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Evaluation of an Instrument (Nova-1) for Direct Potentiometric Analysis of Sodium and Potassium in Blood and Their Indirect Potentiometric Determination in Urine

Jack H. Ladenson

We evaluated and compared the Nova-1 to an alternative direct potentiometric analyzer (Orion-SS/30) and to flame photometry (Beckman "KLiNa Flame"). Interassay precision of the Nova-1 for plasma was better than flame photometry but slightly worse than the Orion SS/30. For urine, interassay precision of the Nova-1 was not as good as for the flame photometer, but adequate for clinical use. Calcium, magnesium, phosphate, pH, uric acid, creatinine, and urea influenced neither sodium nor potassium values. Ammonia did not interfere with blood analysis but could slightly increase potassium values in urine when a maximum acid load is excreted. Unlike flame-photometric values, increasing protein concentrations did not influence the Nova-1 values. Whole blood and plasma gave virtually identical values. In plasma, the Nova-1 gave slightly lower values for sodium (0.8 mmol/L) and potassium (0.016 mmol/L) than the Orion SS/30. Like the Orion SS/30, the Nova-1 gave higher values than flame photometry for both sodium (3.9 mmol/L) and potassium (0.07 mmol/L). Urine samples showed good agreement between the Nova-1, operated in the urine mode, and flame photometry for sodium and for potassium if samples with electrolyte values higher than 50 mmol/L were analyzed after dilution with de-ionized water. Evidently, the Nova-1 is precise, capable of accurately measuring sodium and potassium in whole blood, plasma, or urine (with the above restrictions), and should be more accurate, as is the Orion SS/30, than flame photometry for assaying specimens with above-normal protein or lipid values.

Additional Keyphrases: *ion-selective electrodes · electrolytes · intermethod comparison · flame photometry · Orion SS/30*

The development of the glass sodium electrode (*1, 2*) and the neutral carrier (valinomycin) potassium electrode (*3*) has permitted the potentiometric analysis of sodium and potassium in biological fluids. Many types of instruments available to the clinical chemistry laboratory are now based on this analytical approach to measurement of these cations. Most of these instruments measure sodium and potassium by indirect potentiometry, samples being diluted sufficiently to eliminate possible differences in the activity coefficient or ion binding from sample to sample and then the electrode used as a sensor to measure changes in ion concentration. Therefore, it is not surprising that no differences in sodium or potassium values as analyzed by flame photometry or indirect potentiometry are found when plasma or serum (*4–8*) or urine (*9, 10*) are assayed. Both these approaches require dilution of the sample, so they are both prone to low results from factors that can decrease the plasma water such as hyperlipemia (*11, 12*) and above-normal protein values (*12–14*).

Previous studies from this laboratory with use of the only commercial instrument heretofore available for the direct potentiometric analysis (without sample dilution) of sodium and potassium showed that this technique is not subject to errors from factors that decrease plasma water (*15*). Moreover, direct potentiometry was capable of accurately measuring plasma electrolytes in whole blood (*16*). This report presents an evaluation of a recently introduced instrument that is capable of the direct potentiometric analysis of sodium and potassium in blood or plasma and that can also measure these electrolytes in urine by indirect potentiometry.

Materials and Methods

Direct potentiometric analysis of sodium and potassium was done with an Orion SS/30 sodium/potassium analyzer (Orion Biomedical, Inc., 11 Blackstone St., Cambridge, MA 02139) and a Nova-1 analyzer (Nova Biomedical, 1238 Chestnut St., Newton, MA 02164). In this latter instrument is used a glass sodium electrode, a valinomycin potassium electrode, and a flowing reference electrode in which 2 mmol/L KCl is used to establish the liquid junction.

Operationally the Nova-1 has two modes of operation, the "blood mode" and the "urine mode."

In the blood mode the sample is aspirated through a sample probe and then directly through the electrodes, the system is flushed, and the "A" standard [140.0 mmol/L NaCl, 4.00 mmol/L KCl, and 3 mmol/L $Mg(CH_3COO^-)_2$] is automatically sampled. The microprocessor compares the potential reading of sample and standard and displays the final result in terms of concentration. Two probe positions are available

Division of Laboratory Medicine, Departments of Pathology and Medicine, Washington University School of Medicine; and Barnes Hospital, St. Louis, MO 63110.

