# Quality assessment of the creatinine and electrolytes measurement in the emergency department

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**Running title:** POCT in emergency department

**Keywords:** point-of-care testing, blood gas analyzer, creatinine, electrolyte, emergency department, central laboratory.

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ABSTRACT

**Background & Aims:** The study aim was to validate the usability of a blood gas analyzer for the measurement of creatinine and electrolytes.

**Methods:** A total of 190 patients were retrospectively investigated. Creatinine, sodium, potassium, and chloride concentrations in heparinized whole blood samples taken from an artery (103 patients) and vein (117 patients) measured with the blood gas analyzer and in serum measured in the laboratory were compared.

**Results:** The bias and coefficient values for the measured concentrations between serum and heparinized whole blood taken from an artery were as follows: creatinine, -0.089 mg/dL, 0.966; sodium, 0.214 mEq/L, 0.906; potassium, 0.234 mEq/L, 0.860; chloride, -1.874 mEq/L, 0.924, respectively. The bias and coefficient values for the measured concentrations between serum and heparinized whole blood taken from a vein were as follows: creatinine: -0.12 mg/dL, 0.992; sodium: -0.829 mEq/L, 0.953; potassium: 0.132 mEq/L, 0.969; and chloride: -0.744 mEq/L, 0.951, respectively. Compared with the concentrations measured in the laboratory,

the blood gas analyzer concentrations for creatinine and chloride were slightly higher, but that for potassium was slightly lower.

**Conclusion:** Acceptable agreement was obtained between the blood gas analysis and the laboratory analysis of creatinine and electrolytes for use in time-critical clinical decision-making in the emergency department.

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## Introduction

Exposure of patients with reduced renal function to contrast media increases their risk of a contrast-induced acute kidney injury (CI-AKI) known as contrast-induced nephropathy (CIN).[1,2] A rapid kidney function assessment at point-of-care testing (POCT) improved waiting times before computed tomography (CT) examination in an emergency department and imaging department.[3-5] POCT, such as blood gas analysis, helps reduce delays in real-time contrast-enhanced diagnostic imaging studies, requires only a low blood volume, and potentially enables more rapid and efficient clinical decision-making.[3-6] Furthermore, in intensive care units (ICUs), episodes of small creatinine (Cr) increases, as observed from frequent POCT Cr measurements, are common among critically ill patients and are early and sensitive indicators of illness severity.[7] Frequent measurement of Cr by POCT has been

suggested as a simple, inexpensive, and easy predictive test for diagnosis of AKI in ICUs[8] and nephrology departments.[9] These measurements require the use of a blood gas analyzer to measure circulating Cr concentrations for rapid kidney function assessment. Since whole-blood samples are used for blood gas analysis, as a POCT, it can be analyzed immediately after blood collection. In contrast, it takes ≧20 minutes to separate serum from whole blood for laboratory testing. Therefore, it takes approximately 30–40 minutes to determine Cr concentrations in a central hospital laboratory. Although a blood gas analyzer enables rapid measurement of Cr concentrations, the reliability and agreement between blood gas analysis and laboratory measurements of Cr should be established at each medical institution. The Clinical Laboratory Center of Gunma University Hospital is ISO 15189 certified, which specifies requirements for quality and competence in medical laboratories and can be used by medical laboratories to develop their quality management systems and assess their competence.[10] However, POCT based on a blood gas analyzer in an emergency department is not covered by ISO 15189. The study aim was to determine the agreement between the data measured by POCT by blood gas analysis and by laboratory testing, especially for Cr and electrolytes in our emergency department. The Cr and electrolyte concentrations in serum measured in the central laboratory were compared with those in heparinized whole blood taken from an artery and a vein measured by a blood gas analyzer.

## Methods

### Study design and participants

From January 2020 to March 2020, a total of 1215 patients were treated at the Emergency Department of Gunma University Hospital. Of these 1215 patients, we retrospectively investigated 190 consecutive Japanese patients aged ≧20 years whose blood Cr levels were measured both by a blood gas analyzer using heparinized whole blood taken from an artery or vein and by the central laboratory using serum (Figure 1A). Laboratory data and other information were obtained from the medical records for all subjects.

### Laboratory analyses

Heparinized whole-blood samples were collected in standard, prepared, heparinized blood gas syringes, and measurements using a blood gas analyzer (model ABL800, Radiometer Co., Tokyo, Japan) were taken without delay. The ABL800 is constantly maintained by emergency department staff according to the manufacturer's recommendations. All testing was performed on the ABL800 that was routinely maintained, which included quality control checks and calibration by the emergency department staff. In this study, samples taken from an artery of heparinized whole blood and of serum from 73 patients, samples taken from a vein of heparinized whole blood and of serum from 87 patients, and heparinized whole blood

samples taken from both an artery and a vein and of serum from 30 patients were tested (Figure 1A). The analyzer measured pH, partial pressures of $O_2$ ($PaO_2$) and carbon dioxide ($PaCO_2$), and concentrations of bicarbonate ($HCO_3^+$), sodium ($Na^+$), potassium ($K^+$), chloride ($Cl^-$), Cr, and lactate using whole blood samples at 37° C. The analyzer requires at least 400μL of heparinized whole blood for measurement. The hospital's central laboratory, named the Clinical Laboratory Center of Gunma University Hospital, complies with standards of the National Association of Testing Authorities. The measurement of Cr concentration by the blood gas analyzer is based on an enzymatic method using an amperometric biosensor.[11] Cr measurement by the central laboratory is based on an enzymatic method using the peroxidase activity of copper-creatinine complexes (Cygnus Auto CRE, Shino-Test Corporation, Kanagawa, Japan). At least 100μL of serum is required for measurement in central laboratory. During the study period, blood gas analyses were performed by a trained medical doctor or nurse at the emergency department. Blood samples were also taken and sent to the laboratory within 5 minutes for immediate analysis. Cr concentrations were measured by enzymatic method, whereas $Na^+$, $K^+$, and $Cl^-$ concentrations were measured by using an ion-selective electrode method and an automatic analyzer (LABOSPECT 008; Hitachi, Tokyo, Japan).

