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A Smartphone-Based Predictor of Hypokalemia in Pediatric Acute Gastroenteritis: A Pilot Diagnostic Accuracy Study

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Abstract. Acute gastroenteritis is a common cause of pediatric admission in low- and middle-income settings, where serum potassium results may not be available when initial treatment decisions are made. This pilot study evaluated the feasibility and preliminary diagnostic accuracy of the SE-PO Serum Potassium Predictor, an Android application that converts bedside clinical and electrocardiographic findings into a predicted serum potassium value. A cross-sectional diagnostic accuracy design was used among 530 children aged five months to 17 years admitted for acute gastroenteritis at a tertiary government hospital in the southern Philippines from February to September 2017. The bedside assessment was completed before intravenous fluids were started and before laboratory results were released. Venous serum potassium served as the reference standard, with hypokalemia defined as less than 3.5 mEq/L. Hypokalemia was confirmed in 267 children (50.4%). The application showed 92.1% sensitivity, 97.3% specificity, a positive likelihood ratio of 34.62, a negative likelihood ratio of 0.08, and an area under the receiver operating characteristic curve of 0.988. Bland-Altman analysis showed a mean underestimation of 0.18 mEq/L. Detection was 100% for moderate and severe hypokalemia but 76.1% for mild hypokalemia, while specificity decreased to 81.5% among children with hypovolemic shock. Bedside use was feasible within the admission workflow. These findings are promising but should be interpreted as single-center pilot estimates because the model was evaluated in the same institution in which it was developed. Laboratory measurement must remain the basis for potassium correction, and prospective external validation is required before clinical adoption.

Keywords: diagnostic accuracy; hypokalemia; mHealth; pediatric acute gastroenteritis; point-of-care prediction

Introduction

Acute gastroenteritis remains a major cause of childhood illness, particularly in low- and middle-income countries where access to timely electrolyte testing may be limited (World Health Organization, 2005). At Zamboanga City Medical Center, it has consistently been among the leading causes of pediatric admission. In 2017, 1,200 children were admitted with acute gastroenteritis, making it the second leading cause of morbidity in the Department of Pediatrics. Many presented with dehydration and electrolyte disturbances that required prompt assessment and treatment.

Hypokalemia, commonly defined as a serum potassium concentration below 3.5 mEq/L, may occur when gastrointestinal potassium losses from diarrhea and vomiting exceed physiologic replacement. Clinically important depletion can cause muscle weakness, abdominal distension, paralytic ileus, respiratory compromise, and cardiac arrhythmias (Greenbaum, 2016). Electrocardiographic findings associated with hypokalemia include PR-interval prolongation, T-wave flattening, and prominent U waves (Park, 2008).

Laboratory measurement of serum potassium remains the reference method for diagnosis. In routine care, however, results may be delayed for several hours after blood collection. Clinicians managing a dehydrated child, particularly one with shock, may therefore need to prioritize investigations and supportive care before the potassium result becomes available.

To support early bedside assessment, a clinical scoring model was developed at Zamboanga City Medical Center in 2012 using weighted clinical and electrocardiographic predictors. The model was subsequently

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incorporated into a free Android application, the SE-PO Serum Potassium Predictor, which generates a predicted serum potassium value from findings entered by the clinician.

Individual clinical and electrocardiographic indicators of potassium depletion are well described, and electrolyte results can influence management in children with dehydration (Park, 2008; Wathen et al., 2004). Evidence is limited, however, on whether these indicators can be combined into a reproducible point-of-care estimate before the laboratory result is available. This study evaluated the feasibility of bedside use and generated preliminary estimates of the diagnostic accuracy and agreement of the SE-PO application.

Research Questions

The study addressed the following questions:

1. Can the SE-PO application be completed within the routine admission workflow before intravenous fluids are started and before laboratory potassium results are released?
2. What is the preliminary diagnostic accuracy of the application for detecting hypokalemia, based on sensitivity, specificity, predictive values, likelihood ratios, and area under the receiver operating characteristic curve?
3. What is the level of agreement between the potassium value predicted by the application and the value measured in the laboratory?
4. Does diagnostic performance differ according to degree of dehydration and severity of hypokalemia?

