoor [17]	CLL	49 male	1-Fragility of malignant cells that Makes them prone to lysis 2-High consumption of metabolic fuels by leukemic cells that lead to impaired Na + /K + ATPase pump activity, resulting in potassium release	9.4 (pneumatic transport) 4.2 manual transport	3.7 (manual transport)	3.7	545	47	1.48	Uric acid of 6.4 mg/dL lactate dehydrogenase of 1746 units/L	Normal
8	2016	Huang[13]	CLL	83 male	Mechanical stress on chronic lymphocytic leukemia cells	7.4 (pneumatic transport) 3.1(hand-carried)	NA	3.4 (ABG syringe hand- carried to lab)	300	NA	NA	LDH 328 No evidence of TLS	Normal
9	2017	Li-Ting Juan [18]	ALL	61 male	Sensitivity of fragile leukemic cell membrane to heparin Potassium and LDH levels in plasma were both higher than those measured in serum	6.7–12.2	1.9–2.2	NA	480	45	Normal	Plasma LDH 840 U/L serum LDH 653 U/L	No hyperkalemia changes

Table 1 (continued)

	Year	Author	Diagnosis	Age (year)	Causes of rPHK	Plasma K mEq/L	Serum K mEq/L	K in blood gas (whole blood)	WBC × 10^9/L	Platelet × 10^9/L	Creatinine mg/dL	TLS	ECG
10	2020	Moreno [24]	B-cell NHL	65 male	Heparin induced lysis of WBCs leading to release of ATP that promotes active transport of potassium Out of lymphocytes and influx of Na intracellularly	> 10 plasma Na 123	4.9 serum Na 139	NA	263	55	Normal	None	NA
11	2020	Fresa A [19]	Atypical CLL	81 male	Pathological cells could have undergone death due to the exhaustion of the substrates necessary for survival, due in turn to the extreme hyperleukocytosis of the patient	7.5 3(Dx 81 mg/dl) 8.6 (Dx10mg/dl)	NA	Low (NA)	423.7	82	NA	LDH 2239 U/L	Normal
12	2020	Shamy [20]	Non sever leukocytosis cases 11 HM 34 NHM	(0–94 years) male and female 7 cases < 1 years	1-heparin-induced WBC membrane damage 2-leukocyte-induced consumption of metabolic fuels with resultant inhibition of the sodium pump (Nafl/Kfl-ATPase) and subsequent potassium release	5.5–6.6	4.0–5.2	NA	6.5–19.7	128–302	0.7–2.8	NA	All normal except one with peaked T wave

Table 1 (continued)

	Year	Author	Diagnosis	Age (year)	Causes of rPHK	Plasma K mEq/L	Serum K mEq/L	K in blood gas (whole blood)	WBC $\times 10^9$/L	Platelet $\times 10^9$/L	Creatinine mg/dL	TLS	ECG
13	2020	Ahmed[21]	NA ? CLL	60 male	1-Fragile leukemic cells during the clotting process 2-Severe leukocytosis leads to consumption of metabolic fuels that an impair Na–K ATPase activity, leading to release of potassium from a large number of white blood cells 3-Damage to the membrane of the millions of fragile malignant cells by the heparin in the tubes	6.2	3.5		440	NA	0.7	No	Normal
14	2020	Jafar [22]	CLL	67 woman	1-Fragile leukocyte especially with pneumatic transport 2-high metabolic fuel demand by malignant cells, causing depletion of ATP, which leads to dysfunction of the Na–K ATPase pump that normally helps keep potassium intracellular 3-Heparin induce membrane damage	5.6	4	4.3	161	NA	0.9	Creatine kinase 43 U/L, LDH 177 U/L, phosphorus level of 4.5 mg/dL uric acid 6.4 mg/dL,	Normal

ALL; acute lymphoblastic leukemia, CLL; chronic lymphocytic leukemia, NHL; non-Hodgkin lymphoma, HM; hematological malignancy, NHM; non-hematological malignancy

