New Predictive Equations for Serum Ionized Calcium in Hospitalized Patients

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Key Words
Calcium · Calcium metabolism disorders · Hospitalization · Hypocalcemia · Predictive value of tests

Abstract
Objective: To study a new and easy way to calculate equations to predict ionized calcium (\(Ca^{2+}\)) for adult hospitalized patients with the usual laboratory and clinical parameters.

Subjects and Methods: This retrospective observational study was conducted in a third-level university hospital. An initial learning cohort (cohort L: 269 patients) was selected to derive the new equations. These equations were tested in a validation of another cohort (cohort V: 146 patients). Patients selected were hospitalized adults who had simultaneous determinations of \(Ca^{2+}\) and serum total calcium (CaTot). They were classified using their estimated glomerular filtration rate (GFRre) into normal function, moderate and severe kidney dysfunction. Demographic and biochemical parameters, in addition to comorbidities, were collected from hospital databases. Nine published equations to predict \(Ca^{2+}\) and 2 widely used equations to predict corrected CaTot were also selected to be compared to newer equations for accuracy in detecting serum calcium alterations. New equations were derived by a multiple linear-regression analysis from patients in cohort L. Results: Three equations were derived containing the CaTot square root as the main independent variable. Equation 1: \(Ca^{2+} = 0.815 \times CaTot^{0.5}\), Equation 2: \(Ca^{2+} = 0.826 \times CaTot^{0.5} - 0.023 \times renal\) function.

Equation 3: \(Ca^{2+} = 0.813 \times CaTot^{0.5} - 0.006 \times albumin^{0.75} + 0.079\). These equations performed better than published equations to predict \(Ca^{2+}\) when their error measures were analyzed in cohort V, even in special populations such as critically ill and very old patients. Conclusions: Three new equations predicting \(Ca^{2+}\) were derived requiring easily available clinical and laboratory parameters. They could be valuable in predicting hypocalcemia but are of limited use in hypercalcemia.

Introduction
Calcium plays an essential role in many enzymes, membrane transporters and multiple physiological processes [1]. It is the most abundant mineral in the human body and mainly stored in the bones [2]. In serum, calcium exists in three forms: bound to proteins, predominantly albumin (40–50%), forming complexes with anions such as citrate, lactate or phosphate (5–10%), and in a free ionized form known as ionized calcium (\(Ca^{2+}\); 45–50%) [2]. The \(Ca^{2+}\) is the biologically active form [3], and its measurement has been suggested as a reference test for calcium status [4–7]. However, serum total calcium (CaTot) determination is still the most used test in health centers [1, 2] that needs subsequent correction by equations to obtain a ‘corrected calcium’ [1, 2]. These equations are based on the fact that CaTot is lower in hypoalbuminemia.
than in normoalbuminemia, but being the calcium bound to albumin the only fraction decreased and not the Ca\(^{2+}\). ‘Corrected calcium’ equations try to deduce CaTot supposing normoalbuminemia. The Ca\(^{2+}\) test is viewed by many clinicians as neither practical due to technical reasons nor cost-effective for all patients [1, 2], or, conversely, it is ordered excessively leading to increased costs [8]. Equations to predict Ca\(^{2+}\) could be an alternative when this value is not available, difficult to obtain or for deciding about further tests. However, predictive equations for Ca\(^{2+}\) have been considered complex, outdated and unadapted to patients, since many of them have been derived from laboratory tests or from a healthy population [1, 2].

The objective of this study was to derive new equations to predict Ca\(^{2+}\) for adult hospitalized patients. These equations were intended to contain the usual laboratory or clinical parameters and to be easily calculable.

**Subjects and Methods**

**Study Design and Setting**

This was a retrospective observational study conducted in a third-level university hospital of 400 beds. The Clinical Research Ethics Committee of the institution approved the study.

**Patients**

An initial learning cohort (cohort L) was recruited to derive the equations (January 2007 to June 2008). It comprised 269 patients amongst 1,008 patients screened. Later, a validation cohort (cohort V) was recruited to test the new equations (December 2009 to December 2010). It comprised 146 patients amongst 877 patients screened.

During the two study periods, the computerized hospital records were screened for all patients admitted if they were adults (≥18 years old) and they had had a simultaneous blood determination of Ca\(^{2+}\) and CaTot. These initially selected patients were further screened for serum values of creatinine, sodium, potassium, phosphate, magnesium, total proteins (ProtTot), albumin (Alb) and glycemia obtained in a simultaneous blood drawing to the phosphate, magnesium, total proteins (ProtTot), albumin (Alb) and bone diseases.