Scope and Delimitation of the Study

The study included children aged five months to 17 years who were admitted for acute gastroenteritis to Ward 8 of Zamboanga City Medical Center from February to September 2017. It evaluated an existing prediction model and did not derive a new model or include an external validation cohort. Long-term outcomes, cost, and cost-effectiveness were outside the study scope. Feasibility was defined as successful completion of the bedside assessment before intravenous fluids were started and before laboratory results were released. Completion time, user error, and clinician-rated usability were not formally measured. Because convenience sampling was used at a single tertiary hospital, the findings are presented as preliminary pilot estimates.

Literature Review

Hypokalemia in Pediatric Acute Gastroenteritis

Potassium depletion in acute gastroenteritis results primarily from gastrointestinal losses and may be aggravated by reduced intake and ongoing fluid losses. The clinical effects range from mild weakness to ileus, respiratory compromise, and cardiac arrhythmia, making early recognition important in children with moderate to severe dehydration (Greenbaum, 2016).

Bedside and Electrocardiographic Indicators

PR-interval prolongation, T-wave flattening, and U-wave prominence are recognized electrocardiographic manifestations of hypokalemia (Park, 2008). Clinical findings such as muscle weakness, head lag in infants, wasting, and abdominal distension may also suggest potassium depletion. Individually, however, these signs are neither sufficiently sensitive nor specific to replace laboratory testing. Their combined performance as a quantitative bedside estimate requires empirical evaluation.

Role of Laboratory Confirmation

Serum electrolyte testing can identify abnormalities that alter management in dehydrated children receiving intravenous fluids (Wathen et al., 2004). The clinical value of this information depends partly on turnaround time. A bedside prediction may help clinicians prioritize monitoring and laboratory follow-up, but treatment decisions involving potassium replacement still require a confirmed serum value.

Diagnostic Accuracy and Agreement

Diagnostic accuracy studies should report participant selection, index and reference tests, analysis methods, and estimates with measures of uncertainty in accordance with STARD 2015 (Bossuyt et al., 2015). Exact confidence intervals can be used for sensitivity, specificity, and predictive values (Clopper & Pearson, 1934), while likelihood-ratio intervals may be estimated using the method of Simel et al. (1991). Agreement between predicted and measured values should be assessed separately from correlation because a high correlation does not exclude systematic bias (Bland & Altman, 1986).

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Methodology

Research Design

A cross-sectional pilot diagnostic accuracy design was used. The index test and the reference standard were applied during the same admission episode. The report follows the STARD 2015 framework (Bossuyt et al., 2015). The present manuscript is a secondary analysis of prospectively collected pilot data.

Sampling Design

Eligible admissions were enrolled through convenience sampling during the study period. This approach was considered acceptable for an exploratory pilot but may have introduced selection bias because eligible children admitted when the study team was unavailable were not enrolled. A subsequent validation study should use consecutive sampling and a sample size calculated for the desired precision of sensitivity and specificity, accounting for disease prevalence (Buderer, 1996).

Research Locale

The study was conducted in Ward 8, the pediatric ward of Zamboanga City Medical Center. At the time of data collection, the hospital served as a tertiary referral, training, and research facility for Zamboanga Peninsula and nearby provinces. Ward 8 had 80 beds organized into seven pediatric subunits.

Research Participants

Participants were children aged five months to 17 years admitted with acute gastroenteritis, defined as at least three loose or watery stools within 24 hours. Children were excluded if they had received antibiotics, laxatives, or chemotherapeutic agents during the preceding two weeks; had been transferred from another facility while already receiving intravenous fluids; had a concurrent serious illness such as sepsis or pneumonia; or had global or pure motor developmental delay. Six records with missing application outputs or laboratory potassium results were excluded, leaving 530 participants in the analytic sample.