**Statistical analysis**

Linear regression analysis was performed to compare data from the two methods used for determining Cr, $Na^+$, $K^+$, and $Cl^-$, and the scatter of differences was visualized by generating a Bland-Altman plot.[12] Pearson's correlation analyses were performed to determine the relationships between the concentrations of Cr, $Na^+$, $K^+$, and $Cl^-$. Correlations were considered significant for $p$ values $< 0.05$. Because almost all variables were not normally distributed, data are expressed as median values with a 25th–75th percentile range. Unpaired Student's t-tests or Mann–Whitney U tests were used, as appropriate, to identify statistically significant differences between the two study groups. Kruskal–Wallis tests with Bonferroni multiple comparison tests were performed to compare the two groups classified by quartile. Differences and correlations were considered significant when $p < 0.05$. SPSS Statistics version 25.0 (IBM SPSS Statistics for Windows, IBM Corp., Armonk, NY, USA) was used to perform all statistical analyses.

## Results

The age distribution of the study subjects is shown in Figure 1. More than 50% of the study subjects, both males and females, were over 70 years of age. (Figure 1B and C). In all, 103 patients were assessed by analyzing both heparinized whole blood samples taken from an artery and serum samples, the results of which showed good agreement for Cr, $Na^+$, $K^+$, and

$Cl^-$ (Figures 2 and 3). The serum Cr and $Cl^-$ concentrations measured by laboratory testing were slightly lower than those measured in heparinized whole blood taken from an artery and measured by blood gas analysis (Figures 2 and 3). In heparinized whole blood taken from artery, when the Cr ≧4.0mg/dL, there is a significant discrepancy with the serum Cr concentration. The serum $K^+$ concentrations measured by laboratory testing were slightly higher than those in heparinized whole blood taken from an artery measured by blood gas analysis (Figure 3).

Heparinized whole blood samples taken from a vein and serum samples were analyzed in 117 patients and were in good agreement for Cr, $Na^+$, $K^+$, and $Cl^-$ concentrations (Figures 2 and 4). The serum Cr and $Cl^-$ concentrations in serum measured by laboratory testing were slightly lower than those in heparinized whole blood taken from a vein measured by blood gas analysis (Figures 2 and 4). The $K^+$ concentrations in serum measured by laboratory testing were significantly higher than those in heparinized whole blood taken from a vein and measured by blood gas analysis (Figure 4). The serum $Na^+$ concentrations measured by laboratory testing and those measured in heparinized whole blood taken from an artery or a vein measured by blood gas analysis were the same (Figure 3 and 4).

## Discussion

This study was conducted because the management of the ABL800 blood gas analyzer is not covered by ISO 15189, so it was necessary to confirm the reliability of the ABL800 operation in our hospital. We validated the usability of the blood gas analyzer installed in our emergency department for the measurement of Cr, $Na^+$, $K^+$, and $Cl^-$ concentrations. We confirmed that the Cr and electrolyte concentrations in heparinized whole blood samples taken from an artery and a vein and measured by an ABL800 blood gas analyzer were comparable to those in serum measured in the central laboratory. Slight differences were observed between the Cr and electrolyte concentrations measured in serum by laboratory testing and those measured in heparinized whole blood measured by the blood gas analyzer. Based on the data from this study, venous blood was more suitable for measuring Cr and electrolytes than arterial blood in the blood gas analyzer.

The correlation coefficient and narrow 95% confidence interval between heparinized whole blood taken from a vein and serum suggested the superiority of heparinized whole blood taken from a vein. In heparinized whole blood taken from artery, when the Cr $\geqq$4.0mg/dL, there is a significant discrepancy with the serum Cr concentration, so laboratory measurement results should be referred.

Our central laboratory is ISO 15189 certified. The laboratory is managed and operated by trained technicians in accordance with ISO 15189. In the laboratory, internal

quality control and calibration are routinely performed, and external quality control is performed three times a year. In the emergency department, routine quality control and calibration of the ABL800 are performed by nurses and physicians according to the manufacturer's recommendations.

Our results showed that the results obtained from the ABL800 blood gas analyzer with heparinized whole blood were sufficiently similar to those obtained from laboratory analysis of serum samples. The reliability of these results supports the use of this blood gas analyzer (and possibly others) in our emergency departments. Evidence of the potential of point-of-care Cr tests to assess kidney function for patients requiring intravenous contrast-enhanced diagnostic imaging has been increasing.[3-6] Point-of-care Cr testing has been found to be comparable to laboratory testing in terms of analytical performance and turnaround time.[3-6] The present study results are consistent with previous study findings[3-6] showing that rapid kidney function assessment by POCT in an emergency department facilitated imaging examinations and clinical decision-making.

Short-term point-of-care Cr testing enables identification and monitoring of critically ill patients with AKI.[6, 7, 11, 13–16] Moreover, even in patients with normal Cr on admission, small and early elevations in Cr can help detect AKI.[8] Previous reports suggest that the screening of patients at high risk of AKI is feasible with point-of-care Cr testing in the

emergency department or ICU. Moreno and colleagues[9] described the positive impact of the implementation of point-of-care blood gas analysis in a nephrology department on the clinical, operative, and economic aspects of patient care. However, the same paper reported significant differences in $pCO_2$ and in $Na^+$, glucose, and lactate concentrations between point-of-care blood gas analysis and laboratory testing. Although the $K^+$ and $Cl^-$, but not $Na^+$, concentrations determined by blood gas analysis in our emergency department differed slightly from the laboratory measurements, they were within clinically acceptable limits for use in an emergency department or ICU and consistent with those of previous reports.[6, 17–21] Most studies comparing blood gas analyzers with laboratory Cr and electrolyte measurements have found blood gas analyzer results to be reliable in emergency department and ICU operations. However, there is also a significant difference between the two, and in non-emergency situations, the central laboratory measurements should be recommended.[3-21] Whether the difference between the Cr and electrolyte values measured by the blood gas analyzer and the values measured in the central laboratory is high or low depends on the medical institution.[3-21] This difference is considered to be due to the measurement equipment, reagent, and environment.