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so that Vacutainer Tubes, sample cups, syringes, capillaries, etc. can all be used.

In the urine mode, the cycle is similar except that the sample is diluted at the top of the sample probe by adding 53 mmol/L $Mg(CH_3COO^-)_2$. The final dilution is 1 part of sample to 1.5 parts of diluent. In this mode, the instrument compares the sample reading to that of the "B" standard [50.0 mmol/L NaCl, 40.0 mmol/L KCl, 22 mmol/L $Mg(CH_3COO^-)_2$]. The slope of the instrument is established by analysis of the A and B standards, either by pressing a calibrate button or automatically every 2 h if kept in "STAT" status.

In comparing results for plasma between the Nova-1 and either the Orion SS/30 or flame photometry (KLiNa flame; Beckman Instruments, Inc., 2500 Harbor Blvd., Fullerton, CA 92634), we used the same lot of Nova-1 A standard as the calibration standard for all instruments. For the comparisons of results for urine samples between the Nova-1 and Beckman KLiNa flame it was not possible to utilize the Nova B standard on the flame photometer owing to nonlinearity of the flame-photometric results at higher values. Therefore we prepared a standard containing 100 mmol of NaCl and 100 mmol KCl per liter and used it to standardize the flame photometer. This solution gave results within 1% of their expected value when analyzed on the Nova-1, thus assuring no influence of standard bias in the comparison results. All samples for plasma and urine comparisons were measured in triplicate and the median value utilized.

We compared sodium and potassium values for whole blood and plasma as follows: heparinized venous blood samples were remixed by inversion after removing the plasma separator ("Sure-Sep"; General Diagnostics, Morris Plains, NJ 07590) used for routine processing and transferred to a new plain evacuated blood-collection tube. A specimen of whole blood was removed for analysis and the remaining sample was centrifuged at 2000 × *g* for 10 min and a plasma sample removed. The plasma and whole-blood samples were analyzed in triplicate on the Nova-1 and the hematocrit of the whole blood sample was measured ("Readacrit" Centrifuge; Clay-Adams, Parsippany, NJ 07054). This method of comparing values for whole blood and plasma has been found to be more accurate than mixing the sample after plasma removal (*16*).

The influence of possible interferences on the potentiometric results was tested in either a serum or aqueous matrix. For the experiments with use of a serum matrix, the same lot of lyophilized serum control material was reconstituted either with de-ionized water or with a solution of the potential interferant being tested. Sodium and potassium in the various reconstituted samples were then measured in triplicate with both the Nova-1 (blood mode) and the Orion SS/30. For these experiments we used solutions of NaCl, KCl, $CaCl_2$, $MgCl_2$, LiCl, creatinine, uric acid, and urea. The actual value of each of the above constituents in the reconstituted serum control samples was established by appropriate analysis according to the routine methods in use at Barnes Hospital.

The influence of phosphate, pH, ammonia, magnesium acetate, creatinine, urea, albumin, and calcium were tested in an aqueous matrix in various ways, depending on whether the blood mode or urine mode of the Nova-1 was being evaluated. Phosphate was tested by preparing solutions containing 140 mmol of NaCl and 4 mmol of KCl per liter and increasing amounts of phosphate stock solutions, adjusted to a pH of 7.3 ± 0.2 (either the sodium or potassium salts, depending on whether sodium or potassium was being evaluated). The influence of pH was tested by adding dilute (1 mol/L) HCl to a solution containing Na and K as above and which also contained 3 mmol of Na_2HPO_4 per liter. The actual pH was measured at 37 °C with a Radiometer E5021 capillary pH electrode system. The influence of ammonia was assessed at 140 mmol/L NaCl and 4 mmol/L KCl in the presence of 0, 1, 3, 5, 10, 15, and 20 mmol/L concentrations of NH_4Cl. In addition, we increased the pH of the 20 mmol/L NH_4Cl solution by adding NaOH, to further assess any potential interference. A similar study was performed to assess the influence of ammonia on the values when the Nova-1 was operated in the urine mode, except that the solutions contained 50 mmol of NaCl and 50 mmol of KCl per liter and the concentration of NH_4Cl was varied from 0 to 500 mmol/L in 100 mmol/L increments. Magnesium acetate was evaluated in a matrix of 50 mmol of NaCl and 40 mmol of KCl per liter, in concentrations up to 125 mmol/L. Creatinine, $CaCl_2$, human albumin, and urea were evaluated at 10 times their normal concentrations in urine in a matrix of NaCl and KCl, 50 mmol of each per liter.