**Laboratory Tests**

Once obtained, venous blood samples were centrifuged and the supernatant serum separated. These serum samples were refrigerated to 0–4°C when determined immediately or they were frozen until delayed determination. Ca\(^{2+}\) was measured by ion selective electrode direct potentiometry and was adjusted for pH 7.4 by an analyzer-based equation (GEM Premier 3000, Instrumentation Laboratory-Werfen, Bedford, Mass., USA). CaTot was determined by automated spectrophotometry. The remaining parameters were determined by the usual automated laboratory techniques. All samples were analyzed by the same laboratory. The laboratory operates 24 h per day, 7 days per week. The majority of samples were processed within 2 h. When convenient, conventional units were converted to SI units.

**Data Collected**

Each patient contributed only with the first determination of Ca\(^{2+}\) during his/her admission. Normocalcemia was defined as a Ca\(^{2+}\) between 1.16 and 1.34 mmol/l. Lower values were considered as hypocalcemia and higher values as hypercalcemia. The CaTot normal range was 2.12–2.62 mmol/l. Additional data collected were department of admission, diagnosis and demographics. Patients were classified depending on their renal function (RF), estimated by the CKD-EPI (Chronic Kidney Disease Epidemiology Collaboration) equation [9] into normal function (estimated glomerular filtration rate, GFRe ≥60 ml/min/1.73 m\(^2\)), moderate dysfunction (<60–30 ml/min/1.73 m\(^2\)) and severe dysfunction (<30 ml/min/1.73 m\(^2\)). Comorbidities affecting calcium metabolism were also recorded: acute and/or chronic kidney disease, heart failure, hypertension, diabetes, liver failure, chronic obstructive pulmonary disease, alcoholism, dyslipidemia, active neoplasm, hypo- or hyperthyroidism, hypo- or hyperparathyroidism, and bone diseases.

**Published Calcium Predictive Equations**

The medical literature was searched for predictive equations of Ca\(^{2+}\). Search results were limited to equations applied to adults, with variables easily obtainable, and not designed for specific diseases. Additional references were obtained screening the publications initially found. Widely used equations to calculate corrected CaTot were also selected to compare the accuracy in detecting calcium alterations. Ten equations were found that were used as comparators [10–19]. They are shown in table 1. For each patient in cohort V, predicted Ca\(^{2+}\) and corrected CaTot were calculated using all equations.

**Statistical Analysis**

Patients with outlier values for Ca\(^{2+}\) were excluded. Quantitative variables were tested for normal distribution. Those without this condition were transformed by the box Cox transformation. Linear transformations were also applied to change a variable scale when considered appropriate. Serum variables, transformed when necessary, demographics, and comorbidities, as dichotomous variables, were tested initially as independent variables for univariate linear regression taking Ca\(^{2+}\) as the dependent variable. Independent variables resulting with a p value ≤0.15 were selected to perform a further multiple linear-regression analysis with a stepwise approach. Different sets of variables were manually selected to obtain the simplest equations. Reliability was measured by the intraclass concordance coefficient for a single measure. Values of +1 denote perfect concordance, values of −1 perfect reverse concordance, and a value of zero absence. Accuracy was measured with mean error, mean absolute error, mean absolute percentage error and root mean square error. Agreement between equations in classifying calcium as hypo-, hyper- or normocalcemia was measured by the weighted kappa coefficient for categorical variables. A kappa of 1 indicates perfect agreement, whereas a kappa of 0 indicates agreement by chance. Sensibility, specificity and likelihood ratios were calculated for detecting hypocalcemia. For a positive likelihood ratio, higher values indicate a larger increase in the change in probability of the disease. For a negative likelihood ratio, smaller values indicate a larger decrease in the change in probability of the disease. Comparisons of quantitative variables were performed.
by the Mann-Whitney U test and comparisons of qualitative variables by the Fisher exact test. The agreement between each predictive equation and the Ca\(^{2+}\) measured were plotted in a Bland-Altman plot. The limits of agreement for each comparison were set at an average difference ±1.96 SD of the difference.