ISO 22870 provides specific requirements for POCT and is intended for use in conjunction with ISO 15189.[22] A recent report showed that accreditation of both ISO 15189

199 and ISO 22870 led to an improved total testing process and good quality assurance of patient
200 results.[23] Although the blood gas analyzer installed in the emergency department is not
201 certified by either ISO 15189 or ISO 22870, the measurements obtained by the ABL800 blood
202 gas analyzer showed acceptable agreement with the laboratory measurements for Cr and
203 electrolytes concentrations for use in Gunma University Hospital. In the emergency
204 department of our hospital, ISO 22870 accreditation may contribute to our continuous
205 improvement of performance verification, staff training, and quality control of POCT.

206 Our study had some limitations. First, this was a retrospective single-center study
207 with a small sample size. Second, the cost and time analyses of the improvement in workflow
208 were not performed. Third, in the emergency department, blood gas analysis is generally used
209 for patients with severe illness or in those with moderate to severe respiratory disease, which
210 potentially adds bias but reflects real-world practice in Japanese emergency departments.
211 Future studies involving a large number of targeted emergency patients, inpatients, and
212 outpatients randomized between the POCT and central laboratory would provide more
213 conclusive findings.

214 ## CONCLUSIONS

215 In conclusion, measurements obtained by POCT by blood gas analysis and laboratory analysis
216 for $Na^+$, $K^+$, $Cl^-$, and Cr concentrations showed acceptable agreement for use in time-critical

clinical decision-making in the emergency department of our hospital.

## ACKNOWLEDGEMENT

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## DISCLOSURE

This study was approved by the institutional review board of Gunma University Hospital (Protocol number: HS2019-079). All regulations and measures of ethics and confidentiality were handled in accordance with the Declaration of Helsinki.

Informed Consent: We conducted retrospective research using an opt out approach.

Animal Studies: N/A

Conflict of Interest: The authors declare no competing interests.

## DATA AVAILABILITY STATEMENT

Data will be made available on reasonable request.

## REFERENCES

1. Parfrey P. The clinical epidemiology of contrast-induced nephropathy. Cardiovasc Intervent Radiol 2005; 28: S3-11.
2. McDonald JS, McDonald RJ, Carter RE, *et al*. Risk of intravenous contrast material-

mediated acute kidney injury: A propensity score-matched study stratified by baseline-estimated glomerular filtration rate. Radiology 2014; 271: 65-73.

3. Bargnoux AS, Beaufils O, Oguike M, *et al*. Point-of-care creatinine testing in patients receiving contrast-enhanced computed tomography scan. Clin Chim Acta 2018; 478:111-113.

4. Snaith B, Harris MA, Shinkins B, *et al*. Point-of-care creatinine testing for kidney function measurement prior to contrast-enhanced diagnostic imaging: evaluation of the performance of three systems for clinical utility. Clin Chem Lab Med 2018; 56:1269-1276.

5. Corbett M, Duarte A, Llewellyn A, *et al*. Point-of-care creatinine tests to assess kidney function for outpatients requiring contrast-enhanced CT imaging: Systematic reviews and economic evaluation. Health Technol Assess 2020; 24:1-248.

6. McIntosh BW, Vasek J, Taylor M, *et al*. Accuracy of bedside point of care testing in critical emergency department patients. Am J Emerg Med 2018; 36: 567-570.

7. Toh L, Bitker L, Eastwood GM, *et al*. The incidence, characteristics, outcomes and associations of small short-term point-of-care creatinine increases in critically ill patients. J Crit Care 2019; 52: 227-232.

8. Vaara ST, Glassford N, Eastwood, GM, *et al*. Point-of-care creatinine measurements to predict acute kidney injury. Acta Anaesthesiol Scand 2020; 64: 766-773.

9. Moreno ALQ, Sáez PO, Calle PF, *et al*. Clinical, operative, and economic outcomes of the point-of-care blood gases in the nephrology department of a third-level hospital. Arch Pathol Lab Med 2020;144:1209-1216.
10. ISO 15189:2012 - Medical Laboratories - Requirements For Quality And Competence., (2012). https://www.iso.org/standard/56115.html
11. Kimura S, Iwasaki T, Shimizu K, *et al*. Evaluation of a point-of-care serum creatinine measurement device and the impact on diagnosis of acute kidney injury in pediatric cardiac patients: A retrospective, single center study. Health Sci Rep 2019. 24; 3: e143.
12. Bland JM, Altman DG. Measuring agreement in method comparison studies. Stat Methods Med Res 1999; 8: 135-160.
13. Kost GJ, Vu HT, Inn M, *et al*. Multicenter study of whole-blood creatinine, total carbon dioxide content, and chemistry profiling for laboratory and point-of-care testing in critical care in the United States. Crit Care Med 2000; 28: 2379-2389.
14. Calzavacca P, Licari E, Tee A, *et al*. Point-of-care testing during medical emergency team activations: a pilot study. Resuscitation 2012; 83:1119-1123.
15. Udy A, O'Donoghue S, D'Intini V, *et al*. Point of care measurement of plasma creatinine in critically ill patients with acute kidney injury. Anaesthesia 2009; 64: 403-407.
16. Linder A, Fjell C, Levin A, *et al*. Small acute increases in serum creatinine are associated