The influence of serum proteins was assessed similarly to the procedure used in more extensive studies previously reported with the Orion SS/30 (*15*). De-ionized bovine sera (43% by electrophoresis) was obtained commercially ("ChemVarion"; Clinton Laboratories, Santa Monica, CA) and lyophilized before use. The lyophilized bovine sera was added to the Nova A standard to an estimated concentration of 180 g/L and we analyzed the A standard and protein-containing A standard by direct potentiometry with the Nova-1 and Orion SS/30 and with the Beckman KLiNa flame, using the dilutor supplied with the KLiNa to dilute the samples and also using "to-contain" pipets. In addition, we directly assessed the influence of protein on the flame photometer itself by diluting the A standard without protein with "to-contain" pipets and then adding protein by weight to match the protein value to the sample obtained by diluting the A standard that contained protein. The actual protein value in the A standard was determined by the biuret reaction (DuPont *aca*; Du Pont Instruments, Wilmington, DE 19898) and in the diluted samples by a turbidimetric method involving trichloroacetic acid (DuPont *aca*).

Results

Linearity

At constant potassium concentration (4 mmol/L), all three instruments gave linear responses when we assayed solutions containing NaCl at concentrations of 50, 100, 125, 150, 175, and 200 mmol/L. The results averaged (percent of theoretical) 99.8 ± 0.6%, 100.7 ± 1.5%, and 98.9 ± 2.2%, for the Nova-1 (blood mode), Orion SS/30, and Beckman KLiNa flame, respectively. Potassium values were also linear when tested at constant sodium (140 mmol/L) at concentrations of 2, 4, 6, 8, and 10 mmol of KCl per liter. The percent-of-theoretical values were 98.4 ± 0.5%, 97.0 ± 0.8%, and 101.7 ± 2.5% for the three instruments.

The linearity of the Nova-1 operated in the urine mode was tested somewhat differently. We analyzed solutions with concentrations (in mmol/L, chloride salts) of 50, 50; 100, 100; 150, 150; and 200, 200 for sodium and potassium, respectively, periodically during a three-month period. Each solution was analyzed in triplicate on at least 25 different days. The results (sodium, potassium; mean ± SD) were: 50.1 ± 1.2, 49.9 ± 1.0; 100.4 ± 2.6, 101.0 ± 2.1; 148.9 ± 3.9, 151.0 ± 4.0; and 196.7 ± 5.0, 199.0 ± 5.5 mmol/L. Thus the Nova-1 gave linear responses for both sodium and potassium over the range of interest for both plasma and urine.

Interferences

The influence of various substances on the results with the Nova-1 (blood mode) and the Orion SS/30 was tested in a serum matrix. Increasing the sodium from 119 to 171 mmol/L had no effect on the potassium values, and increasing the potassium from 3.5 to 13.1 mmol/L had no effect on the so-

Table 1. Influence of pH on Sodium and Potassium Values from Nova-1 and Orion SS/30 [a]

pH	Sodium, mmol/L		Potassium, mmol/L	
	Nova-1 [b]	Orion SS-30	Nova-1 [b]	Orion SS-30
9.64	141.6	139.5	3.85	3.82
7.57	141.8	140.7	3.87	3.84
7.02	141.6	142.1	3.86	3.89
6.57	142.8	142.1	3.91	3.87
5.93	143.4	144.4	3.94	3.93
5.55	142.9	145.0	3.93	3.94
4.26	143.9	147.1	3.95	3.96
2.84	152.5	191	3.96	4.27

[a] The same calibration standard was not used for both instruments in these experiments. Values shown are the median of triplicates.
[b] Performed in blood mode.

dium results. Increasing the creatinine from 51 to 219 mg/L, the uric acid from 94 to 265 mg/L, the urea from 350 to 1810 mg/L, the calcium from 2.77 to 6.10 mmol/L, the lithium from 1.5 to 6.6 mmol/L, or the magnesium from 0.54 to 1.73 mmol/L had no influence on the sodium or potassium values obtained with either instrument.