Data were analyzed using IBM SPSS Statistics 19.0 (IBM Corporation, Armonk, N.Y., USA) and Microsoft Excel 2010 (Microsoft Corporation, Redmond, Wash., USA).

### Results

Cohort L and cohort V differed in several parameters as shown in table 2. Cohort V included more males, presented worse GFR\text{e} and had more comorbidities. In contrast, it presented a lower neoplasm rate and less mortality. Admission departments differed also between cohorts. In cohort L, the range of Ca\(^{2+}\) was 0.78–1.56 mmol/l; 120 (44.6%) patients were hypocalcemic and 26 (9.7%) hypercalcemic. In cohort V, the range of Ca\(^{2+}\) was 0.59–1.60 mmol/l, and 87 (59.6%) patients presented hypocalcemia and 7 (4.8%) were hypercalcemic. Independent variables that initially entered the analysis were transformed age [log(100 – age)], sex, transformed Ca\text{Tot} (Ca\text{Tot}^{\text{0.5}} or Ca\text{Tot} square root), Prot\text{Tot}, transformed albumin (Alb^{0.75} – 2.2), transformed creatinine (Creat^{–0.87}), sodium, transformed potassium (K^{0.25}), magnesium, phosphate, RF (normal function = 0; moderate dysfunction = 1; severe dysfunction = 2), glycemic status (hypoglycemia = –1; normoglycemia = 0; hyperglycemia = 1), and comorbidities shown in table 2.

The univariate analysis found only 9 variables to affect Ca\(^{2+}\): transformed Ca\text{Tot} (F = 37,829.57, p < 0.001), Prot\text{Tot} (F = 14.21, p < 0.001), transformed albumin (F = 10.27, p = 0.002), transformed potassium (F = 5.75, p = 0.018), RF (F = 3.74, p = 0.054), sodium (F = 3.07, p = 0.081), diabetes (F = 2.99, p = 0.085), transformed creatinine (F = 2.44, p = 0.119), and chronic obstructive pulmonary disease (F = 2.38, p = 0.124). The remaining variables were discarded for further analysis. In the multivariate analysis, several sets of variables had to be discarded for problems in multicollinearity, autocorrelation and independence. Diabetes and chronic obstructive

### Table 1. Published predictive equations for serum calcium

| Equation | Year | Mathematical expression | Study characteristics | Ref. |
|----------|------|--------------------------|-----------------------|------|
| General predictive equations for Ca\(^{2+}\) | | | | |
| McLean-Hastings | 1935 | \(\text{Ca}^{2+} = \text{Ca}^{\text{Tot}} - 0.122 \times \text{Prot}^{\text{Tot}} - 0.006 + 0.5 \times [(0.024 \times \text{Ca}^{\text{Tot}}) + (0.122 \times \text{Prot}^{\text{Tot}} - \text{Ca}^{\text{Tot}} + 0.006)^{0.5}]\) | In vitro model of frog heart; derived from an undetermined number of serum samples | 10 |
| Zeisler | 1954 | \(\text{Ca}^{2+} = [(250.50 \times \text{Ca}^{\text{Tot}}) - (\text{Prot}^{\text{Tot}} \times 0.375)]/[4.01 \times \text{Prot}^{\text{Tot}} + 260.52]\) | Theoretical formula derived from McLean-Hastings nomogram; neither learning nor validation samples | 11 |
| Zeisler simplified | 1954 | \(\text{Ca}^{2+} = [(240 \times \text{Ca}^{\text{Tot}}) - (\text{Prot}^{\text{Tot}}/3)]/[4 \times \text{Prot}^{\text{Tot}} + 240]\) | Same as Zeisler equation | 11 |
| Hanna | 1964 | \(\text{Ca}^{2+} = (118 \times \text{Ca}^{\text{Tot}})/(118 + \text{Prot}^{\text{Tot}})\) | Theoretical nomogram; derived partially from 100 patient samples; no validation cohort | 12 |
| Pottgen | 1976 | \(\text{Ca}^{2+} = (721.5 \times \text{Ca}^{\text{Tot}} - K)/(120.24 \times K + 721.5)\) | Corrected from Zeisler equation; derived from 44 inpatients; no validation cohort | 13 |
| Sigggaard-Andersen | 1983 | \(\text{Ca}^{2+} = 0.8333 \times \text{Ca}^{2+}\) calculated by the McLean-Hastings equation | Theoretical correction of McLean-Hastings equation; 24 undetermined samples to calculate accuracy | 14 |
| Butler | 1984 | \(\text{Ca}^{2+} = 0.005 \times \text{albumin} + 0.980\) | Derived from 111 inpatient + 48 normal-subject samples | 19 |
| Predictive equations for Ca\(^{2+}\) in selected populations | | | | |
| Forster | 1985 | For critically ill surgical patients: \(\text{Ca}^{2+} = 0.225 + (0.55 \times \text{Ca}^{\text{Tot}}) - (0.007 \times \text{albumin})\) | Derived from 389 inpatient samples; no validation cohort | 15 |
| Pfitzenmeyer | 2007 | For patients of ≥80 years old: \(\text{Ca}^{2+} = 0.592 – 0.00449 \times \text{Prot}^{\text{Tot}} + 0.410 \times \text{Ca}^{\text{Tot}}\) | Derived from 294 inpatient samples; validation cohort: 77 patient samples | 16 |
| General predictive equations for Ca\text{Tot} | | | | |
| Payne | 1973 | \(\text{Ca}^{\text{Adj}} = \text{Ca}^{\text{Tot}} - 0.025 \times \text{albumin} + 1\) | Derived from 200 patient samples; no validation cohort | 17 |
| James | 2008 | \(\text{Ca}^{\text{Adj}} = \text{Ca}^{\text{Tot}} + [0.012 \times (39.9 – \text{albumin})]\) | Derived from 4,613 outpatient samples; validation cohort: 1,538 outpatient samples | 18 |