271 with decreased long-term survival in the critically ill. Am J Respir Crit Care Med 2014;
272 189: 1075-1081.
273 17. Kapoor D, Srivastava M, Singh P. Point of care blood gases with electrolytes and lactates
274 in adult emergencies. Int J Crit Illn Inj Sci 2014; 4: 216-222.
275 18. Chhapola V, Kanwal SK, Sharma R, *et al*. A comparative study on reliability of point of
276 care sodium and potassium estimation in a pediatric intensive care unit. Indian J Pediatr
277 2013; 80: 731-735.
278 19. Morimatsu H, Rocktäschel J, Bellomo R, *et al*. Comparison of point-of-care versus central
279 laboratory measurement of electrolyte concentrations on calculations of the anion gap and
280 the strong ion difference. Anesthesiology 2003; 98:1077-1084.
281 20. Gibbons M, Klim S, Mantzaris A, *et al*. How closely do blood gas electrolytes and
282 haemoglobin agree with serum values in adult emergency department patients: An
283 observational study. Emerg Med Australas 2019; 31: 241-246.
284 21. Triplett KE, Wibrow BA, Norman R, *et al*. Can the blood gas analyser results be believed?
285 A prospective multicentre study comparing haemoglobin, sodium and potassium
286 measurements by blood gas analyzers and laboratory auto-analysers. Anaesth Intensive
287 Care 2019; 47:120-127.
288 22. ISO 22870:2016 - Point-of-Care Testing (POCT) - Requirements For Quality And

289 Competence. 2016. https://www.iso.org/standard/71119.html.

290 23. Oliver P, Fernandez-Calle P, Buno A. POCT Accreditation ISO 15189 and ISO 22870:

291 Making the Point. EJIFCC 2021; 32:131-139.

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## Figure legends

**Figure 1.** (A) Study protocol. Age distribution of the study participants of 102 males (B) and 88 females (C).

**Figure 2.** Difference in creatinine concentrations between blood gas analysis and laboratory analysis. (A) Bland-Altman plot showing the absolute bias, partitioned bias for different subgroups, and regression line for creatinine in serum measured by laboratory testing and heparinized whole blood taken from an artery and measured by the ABL800 blood gas analyzer (n = 103). The difference between two values in the y axis is plotted against the average of the two measurements in the x axis. The dash-dotted horizontal line represents the mean difference in measured creatinine concentration between the methods, and the dotted lines represent 95% limits of agreement (mean of difference ± 1.96 standard deviation). The bias is -0.089 mg/dL, and the 95% limits of agreement range from -0.548 to 0.371 mg/dL. (B) Linear regression analysis between heparinized arterial blood creatinine concentrations and serum creatinine concentrations. (C) Comparison of creatinine concentrations using the two methods. (D) Bland-Altman plot showing the absolute bias, partitioned bias for different subgroups, and regression line for creatinine concentrations in serum measured by laboratory testing and heparinized whole blood taken from a vein measured by the ABL800 blood gas

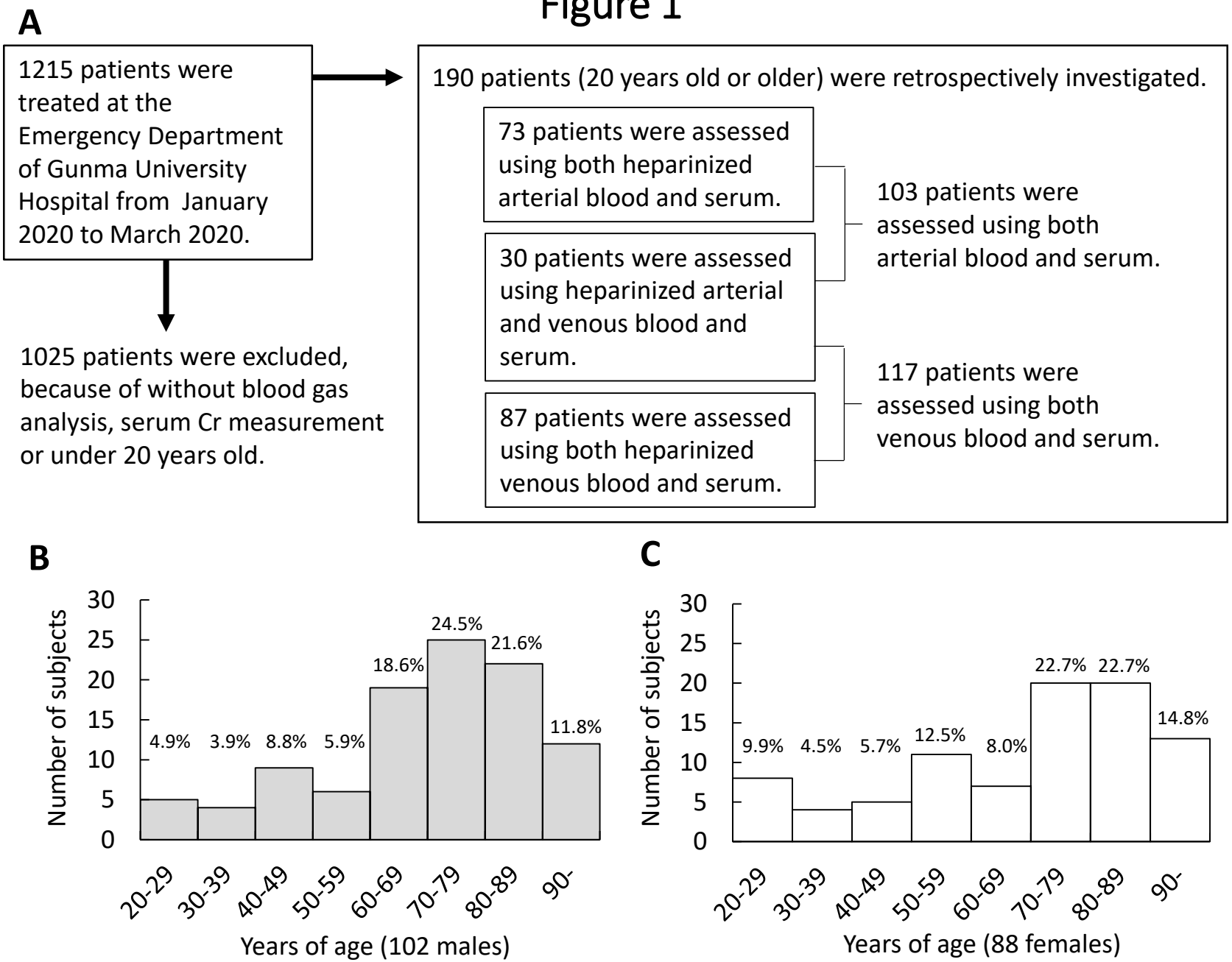
analyzer (n = 117). The difference between two values in the y axis is plotted against the average of the two measurements in the x axis. The dash-dotted horizontal line represents the mean difference in measured creatinine concentration between the methods, and the dotted lines represent 95% limits of agreement (mean of difference ± 1.96 standard deviation). The bias is -0.12 mg/dL, and the 95% limit of agreement range from -0.400 to 0.16 mg/dL. (E) Linear regression analysis between heparinized venous blood creatinine concentrations and serum creatinine concentrations. (F) Comparison of creatinine concentrations measured using the two methods.