Table 2 Published case reports on rPPK management and outcomes

	Medication used to lower k	CRRT	WBC after chemotherapy	K level after normalization of WBC (mmol/L)	Outcome
1	NA	NA	NA	NA	NA
2	Calcium chloride, albuterol, dextrose-insulin, furosemide, and sodium polystyrene sulfonate	Planned but not done	NA	NA	no dialysis was performed, and potassium supplements were administered
3	NA	NA	3.7	4	NA
4	None	None	NA	NA	NA
5	None	None	150	4	
6	Intravenous calcium gluconate, intravenous insulin, and oral sodium polystyrene sulfonate	Partial hemodialysis	NA	NA	Hemodialysis stoped and patient treatend as rPHK
7	None	None	NA	4.3	Received chemo without complication and discharge home in good condition
8	Insulin plus glucose and sodium polystyrene	NA	NA	3.1 (after chemotherapy)	Received chemotherapy, no TLS or complication
9	Insulin and oral sodium Polystyrene sulfonate	Hemodialysis Day 3–6	100	3–3.2	Chemotherapy initiated His serum potassium level was maintained within the normal range during the rest of his hospital stay, whereas WBC counts continued to decrease with the progression of chemotherapy
10	NA	NA	364	WBC Never normalized	entered palliative care following multifocal intracerebral hemorrhage and died approximately two weeks after presentation
11	NA	NA	NA	NA	Paroxysmal atrial fibrillation (Ibrutinib was suspended and cardioversion with amiodarone was performed with success) Oral Cyclophosphamide with no SE
12	17 cases received either SPS, insulin, furosemide, NaHco3,	Hemodialysis in 3 cases (who are CKD or ESRD)	NA	NA	6(15%) died during hospitalization 4 received Potassium-lowering therapy and 4 had an HM
13	NA	NA	NA	NA	NA
14	Calcium gluconate, insulin, and dextrose cocktail	None			Discharged to home and advised regular follow-ups with her oncologist

12-lead ECG readings and normal serial readings of potassium level from venous blood-gas samples (Table 3, Fig. 1).

The following day, the patient was confirmed to have T-cell acute lymphoblastic leukemia and received her first cycle of chemotherapy course while maintaining a normal potassium level (venous blood-gas samples) with no evidence of tumor lysis. Following a further 24-h period, her leukocyte count dropped to $< 150 \times 10^9$/L. In addition, serum potassium level normalized to 4.5 mmol/L, matching the venous blood gas sample level (Table 3, Fig. 1).

Discussion

Hyperkalemia is not uncommon occurrence in pediatric hospital admissions, accounting for up to 29% of all pediatric intensive care unit admissions [6]. Hyperkalemia is a serious clinical manifestation that requires immediate and effective treatment, since a serum (or plasma)

Table 3 Serum potassium levels versus blood gas potassium level in relation to WBC counts

Sample	Serum Potassium (mmol/L)	Plasma potassium level	Potassium in blood gas (mmol/L)	WBC count × 10^9/L
1	7.5	N/D	3.9	400
2	7.2	N/D	N/D	N/D
3	6.3	7.4	N/D	440
4*	6.8	N/D	2.5	360.51
5	8.4	N/D	3.1	N/D
6	6.7	N/D	4.4	392.1
7**	4.5	N/D	4.3	135