Equations were transformed to SI units when necessary. Ca\text{Adj} = Adjusted total calcium.
pulmonary disease lost significance in all cases. Finally, 3 equations were selected to be tested in cohort V (units: Ca\(^{2+}\) in mmol/l, CaTot in mmol/l, Alb in g/l):

\[
\text{Equation 1: } Ca^{2+} = 0.815 \times CaTot^{0.5} \\
\text{corrected } R^2 = 0.993, F = 37,829.57, \text{ standard error of the estimate (SEE) } = 0.395, p < 0.001 \\
\text{Equation 2: } Ca^{2+} = 0.826 \times CaTot^{0.5} - 0.023 \times RF \\
\text{corrected } R^2 = 0.993, F = 19,527.65, \text{ SEE } = 0.389, p < 0.001 \\
\text{Equation 3: } Ca^{2+} = 0.813 \times CaTot^{0.5} - 0.006 \times Alb^{0.75} + 0.079 \\
\text{corrected } R^2 = 0.993, F = 16,073.40, \text{ SEE } = 0.390, p < 0.001
\]

The derived equations converted into conventional units were as follows (units: Ca\(^{2+}\) in mg/dl, CaTot in mg/l, Alb in g/dl):

\[
\text{Equation 1: } Ca^{2+} = 1.629 \times CaTot^{0.5} \\
\text{Equation 2: } Ca^{2+} = 1.651 \times CaTot^{0.5} - 0.093 \times RF \\
\text{Equation 3: } Ca^{2+} = 1.631 \times CaTot^{0.5} - 0.144 \times Alb^{0.75} + 0.317
\]

Table 3 presents the concordance and accuracy of the actual values of Ca\(^{2+}\) in cohort V with the predicted values for the new equations and for the published general equa-

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**Table 2. Characteristics of cohorts L and V**