**Figure 3.** Difference in electrolyte concentrations between heparinized whole blood taken from an artery measured by the ABL800 blood gas analyzer and serum measured by laboratory analysis. Bland–Altman plot showing the absolute bias, partitioned bias for different subgroups, and regression line in serum measured by laboratory analysis and in heparinized whole blood taken from an artery measured by the ABL800 blood gas analyzer (n = 103). In Bland-Altman plot, the difference between two values in the y axis is plotted against the average of the two measurements in the x axis. The dash-dotted horizontal line represents the mean difference in measured electrolytes concentration between the methods, and the dotted lines represent 95% limits of agreement (mean of difference ± 1.96 standard deviation). (A)

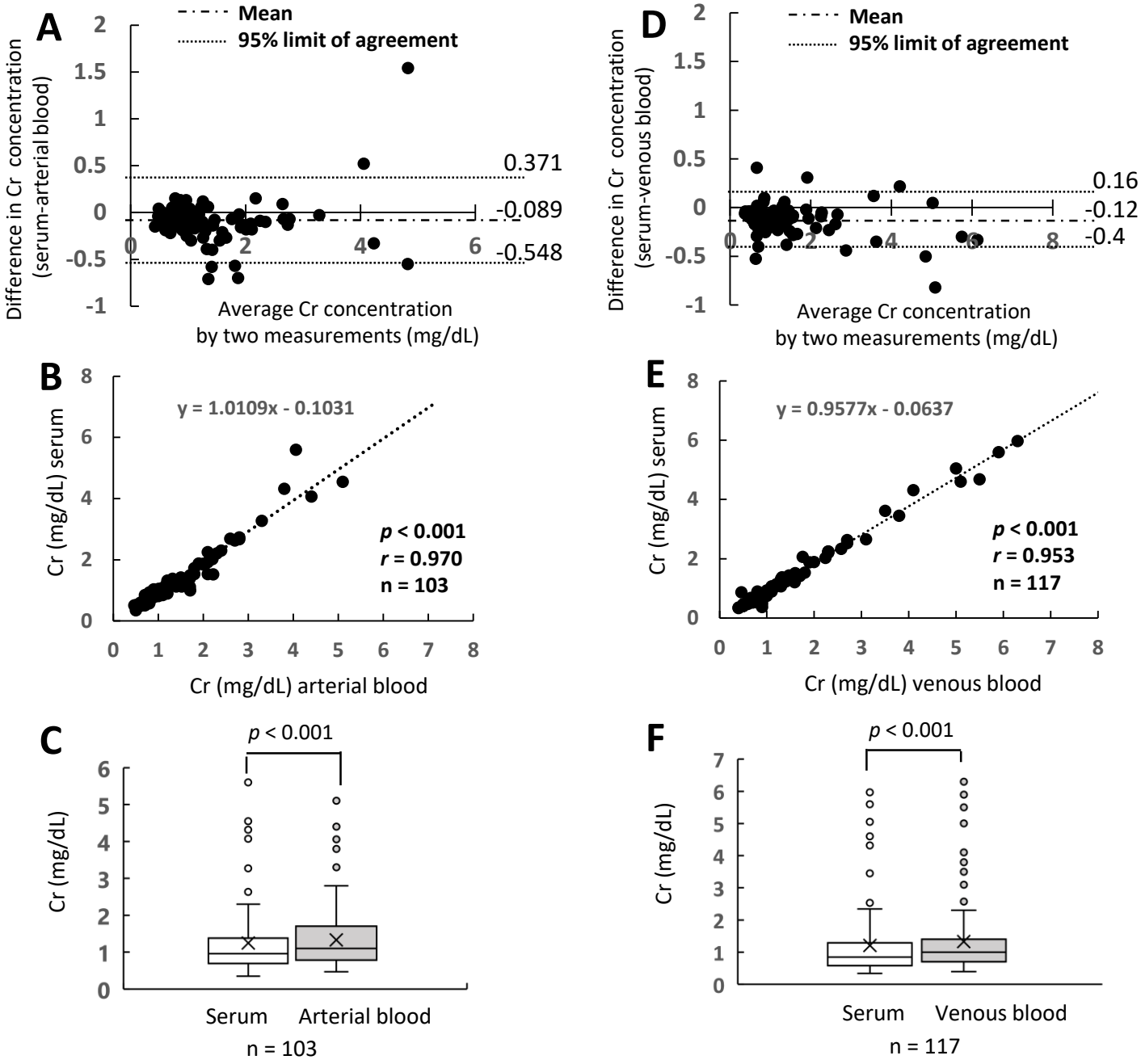
330 Bland–Altman plot for sodium, the bias is 0.214 mEq/L, and the 95% limits of agreement
331 range from -4.822 to 5.25 mEq/L. (B) Linear regression analysis between heparinized arterial
332 blood sodium concentrations and serum sodium concentrations. (C) Comparison of sodium
333 concentrations measured using the two methods. (D) Bland–Altman plot for potassium, the
334 bias is 0.234 mEq/L, and the 95% limits of agreement range from -1.355 to 1.823 mEq/L. (E)
335 Linear regression analysis between heparinized arterial blood potassium concentrations and
336 serum potassium concentrations. (F) Comparison of potassium concentrations measured
337 using the two methods. (G) Bland–Altman plot for chloride, the bias is -1.874 mEq/L, and
338 the 95% limits of agreement range from -6.727 to 2.979 mEq/L. (H) Linear regression
339 analysis between heparinized arterial blood chloride concentrations and serum chloride
340 concentrations. (I) Comparison of chloride concentrations measured using the two methods.
341
342 Figure 4. Difference in electrolyte concentrations between heparinized whole blood taken
343 from a vein measured by the ABL800 blood gas analyzer and serum measured by laboratory
344 analysis. Bland-Altman plot showing the absolute bias, partitioned bias for different
345 subgroups, and regression line in serum measured by laboratory analysis and in heparinized
346 whole blood taken from a vein measured by the ABL800 blood gas analyzer (n = 117). The
347 difference between two values in the y axis is plotted against the average of the two