N/D: not done

*Patient received treatment for hyperkalemia

**24-h post-chemotherapy

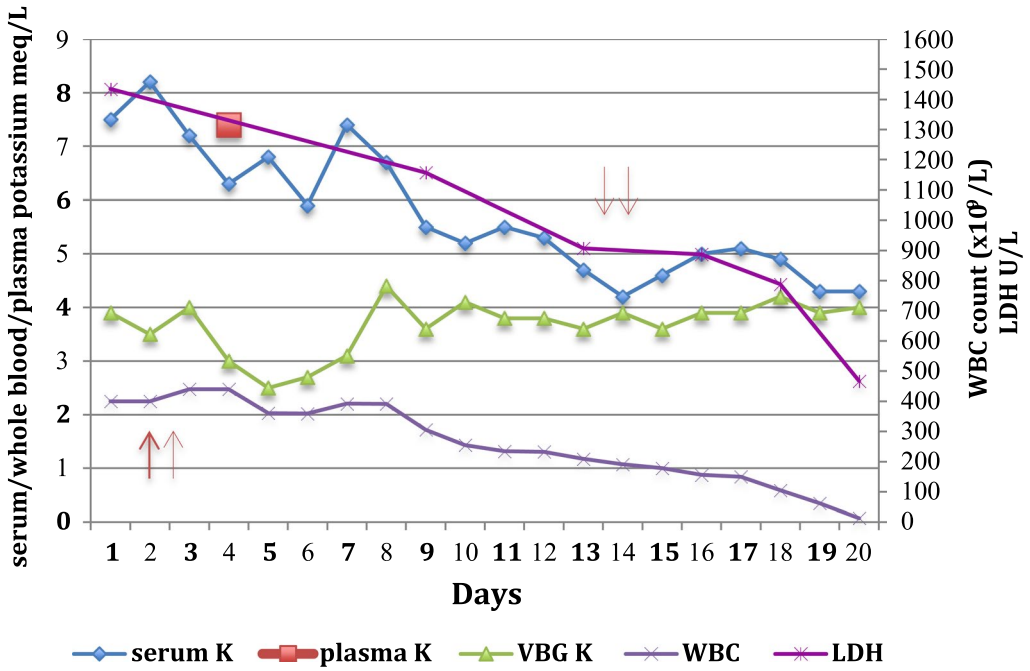

Fig. 1 Serum potassium, whole blood potassium levels and white blood cell counts in a patient with T-cell acute lymphocytic leukemia. Showed the discrepancy between serum (high level) compared to whole blood potassium level (low-normal), which indicates pseudohyperkalemia. Plasma potassium (red dot) is even higher than serum potassium, which indicates reverse pseudohyperkalemia. Potassium level in blood gas dropped to 2.5 after receiving K-lowering agent (up-arrow). Serum potassium level normalized when WBC count dropped below 150 (down-arrow)

potassium level > 7 mmol/L is potentially lethal due to its cardiotoxicity [6, 7].

Since the ratio of total body intracellular to extracellular potassium is approximately 40:1, while the ratio of circulating blood cells to plasma potassium is approximately 20–30:1, any minute release of intracellular potassium can inaccurately raise its serum or plasma levels. Consequently, it is essential to differentiate between true hyperkalemia and spurious PHK, in order to avoid exposing the patient to unnecessary medications and needless acute dialysis that carries significant adverse effects and can lead to fatal hypokalemia [7, 8] Unfortunately, in the case described above, this was recognized following the patient having received medical treatment for hyperkalemia, where venous blood-gas potassium level dropped significantly, though without complications (Table 3, Fig. 1).

Spurious hyperkalemia is considered when in vitro-measured serum (or plasma) potassium level is falsely raised to above the local reference range upper limit,