|                       | Cohort L | Cohort V | p value  |
|-----------------------|----------|----------|----------|
| **Demographics**      |          |          |          |
| Patients, n           | 269      | 146      | 0.889    |
| Age, years            | 71.0 [55.5–78.0] | 70.0 [56.8–78.0] | 0.009 |
| Male/female sex       | 146/123  | 99/47    | 0.003    |
| GFRe, ml/min/1.73 m²  | 60.5 [34.7–85.6] | 38.3 [17.1–81.2] | >0.001 |
| Ca\(^{2+}\), mmol/l   | 1.18 [1.08–1.25] | 1.13 [1.06–1.21] | 0.917 |
| CaTot, mmol/l         | 2.07 [1.87–2.27] | 2.07 [1.92–2.20] | 0.450 |
| **Comorbidities**     |          |          |          |
| Hypertension          | 151 (56.1) | 106 (72.6) | 0.001   |
| Neoplasm              | 122 (45.4) | 47 (32.2) | 0.012   |
| Acute renal impairment moderate/severe | 75/56 (27.9/20.8) | 33/66 (22.6/45.2) | >0.001 |
| Diabetes mellitus     | 63 (23.4) | 64 (43.8) | >0.001  |
| Dyslipidemia          | 61 (22.7) | 53 (36.3) | 0.04    |
| Chronic renal impairment | 54 (20.1) | 81 (55.5) | >0.001  |
| Chronic liver disease | 42 (15.6) | 22 (15.1) | 1.00    |
| Chronic obstructive pulmonary disease | 40 (14.9) | 30 (20.5) | 0.170   |
| Chronic heart failure | 33 (12.3) | 26 (17.8) | 0.141   |
| Chronic alcoholism    | 26 (9.7)  | 16 (11.0) | 0.734   |
| Bone diseases         | 22 (8.2)  | 10 (6.8)  | 0.703   |
| Hypothyroidism/hyperthyroidism | 19/2 (7.1/0.7) | 7/10 (4.8/6.8) | 0.001 |
| Hypoparathyroidism/hyperparathyroidism | 1/25 (0.4/9.3) | 32/7 (21.9/4.8) | <0.001 |
| **Initial department of admission** |          |          |          |
| General surgery       | 53 (19.7) | 17 (11.6) | 0.040   |
| Medical oncology      | 34 (12.6) | 2 (1.4)   | <0.001  |
| Internal medicine     | 24 (8.9)  | 3 (2.1)   | 0.006   |
| Nephrology            | 24 (8.9)  | 70 (47.9) | <0.001  |
| Gastroenterology      | 18 (6.7)  | 10 (6.8)  | 1.000   |
| Hematology            | 15 (5.6)  | 2 (1.4)   | 0.040   |
| Intensive care unit   | 12 (4.5)  | 13 (8.9)  | 0.084   |
| Other departments     | 89 (33.1)| 29 (19.9)| –       |
| **Outcomes**          |          |          |          |
| Length of stay, days  | 18.0 [10.0–34.0] | 16.0 [8.0–31.5] | 0.204 |
| Mortality             | 60 (22.3) | 14 (9.6) | 0.001   |

Values are expressed in medians with quartile 1 to quartile 3 in square brackets or alternatively in numbers with percentages in parentheses. a Calculated by the CKD-EPI 2009 equation. b At the time of Ca\(^{2+}\) determination.
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Table 3. Reliability and accuracy for the predictive equations

|                      | ICC     | ME, mmol/dl | MAPE, % | MAE, mmol/dl | RMSE, mmol/dl |
|----------------------|---------|-------------|---------|--------------|--------------|
| **All patients**     |         |             |         |              |              |
| Equation 1           | 0.539   | –0.04       | 7.35    | 0.08         | 0.04         |
| Equation 2           | 0.609   | –0.03       | 6.51    | 0.07         | 0.03         |
| Equation 3           | 0.521   | –0.04       | 7.30    | 0.08         | 0.04         |
| **Published general predictive equations** |         |             |         |              |              |
| McLean-Hastings      | 0.345   | –0.24       | 21.72   | 0.24         | 0.30         |
| Zeisler              | 0.496   | 0.11        | 10.64   | 0.12         | 0.07         |
| Zeisler simplified   | 0.506   | 0.11        | 10.37   | 0.12         | 0.08         |
| Hanna                | 0.264   | –0.26       | 23.65   | 0.26         | 0.30         |
| Potten               | 0.508   | –0.08       | 9.67    | 0.11         | 0.08         |
| Siggaard-Andersen    | 0.731   | –0.01       | 8.04    | 0.09         | 0.05         |
| Butler               | 0.095   | 0.02        | 8.48    | 0.09         | 0.06         |
| **Special populations** |       |             |         |              |              |
| Critically ill patients<sup>a</sup> |         |             |         |              |              |
| Equation 1           | 0.556   | –0.04       | 6.20    | 0.07         | 0.02         |
| Equation 2           | 0.640   | –0.03       | 5.21    | 0.06         | 0.05         |
| Equation 3           | 0.528   | –0.05       | 6.44    | 0.07         | 0.05         |
| Forster              | 0.623   | –0.02       | 8.73    | 0.07         | 0.04         |
| Patients ≥80 years old<sup>b</sup> |         |             |         |              |              |
| Equation 1           | 0.417   | –0.06       | 7.36    | 0.08         | 0.06         |
| Equation 2           | 0.494   | –0.04       | 6.48    | 0.07         | 0.04         |
| Equation 3           | 0.390   | –0.07       | 7.81    | 0.08         | 0.04         |
| Pfitzenmeyer         | 0.441   | –0.08       | 5.94    | 0.09         | 0.04         |

ICC = Intraclass concordance coefficient, values of +1 denote perfect concordance and 0 denotes absence of concordance; ME = mean error; MAPE = mean absolute percentage error; MAE = mean absolute error; RMSE = root mean square error, in all cases lower is better. 95% CIs are given in parentheses.