Research Instrument

The research instrument utilized in this study was the SE-PO Serum Potassium Predictor, an Android-based application derived from an internally developed 2012 regression model. Upon patient admission, the resident pediatrician documented three clinical indicators—severe wasting, head lag, and abdominal distension—as well as three electrocardiographic findings obtained from a long Lead II tracing, namely prolonged PR interval, flat T wave, and prominent U wave. In addition, pairwise and three-way combinations of selected electrocardiographic findings were incorporated into the model. Each predictor variable was encoded dichotomously as present (1) or absent (0), enabling the application to generate an estimated serum potassium level expressed in milliequivalents per liter (mEq/L). The predictive equation applied was: Predicted K^+ (mEq/L) = 3.9 − 0.82(severe wasting) − 0.60(head lag) − 0.34(abdominal distension) − 0.90(prolonged PR interval) − 0.88(flat T wave) − 0.72(prominent U wave) − 0.83(prolonged PR interval with flat T wave) − 1.34(prolonged PR interval with prominent U wave) − 0.68(prolonged PR interval with flat T wave and prominent U wave). Corresponding coefficients for each predictor were established based on the regression model. Laboratory-determined serum potassium served as the reference standard for validation. At the time of bedside assessment, approximately 5 mL of venous blood was collected, properly labeled with the assigned study number, and promptly transported to the hospital laboratory for analysis by licensed medical technologists. Standard phlebotomy procedures were strictly followed to minimize the risk of hemolysis. Hypokalemia was operationally defined as a serum potassium concentration below 3.5 mEq/L, consistent with the criteria established by Greenbaum (2016).

Data Gathering Procedure

Eligible children were identified at admission. After written parental or guardian consent, the resident on duty completed the clinical examination and electrocardiographic long Lead II tracing, entered the findings into the SE-PO application, and recorded the predicted value. This process was completed before intravenous fluids were started and before the laboratory result was released. Laboratory personnel processed the samples through routine procedures and were not given the application output. Formal documentation of assessor blinding was not implemented during the original data collection and is therefore treated as a study limitation.

Results and Discussions

Research Question 1: Can the SE-PO application be completed within the routine admission workflow before intravenous fluids are started and before laboratory potassium results are released?

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Table 1. Baseline Characteristics of the Study Population (N = 530)

Characteristic	n	% or Mean (SD)
Sex, male	310	58.5
Sex, female	220	41.5
Moderate dehydration	407	76.8
Severe dehydration	45	8.5
Hypovolemic shock	78	14.7
Measured serum potassium, mean (SD)	n.a.	3.476 (0.831)
Measured serum potassium, median	n.a.	3.490
SE-PO predicted potassium, mean (SD)	n.a.	3.293 (0.643)
SE-PO predicted potassium, median	n.a.	3.560
Hypokalemia confirmed (K+ <3.5 mEq/L)	267	50.4

The observed prevalence of hypokalemia was substantially higher than the 30% prevalence assumed during the initial sample-size planning. Because predictive values depend on disease prevalence, the positive and negative predictive values reported here should not be transferred directly to populations in which hypokalemia is less or more common. The analytic sample included 530 children, of whom 310 (58.5%) were boys. Most had moderate dehydration (407, 76.8%); 45 (8.5%) had severe dehydration and 78 (14.7%) presented with hypovolemic shock. The mean laboratory serum potassium was 3.476 mEq/L (SD 0.831), compared with a mean predicted value of 3.293 mEq/L (SD 0.643). Hypokalemia was confirmed in 267 children, giving a prevalence of 50.4%.

Feasibility of Bedside Use

The SE-PO assessment was completed for every enrolled child before intravenous fluids were started and before the laboratory result was released. Under the study definition, bedside use was therefore feasible within the routine admission workflow. This conclusion is limited to timely completion. The study did not measure completion time, user error, ease of use, or clinician acceptability. In addition, the requirement for an electrocardiograph may limit use in facilities without functioning equipment.