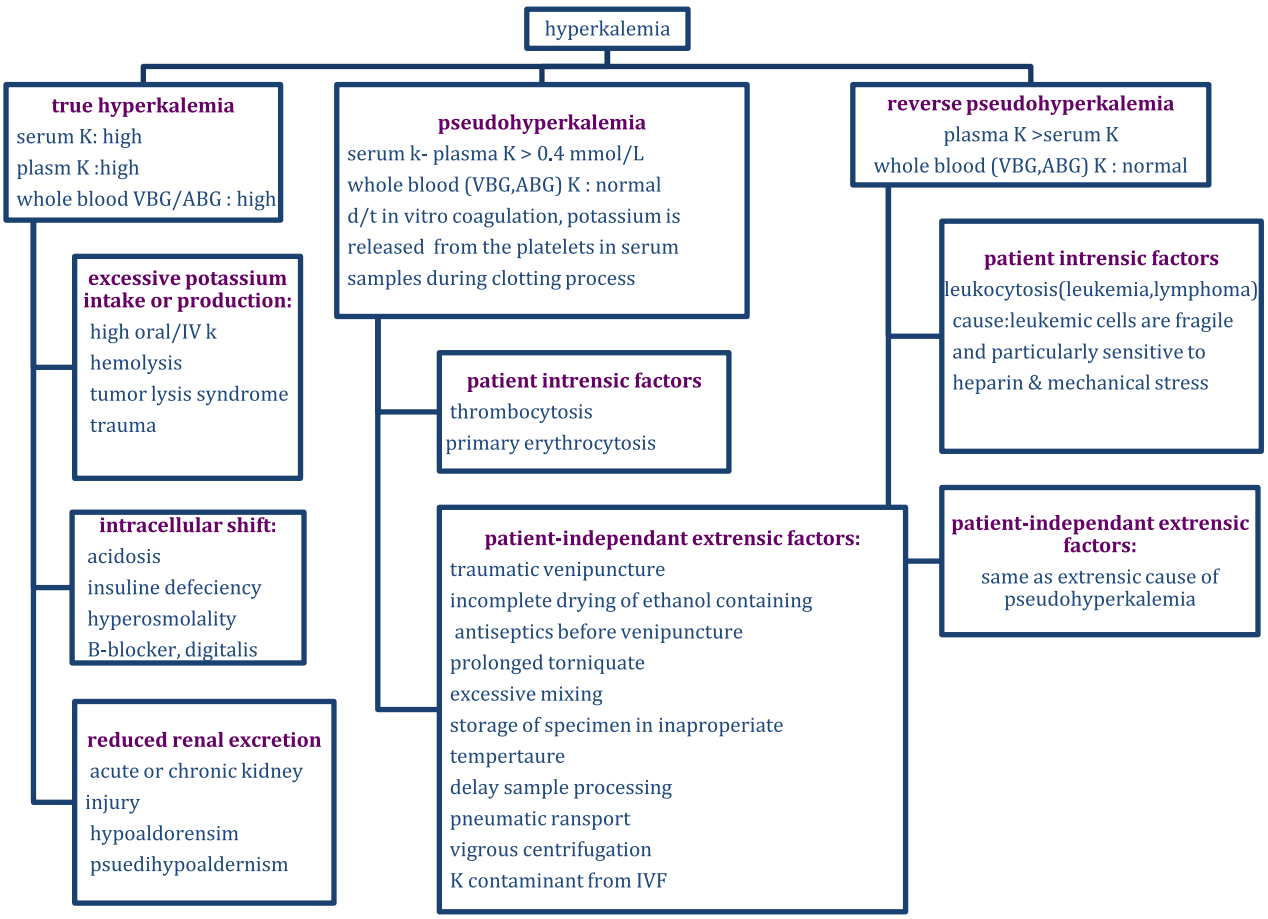

Fig. 2 Summary of how to differentiate between hyperkalemia, pseudohyperkalemia, and reverse pseudohyperkalemia with selected possible causes. Blood plasma potassium level (blood sample with coagulation), blood serum potassium level (blood sample with no coagulation), whole blood (arterial or venous) blood gas sample with no coagulation and direct analysis without pneumatic transport or centrifugation. Normally, serum K > plasma K by 0.36 ± 0.18 mmol/L

while the actual in vivo level is normal [4]. There are two defined clinical conditions that lead to spurious hyperkalemia: PHK and rPHK. Serum is defined as the remainder-portion of blood, post-coagulation. However, plasma is obtained when blood clotting is prevented, with addition of anti-coagulants such as heparin. Based on previous reports, PHK is defined as a serum potassium level exceeding plasma potassium level by 0.4 mmol/L, provided that samples are collected under strict standardized techniques, maintained at room temperature (15–25 °C), and analyzed within one hour post-blood sample collection [7, 8].