<sup>a</sup> For 12 (8.2%) critically ill patients.

<sup>b</sup> For 26 (17.8%) patients ≥80 years old.

Table 3. Reliability and accuracy for the predictive equations

The new equations derived and validated in this study predicted better Ca<sup>2+</sup>, especially equation 2, than the equations published so far. They contained the usual clinical and laboratory parameters and could be easily calculated, especially equation 1. In addition, they predicted equally well as the published specific equations for critically ill or very old patients. The purpose of this study was not to obviate the determination of Ca<sup>2+</sup> when necessary, but to obtain a reliable approximation when this parameter is not available. Ca<sup>2+</sup> determination is not a routine test in several health settings [17, 20], has increased costs concerning CaTot [8, 21] and has technical difficulties in...
processing samples [20, 22]. Ca²⁺ prediction is difficult. Blood calcium homeostasis depends on several factors such as blood proteins, pH, parathyroid hormone levels, calcitonin, 1,25-dihydroxyvitamin D status, intestinal calcium transport proteins, and the action of several organs and systems [2]. In addition, calcium complexes with several blood ligands such as albumin, globulin, bicarbonate, phosphate, lactate and citrate, and it is affected by the anion gap [23, 24]. The variability of these fractions makes the accuracy of Ca²⁺ equations lower than equations predicting other biological parameters. Very accurate equations for Ca²⁺ should include many parameters, but this would be unpractical in a clinical setting.

In these new equations, the square root of CaTot was the main independent variable. This mathematical treatment differed from published equations that used the more intuitive CaTot plain value. The transformed albumin in equation 3 is more difficult to calculate. However, the exponent 3/4 or 0.75 is one of the most frequent exponents found in allometric equations to predict numerous biological phenomena [25]. Albumin [13, 15, 16, 18, 19] and ProtTot [10–14, 17] are found in several Ca²⁺-predicting equations. However, in this study, many equations containing them were discarded due to problems of multicollinearity and independence. In equation 2, RF classification was made using the CKD-EPI equation [9]. Other equations for estimating RF such as MDRD (modification of diet in renal disease) have not been tested, but they were not expected to change the accuracy in predicting. In another study, MDRD was highly correlated with the CKD-EPI equation [26].

The new equations tended to moderately overestimate Ca²⁺ as shown by the mean error in table 3. However, they were slightly more accurate than the Siggaard-Andersen equation [14], the most accurate amongst those published. This equation requires the initial calculation of the McLean-Hastings equation [10] and a further multiplication by a coefficient that represents a correction for complex-bound calcium. The need of an initial cumbersome calculation makes the Siggaard-Andersen equation less practical in a clinical setting.

The kappa coefficient is a statistic that takes into account the fact that predictors (equations in this case) will sometimes agree or disagree by chance in classifying the result of a test. It is more accurate than simple percent agreement calculation. In general, the agreement of published predictive equations is from slight to fair in detecting hypocalcemia (table 4). Equation 2 performed better than all of them and presented a moderate agreement. Considering specificity and sensitivity (table 4), again equation 2 performed better than the published predic-
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Recently, Ca\(^{2+}\) adjusted for pH has been questioned as a good marker of calcium status [22]. However, this remains controversial due to possible technical artifacts [20, 22] and the actual correlation with pH [28, 29]. Ca\(^{2+}\) adjusted for pH is still recommended [30].

### Conclusion

Three new equations requiring easily available clinical or laboratory parameters predicted Ca\(^{2+}\) better than the currently available equations. They could be valuable in predicting hypocalcemia but are of limited use in hypercalcemia. They could be useful as an initial approximate value for deciding further calcium tests or as an alternative when the adequate technology to determine Ca\(^{2+}\) is not available.

### Disclosure Statement

There is no conflict of interest.
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