Diagnostic Accuracy of the SE-PO Application

The application correctly classified 246 of 267 children with laboratory-confirmed hypokalemia and 256 of 263 children without hypokalemia. There were 21 false-negative and 7 false-positive results

Table 2. SE-PO Classification Versus Laboratory-Confirmed Hypokalemia (N = 530)

SE-PO predictor	Hypokalemia (K+ <3.5 mEq/L)	No hypokalemia (K+ ≥3.5 mEq/L)	Total
Hypokalemia predicted	246 (TP)	7 (FP)	253
No hypokalemia predicted	21 (FN)	256 (TN)	277
Total	267	263	530

Note. *TP = true positive; FP = false positive; FN = false negative; TN = true negative.*

Research Question 2: What is the preliminary diagnostic accuracy of the application for detecting hypokalemia, based on sensitivity, specificity, predictive values, likelihood ratios, and area under the receiver operating characteristic curve?

Table 3. Diagnostic Performance of the SE-PO Application

Metric	Value	95% CI or limits of agreement
Sensitivity	92.13%	88.23–95.07%
Specificity	97.34%	94.59–98.92%
Positive predictive value	97.23%	94.38–98.88%
Negative predictive value	92.42%	88.64–95.25%
Positive likelihood ratio	34.62	16.65–71.96
Negative likelihood ratio	0.08	0.04–0.17
Diagnostic odds ratio	428.41	178.92–1025.78
Area under the ROC curve	0.988	0.979–0.997
Pearson correlation (association)	0.902	0.884–0.916
Bland-Altman bias (predicted – measured)	−0.18 mEq/L	Bias 95% CI: -0.22 to -0.15; LoA: -0.92 to 0.55
Hypokalemia prevalence	50.38%	46.03–54.72%

Note. *ROC = receiver operating characteristic; CI = confidence interval; LoA = 95% limits of agreement. The AUC confidence interval was estimated using the method of Hanley and McNeil (1982).*

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The likelihood ratios indicate substantial separation between positive and negative results. At the 50.4% pretest probability observed in this sample, a positive result corresponds to a post-test probability of approximately 97%, while a negative result reduces the post-test probability to approximately 8%. These estimates may help prioritize laboratory review and monitoring, but they do not support potassium replacement without laboratory confirmation (McGee, 2002; Simel et al., 1991). The high accuracy estimates require cautious interpretation. The model was developed and evaluated within the same institution and a closely related patient population, creating a risk of optimism and overfitting. No independent comparator tool or external validation cohort was included. The present estimates should therefore be regarded as pilot performance rather than established generalizable accuracy.

Research Question 3: What is the level of agreement between the potassium value predicted by the application and the value measured in the laboratory?

Discriminative Ability

The continuous predicted values produced an area under the receiver operating characteristic curve of 0.988 (95% CI 0.979 to 0.997), indicating very high discrimination within this sample (Figure 1).