348 measurements in the x axis. The dash-dotted horizontal line represents the mean difference
349 in measured electrolytes concentration between the methods, and the dotted lines represent
350 95% limits of agreement (mean of difference ± 1.96 standard deviation). (A) Bland-Altman
351 plot for sodium, the bias is -0.829 mEq/L, and the 95% limits of agreement range from -4.957
352 to 3.3 mEq/L. (B) Linear regression analysis between heparinized venous blood sodium
353 concentrations and serum sodium concentrations. (C) Comparison of sodium concentrations
354 measured using the two methods. (D) Bland-Altman plot for potassium, the bias is 0.132,
355 and the 95% limits of agreement range from -4.91 to 0.754 mEq/L. (E) Linear regression
356 analysis between heparinized venous blood potassium concentrations and serum potassium
357 concentrations. (F) Comparison of potassium concentrations measured using the two
358 methods. (G) Bland-Altman plot for chloride, the bias is -0.744 mEq/L and the 95% limits of
359 agreement range from -5.47 to 3.982 mEq/L. (H) Linear regression analysis between
360 heparinized venous blood chloride concentrations and serum chloride concentrations. (I)
361 Comparison of chloride concentrations measured using the two methods.

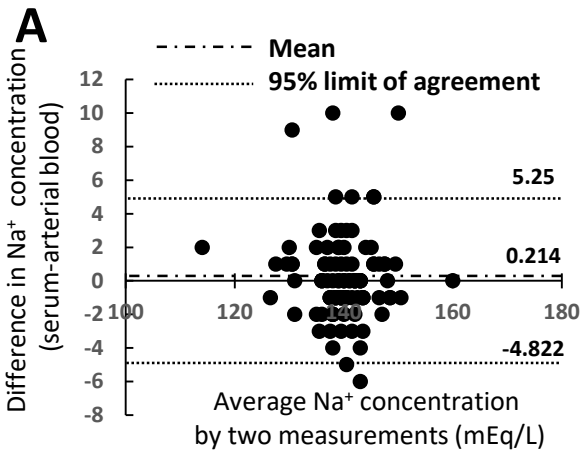
# Figure 1

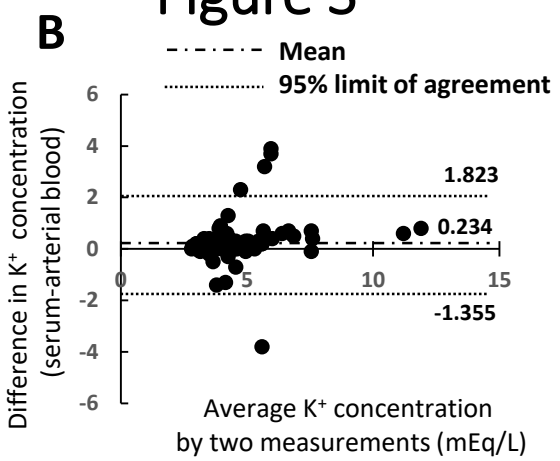

A
1215 patients were treated at the Emergency Department of Gunma University Hospital from January 2020 to March 2020.
1025 patients were excluded, because of without blood gas analysis, serum Cr measurement or under 20 years old.
190 patients (20 years old or older) were retrospectively investigated.
73 patients were assessed using both heparinized arterial blood and serum.
30 patients were assessed using heparinized arterial and venous blood and serum.
87 patients were assessed using both heparinized venous blood and serum.
103 patients were assessed using both arterial blood and serum.
117 patients were assessed using both venous blood and serum.
B
Number of subjects
0
5
10
15
20
25
30
4.9%
3.9%
8.8%
5.9%
18.6%
24.5%
21.6%
11.8%
20-29
30-39
40-49
50-59
60-69
70-79
80-89
90-
Years of age (102 males)
C
Number of subjects
0
5
10
15
20
25
30
9.9%
4.5%
5.7%
12.5%
8.0%
22.7%
22.7%
14.8%
20-29
30-39
40-49
50-59
60-69
70-79
80-89
90-
Years of age (88 females)