PHK was first described by Hartmann and colleagues in 1955, where he reported a case of hyperkalemia in a patient with thrombocytosis and attributed this to the excess of potassium released by platelets during the clotting process [2, 3]. Thereafter, several theories were postulated for the possible etiology of PHK, including in vitro hemolysis during blood sample collection using narrow-gauge needles, fist clenching during phlebotomy and prolonged use of a tourniquet. Other researchers suggested that in vitro hemolysis could result from improper processing of blood samples, such as vigorous shaking of samples post-collection, prolonged sample incubation period in inappropriate temperatures, and excessive centrifugation [7, 9–11],(Fig. 2). Ku and colleagues, similarly to Dickinson and colleagues, had compared plasma and serum potassium levels in acute leukemia using two transport methods, concluding that the potassium level is highly exacerbated within pneumatic transport of samples, in comparison to messenger / hand transport [7, 12]. These possible extrinsic causes of PHK might be exaggerated in patients with extreme hyperleukocytosis, thrombocytosis, and polycythemia, especially in cases of leukemia—where the cell fragility is highly increased.

(Table 3, Fig. 2). Moreover, inherited defects in the erythrocyte membrane structure that causes in vitro leak of potassium, such as leaky cell syndrome (familial pseudohyperkalemia) were reported in selected cases [7, 9–11](Fig. 2).

Our patient initially demonstrated an elevated serum potassium level. Consequently, in order to eliminate all possible mechanical causes of cell lysis—secondary to delayed transportation or using a pneumatic transport system—blood samples were collected by an expert nurse from the central line and sent immediately to the hospital laboratory by hand for analysis. The analyzed serum potassium level was 6.3 mmol/L, in comparison to the serum potassium level of 7.5 mmol/L, from another sample transported through pneumatic tube facilities. This discrepancy indicated that pneumatic transport can play a role in the pseudo-elevation of serum potassium. This was also demonstrated by Garwicz et al., together with and Huang and colleagues, where both research groups identified that pneumatic tube-transported samples resulted in exacerbated plasma potassium levels in comparison to manually-transported samples in a patient with chronic lymphocytic leukemia (CLL) and hyperleukocytosis [9, 13].

In addition, our medical team considered the possibility of potassium discharge from platelets during the clotting process within the serum sample, so an additional plasma blood sample was collected within a heparinized tube and sent immediately to the laboratory by hand, along with another serum sample (un-heparinized tube). Surprisingly, the potassium level was found to be elevated within plasma, in comparison to the serum potassium level (7.42 mmol/L and 6.4 mmol/L, respectively). This raised the possibility of rPHK, where plasma-potassium levels are typically higher than serum- potassium levels, and is an opposing clinical finding in comparison to PHK.

Singh et al. first described rPHK in 1997, in a patient with chronic lymphocytic leukemia (CLL) when the team noticed a discrepancy in potassium levels (between heparinized and un-heparinized blood samples) [1]. Previous literature concerning rPHK is limited, although our literature review identified 14 case reports that were predominantly adult patients with chronic lymphocytic leukemia (CLL) and lymphoma [1, 9, 13–22]. This study identified only one case similar to the above-described case, that was reported in a child with ALL, indicating that rPHK can occur in any age group [23]. Interestingly, Mansour and colleagues hypothesized that rPHK might carry a good prognostic indicator for CLL patients, since rPHK has a directly-proportional correlation with higher fragile cell numbers (i.e. smudge cell in CLL) which is a known prognostic factor in CLL [24].

The mechanism of rPHK is not clearly understood, though several observations have been made. Meng and colleagues demonstrated that increasing heparin concentrations within collection tubes were associated with increased potassium and LDH levels, implying increased WBC lysis since no hemolysis was observed [15]. These findings are not surprising given that the cells in patients with leukemia are both fragile and in higher abundance, consequently having increased heparin sensitivity and susceptibility to lysis, particularly during processing, pneumatic-tube transportation, and centrifugation [25]. This could explain the finding in our leukemic patient, where her leukocyte count was extremely high ($WBC > 400 \times 10^9/L$, with 90% blasts). Furthermore, the clotting process within serum samples might prevent movement of entangled white blood cells and, consequently, minimize their exposure to traumatic lysis and leading to lower serum potassium levels, in comparison to plasma levels [26]. This theory was argued against by El Shamy and colleagues in their recent retrospective cohort study, who demonstrated that 44% of the study population had developed rPHK in the absence of leukocytosis, with approximately 17% of of this cohort having a hematological malignancy [20].