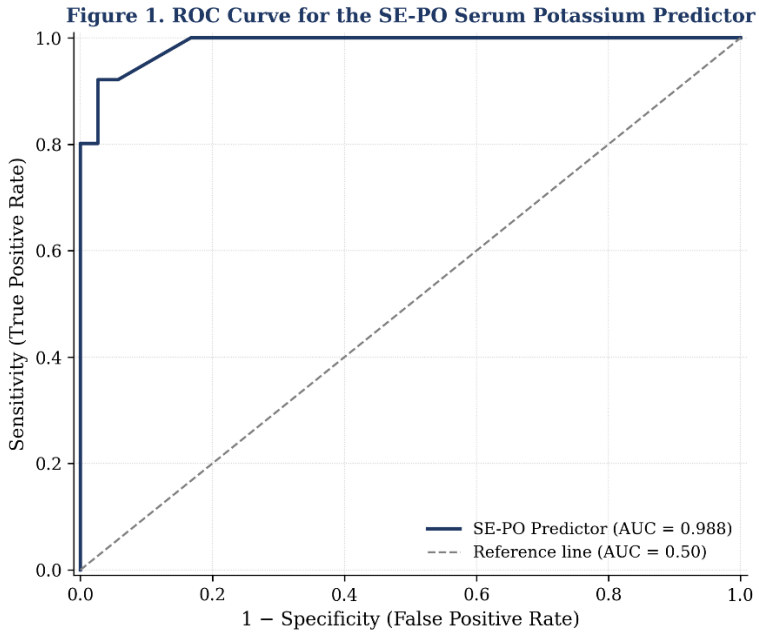

Figure 1. *Receiver operating characteristic curve for the SE-PO Serum Potassium Predictor. The continuous predicted serum potassium value was used as the classifier score. The area under the curve was 0.988 (95% CI 0.979 to 0.997); the diagonal line represents chance discrimination.*

Agreement Between Predicted and Measured Values

The Pearson correlation between predicted and laboratory potassium values was 0.902 (95% CI 0.884 to 0.916, $p < 0.001$), showing a strong linear association. Correlation alone does not establish agreement. Bland-Altman analysis showed that the application underestimated serum potassium by a mean of 0.18 mEq/L (95% CI -0.22 to -0.15), with 95% limits of agreement from -0.92 to 0.55 mEq/L. This downward bias tends to increase positive classifications and may trade fewer missed cases for more false-positive results. The width of the limits of agreement also indicates that calibration should be examined in an external validation study. Figure 2 displays the paired predicted and measured values.

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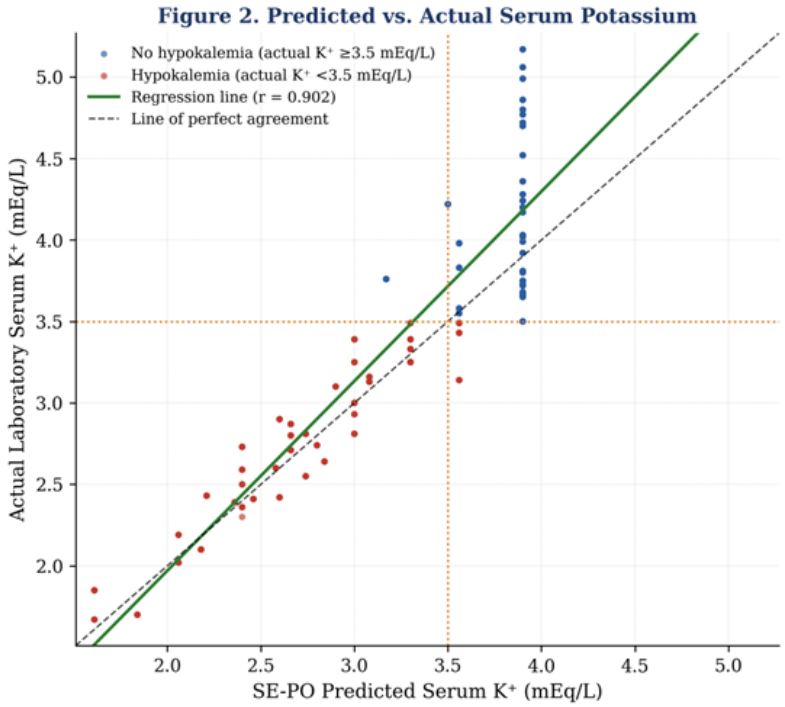

Figure 2. *SE-PO-predicted versus laboratory-measured serum potassium (N = 530). Points are classified by laboratory-confirmed hypokalemia status. The solid line is the fitted regression line (r = 0.902), the dotted horizontal and vertical lines mark the 3.5 mEq/L threshold, and the diagonal line represents perfect agreement.*

Research Question 4: Does diagnostic performance differ according to degree of dehydration and severity of hypokalemia?