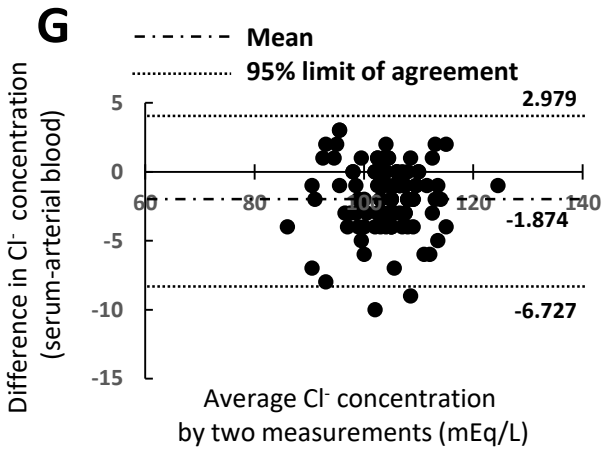
# Figure 2

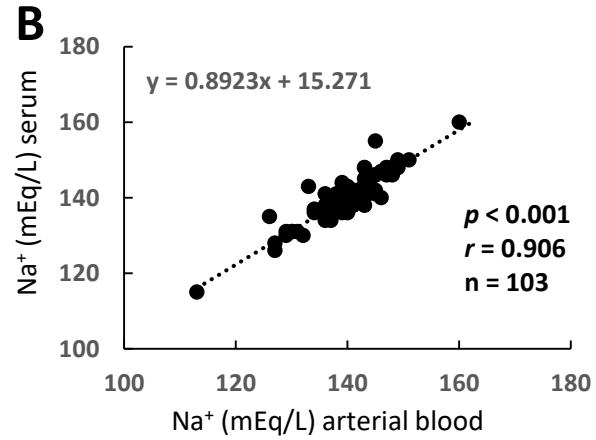

A
Mean
95% limit of agreement
Difference in Cr concentration (serum-arterial blood)
0.371
-0.089
-0.548
Average Cr concentration by two measurements (mg/dL)
B
y = 1.0109x - 0.1031
p < 0.001
r = 0.970
n = 103
Cr (mg/dL) serum
Cr (mg/dL) arterial blood
C
p < 0.001
Cr (mg/dL)
Serum
Arterial blood
n = 103
D
Mean
95% limit of agreement
Difference in Cr concentration (serum-venous blood)
0.16
-0.12
-0.4
Average Cr concentration by two measurements (mg/dL)
E
y = 0.9577x - 0.0637
p < 0.001
r = 0.953
n = 117
Cr (mg/dL) serum
Cr (mg/dL) venous blood
F
p < 0.001
Cr (mg/dL)
Serum
Venous blood
n = 117

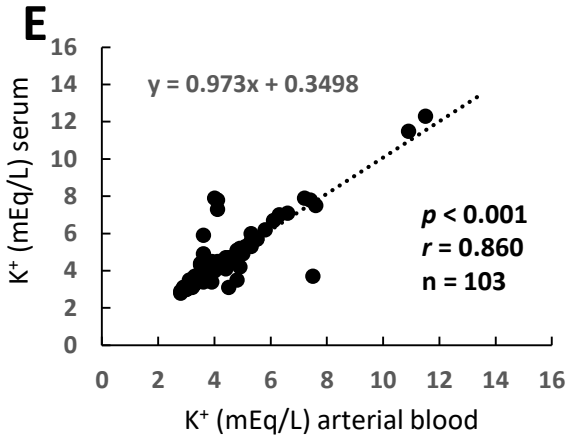
# Figure 3

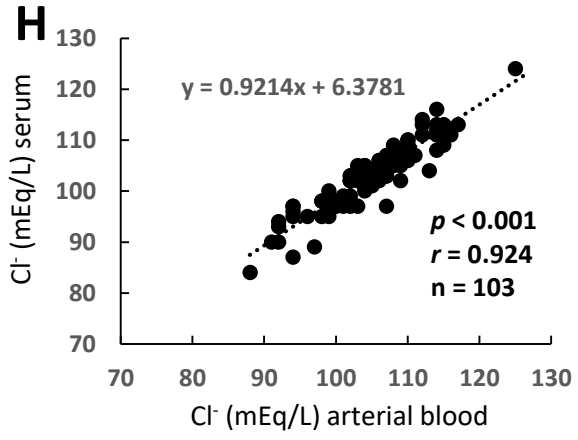

A
Mean
95% limit of agreement
5.25
0.214
-4.822
Difference in Na+ concentration (serum-arterial blood)
Average Na+ concentration by two measurements (mEq/L)

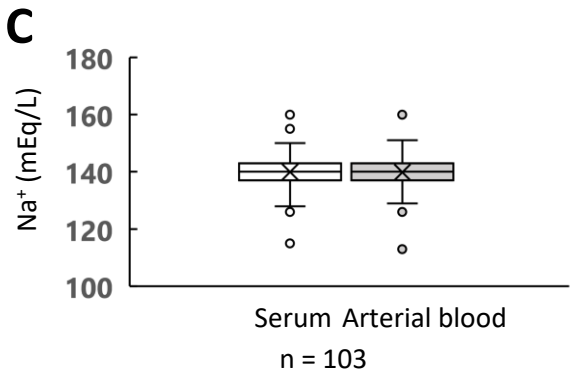

B
Mean
95% limit of agreement
1.823
0.234
-1.355
Difference in K+ concentration (serum-arterial blood)
Average K+ concentration by two measurements (mEq/L)

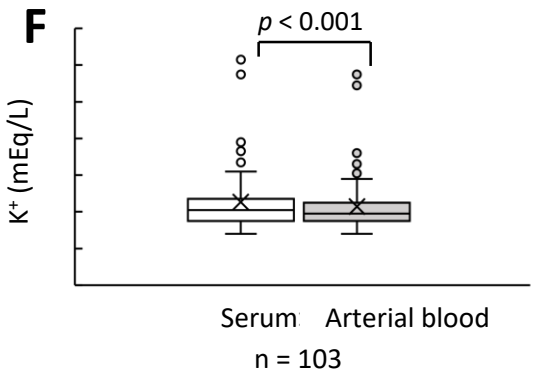

G
Mean
95% limit of agreement
2.979
-1.874
-6.727
Difference in Cl- concentration (serum-arterial blood)
Average Cl- concentration by two measurements (mEq/L)

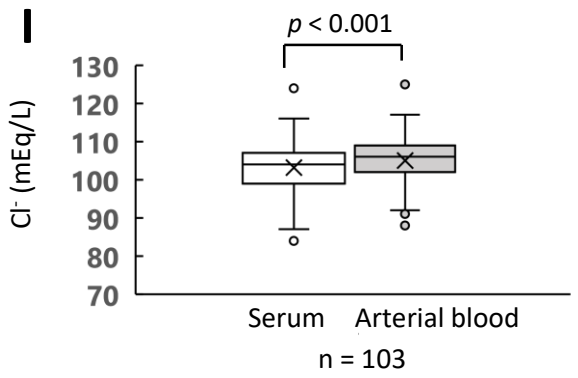

B
y = 0.8923x + 15.271
p < 0.001
r = 0.906
n = 103
Na+ (mEq/L) serum
Na+ (mEq/L) arterial blood