Another theory suggested that severe leukocytosis and malignant cells have increased consumption of metabolic fuels, causing depletion of adenosine triphosphate (ATP), that can lead to impaired Na+/K+ATPase pump activity (which typically maintains intracellular potassium levels constant). This results in the extracellular release of potassium from the exacerbated number of WBCs that are present in such cases [9, 14, 15, 17, 27].

An alternative explanation could be that leukemic cells undergo in vitro lysis, which leads to the release of cytoplasmic adenosine triphosphate (ATP) into plasma. Extracellular ATP has previously been shown to increase the in vitro cation permeability of lymphocytes from patients with CLL [17]. Influx of monovalent sodium (Na+) and lithium (Li+) ions was increased, while there also was a decrease in total cellular potassium (K+) levels, suggesting that extracellular ATP is an energy source for the active transport of potassium ions out of undamaged cells [17].

Considering other contributing factors for the pseudo-elevation of potassium levels in serum and plasma samples, blood gas or whole-blood potassium level appears to be more accurate and remains the analysis of choice, particularly since it is a rapid and reliable analytical procedure due to the short interval between the sample-drawing and actual analysis, as demonstrated in the above-described case. Lee and colleagues have reported this observation in four adult cases with CLL, where plasma potassium levels were exacerbated in comparison

to potassium levels following whole-blood gas analysis [25].

A total of six out of the 14 reported previous literature cases with rPHK had received a potassium-lowering agent, together with dialysis that was initiated in three of such cases. Some patients developed hypokalemia following such interventions and required potassium supplements (Table 2). This raised the importance of carefully interpreting elevated potassium levels in children with leukemia and hyperleukocytosis, who typically have a normal renal function, and instead consider the possibility of PHK or rPHK. Additionally, we recommend using potassium levels in whole-blood gas samples as a reference for the diagnosis and management of true hyperkalemia in patients with acute leukemia and hyperleukocytosis, in order to avoid any treatment-related complications.

Conclusion

Early recognition and diagnoses of rPHK are vital in all patients with significant leukocytosis (from hematologic neoplasms) that present with hyperkalemia, in the absence of other clinical or EKG-based evidence of hyperkalemia, in order to avoid any harmful outcomes following any invasive intervention.

We conclude that the potential for PHK and rPHK exists in serum and plasma samples, within the setting of leukocytosis in a patient with hematological malignancy. In such cases, whole-blood analysis is more accurate.

Finally, cancer centers should establish a mechanism through which their information system flags results of high potassium levels, specifically in patients with leukocyte counts > 100,000/mm^3 that raise the possibility of PHK and hence minimize medical errors and improper management, in order to ensure a better quality of care and enhance patient safety.

Further investigation is still needed to identify in greater precision any factors that are associated with rPHK, and to clearly understand the pathophysiologic mechanisms underlying cell lysis.

Abbreviations

PHK: Pseudohyperkalemia; rPHK: Reverse pseudohyperkalemia; ECG: Electrocardiography; WBC: White blood cell; PICU: Pediatric intensive care unit; CBC: Complete blood count; Hgb: Hemoglobin; LDH: Lactate dehydrogenase; CLL: Chronic lymphocytic leukemia.

Acknowledgements

Not applicable.

Authors' contributions

MA; collected all patient data and wrote the case. HA; systematic literature review, manuscript editing, prepared all tables/figures/graphs/references, and submitted the article for publication as 'corresponding author'. MK; wrote the manuscript and reviewed literature. AF; reviewed and edited the manuscript. AO; reviewed and edited the manuscript.

Funding

Not applicable.

Availability of data and materials

Data sharing not applicable to this article as no data sets were generated or analyzed during the current study.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Received: 1 November 2020 Accepted: 27 October 2021
Published online: 11 December 2021

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