Accuracy by Degree of Dehydration

Sensitivity remained above 91% in each dehydration subgroup. Specificity was 99.5% among children with moderate dehydration, 95.2% among those with severe dehydration, and 81.5% among those with hypovolemic shock.

Table 4. Sensitivity and Specificity by Degree of Dehydration

Subgroup	n	Hypokalemia (n)	TP	Sensitivity	Specificity
Moderate dehydration	407	192	175	91.1%	99.5%
Severe dehydration	45	24	24	100.0%	95.2%
Hypovolemic shock	78	51	47	92.2%	81.5%

The lower specificity in hypovolemic shock means that false-positive classifications were more frequent among the most critically ill participants. Possible explanations include physiologic instability and electrocardiographic changes that are not specific to potassium depletion. Because this subgroup was relatively small and the study was not designed to test these mechanisms, the finding should be confirmed prospectively. In children with shock, the application should be interpreted only as an adjunct to urgent clinical assessment and laboratory testing.

Accuracy by Severity of Hypokalemia

Detection increased with the severity of potassium depletion. The application identified all moderate and severe cases but detected 67 of 88 mild cases, corresponding to 76.1% sensitivity in the mild subgroup.

Table 5. Detection Rate by Severity of Hypokalemia

Hypokalemia severity	n (confirmed)	Correctly detected	Detection rate
Mild (K+ 3.0–3.4 mEq/L)	88	67	76.1%
Moderate (K+ 2.5–2.9 mEq/L)	109	109	100.0%
Severe (K+ <2.5 mEq/L)	70	70	100.0%
Total	**267**	**246**	**92.1%**

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Mild hypokalemia may produce less pronounced clinical and electrocardiographic findings, which could reduce the sensitivity of a bedside scoring model (Park, 2008). Although the missed cases occurred in the mild category, they remain clinically relevant. A negative application result should therefore not be used to exclude hypokalemia or to cancel laboratory testing.

Ethical Considerations

The Zamboanga City Medical Center Ethics Review Committee approved the protocol under ERC Protocol No. 2017-26. Written informed consent was obtained from a parent or legal guardian before enrollment, and assent was sought from older children when appropriate. Participation was voluntary and declining did not affect care. Records were coded, identifiers were stored separately from the analytic dataset, and access was limited to the investigators in accordance with the Data Privacy Act of 2012. The additional venous blood collection posed minimal risk beyond routine phlebotomy, and study data were stored securely and used only for the approved research purposes.

Conclusion

In this single-center pilot study of 530 children admitted with acute gastroenteritis, the SE-PO application showed 92.1% sensitivity, 97.3% specificity, a positive likelihood ratio of 34.62, and an area under the curve of 0.988 for detecting laboratory-confirmed hypokalemia. The assessment was completed within the admission workflow before intravenous fluids were started and before laboratory results were released. Performance was strongest for moderate and severe hypokalemia, while approximately one in four mild cases was missed and specificity decreased among children with hypovolemic shock. Because the model was evaluated in the same institutional setting in which it was developed, the estimates may be optimistic. The application should not replace laboratory measurement, and potassium correction should continue to be based on confirmed serum values. Prospective external validation is required before clinical adoption.

Recommendations

For clinical use, the application should be presented only as an adjunct that prompts early attention to potassium status while laboratory confirmation is pending. Any guidance accompanying the tool should explicitly state its reduced sensitivity for mild hypokalemia and reduced specificity in hypovolemic shock. For implementation, a simplified model that does not require electrocardiographic inputs may be explored and independently evaluated, particularly for rural and primary care settings. Such a model should not be deployed until its discrimination, calibration, and clinical safety have been tested. For research, the next study should use prospective consecutive enrollment across multiple centers, document blinding of index-test and reference-standard assessors, calculate the sample size using the desired precision of sensitivity and specificity, and prespecify age-stratified analyses. External validation should include calibration plots and measures, decision-curve or clinical-utility analysis where appropriate, and usability outcomes such as completion time, user error, and clinician acceptability.

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