E
y = 0.973x + 0.3498
p < 0.001
r = 0.860
n = 103
K+ (mEq/L) serum
K+ (mEq/L) arterial blood

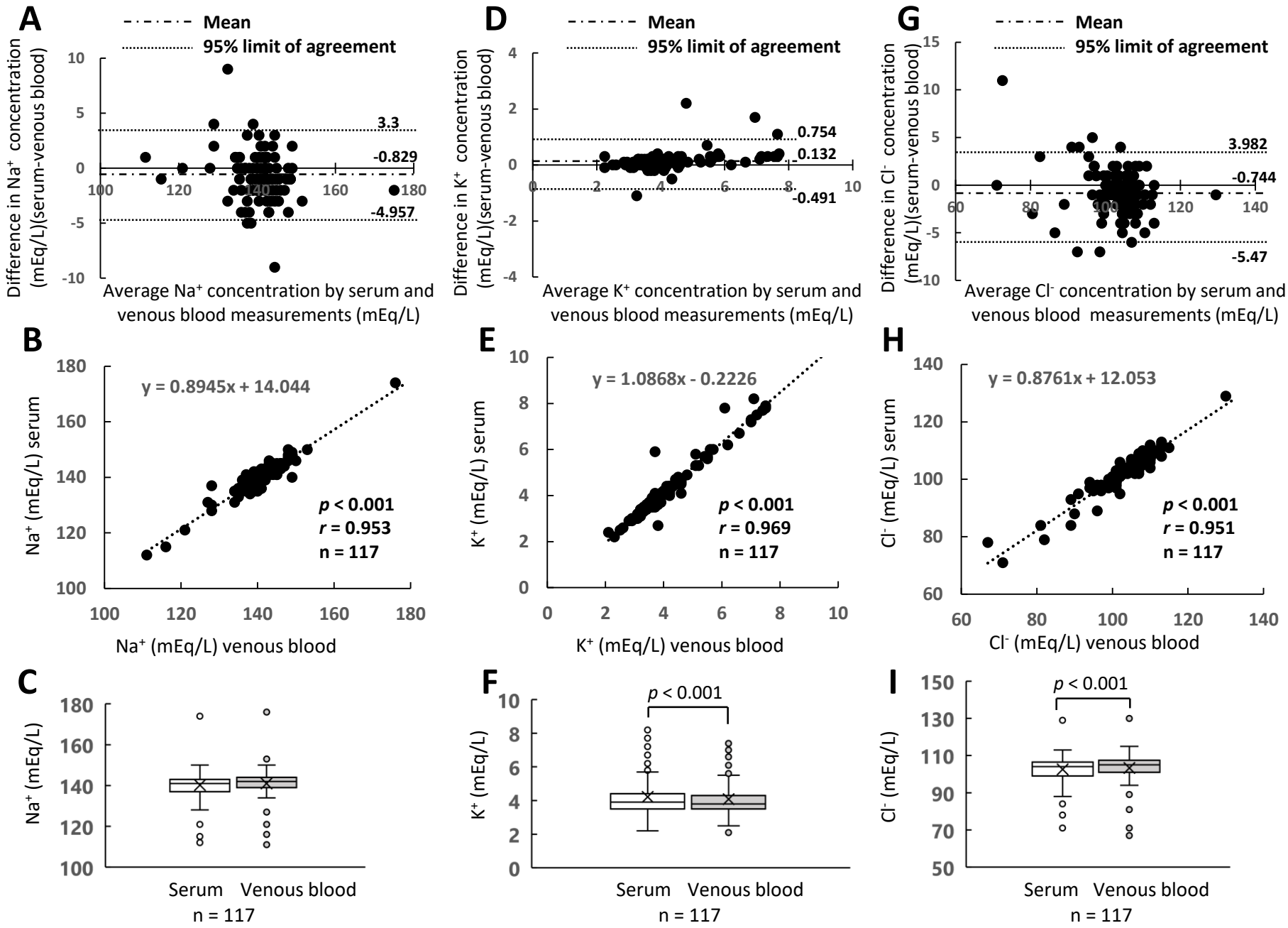

H
y = 0.9214x + 6.3781
p < 0.001
r = 0.924
n = 103
Cl- (mEq/L) serum
Cl- (mEq/L) arterial blood


C
Na+ (mEq/L)
Serum
Arterial blood
n = 103


F
p < 0.001
K+ (mEq/L)
Serum
Arterial blood
n = 103


I
p < 0.001
Cl- (mEq/L)
Serum
Arterial blood
n = 103

# Figure 4


A
Mean
95% limit of agreement
Difference in Na+ concentration (mEq/L)(serum-venous blood)
3.3
-0.829
-4.957
Average Na+ concentration by serum and venous blood measurements (mEq/L)
B
y = 0.8945x + 14.044
p < 0.001
r = 0.953
n = 117
Na+ (mEq/L) serum
Na+ (mEq/L) venous blood
C
Na+ (mEq/L)
p < 0.001
Serum
Venous blood
n = 117
D
Mean
95% limit of agreement
Difference in K+ concentration (mEq/L)(serum-venous blood)
0.754
0.132
-0.491
Average K+ concentration by serum and venous blood measurements (mEq/L)
E
y = 1.0868x - 0.2226
p < 0.001
r = 0.969
n = 117
K+ (mEq/L) serum
K+ (mEq/L) venous blood
F
K+ (mEq/L)
p < 0.001
Serum
Venous blood
n = 117
G
Mean
95% limit of agreement
Difference in Cl- concentration (mEq/L)(serum-venous blood)
3.982
-0.744
-5.47
Average Cl- concentration by serum and venous blood measurements (mEq/L)
H
y = 0.8761x + 12.053
p < 0.001
r = 0.951
n = 117
Cl- (mEq/L) serum
Cl- (mEq/L) venous blood
I
Cl- (mEq/L)
p < 0.001
Serum
Venous blood
n = 117