For aqueous solutions, we saw no influence of phosphate at 40 or 80 mg/L, but the sodium and potassium values were 1.8% low at 230 mg/L phosphate and 2.8% low at 380 mg/L phosphate on both the direct potentiometric instruments. Such concentrations are not achieved in physiological circumstances, and thus phosphate will not interfere with the analyses.

The influence of pH is shown in Table 1. The error at low pH is greater with the Orion SS/30 than the Nova-1, but there is little effect of pH on the results from either instrument over the pH range found in plasma, even if the plasma is exposed to the air.

Because ammonia is a potential interferent with the potassium electrode (*6, 17*), we studied its effects in both the blood and urine mode. The presence of ammonia had no influence on the flame-photometric values for either Na or K. The potassium values were influenced on both potentiometric instruments, but to very different extents. With the Orion SS/30 the potassium results were 2% low for each mmol of NH_4Cl per liter while with the Nova-1 (blood mode) the values were only 0.6% low. Addition of NaOH to the solution which contained 20 mmol of NH_4Cl per liter to a pH of 8.4 (original pH 6.4) did not change the potassium error with either the Orion SS/30 or the Nova-1 (blood mode). Since even in patients with hepatic coma, ammonia values of only 0.5 mmol/L are found (*17*), the results for potassium will be minimally influenced by the ammonia concentrations found in blood.

In the urine mode, sodium values were unaffected at ammonia concentrations up to 500 mmol/L. Potassium values were increased by 2% for each 100 mmol of NH_4Cl per liter. This error was the same at pH 5.9 as at pH 8.7. Thus the potassium values on the Nova-1 (urine mode) should be only slightly increased, even when a maximum acid load (200–300 mmol of ammonia per liter per 24 h) is being excreted.

We also tested the influence of other substances on the Nova-1 operated in the urine mode. Because magnesium acetate is used in the diluent and the standards, its effects were tested, but no influence was detected for concentrations up to 125 mmol/L. Creatinine (67 g/L), calcium (1.25 mmol/L), albumin (0.3 g/L), and urea (67 g/L) were without influence on the sodium or potassium values.

The influence of bovine serum proteins on the direct potentiometric and flame-photometric values was similar to that detailed elsewhere (*15*) and in some recently published studies with use of human serum albumin (*18*). The Nova-1 (blood mode) median values (sodium, potassium, both in mmol/L) were 139.2 and 3.96 for standard A (expected values, 140.0 and 4.00) and 140.9 and 4.05 for standard A containing 177 g of bovine protein per liter. Similar values were found for the Orion SS/30. The flame photometer, however, gave values of 121 and 3.6 when the KLiNa dilutor was used and 122 and 3.5 when pipets were used to perform the dilutions. It had been suggested to me that the protein effect that I attributed to a decrease in plasma water in the sample owing to volume displacement by proteins could have been a direct influence of protein on the flame photometer. I tested this by diluting the Nova A standard for flame-photometric analysis and then adding the estimated amount of protein to match that of the diluted standard A + protein solution. The final protein concentration was 1.81 g/L for the sample which contained protein prior to dilution and 1.73 g/L for the sample to which I added the protein after dilution. The low electrolyte values (122, 3.5) were found only in the sample that had protein present before dilution and not (139, 3.8) in the sample with protein added after dilution, thus confirming that the influence of protein on flame photometric analysis is a function of the sample dilution and not a protein influence on the flame-detection system.

Carryover

No carryover was found in either the blood or urine mode of the Nova-1. In the blood mode, carryover was tested by measuring a lyophilized serum quality-control material, reconstituted with water, before and after one from the same lot, reconstituted with either 1400 mmol/L NaCl or 40 mmol/L KCl. Carryover was calculated by dividing the differences in the values for the water-reconstituted sera by the high-electrolyte sera. Carryover was less than 0.1% for both sodium and potassium. In the urine mode, similar experiments were performed with aqueous solutions of 100 mmol/L NaCl and 1400 mmol/L NaCl, and 100 mmol/L KCl and 1000 mmol/L KCl. The carryover was less than 0.05% for either electrolyte.

Precision

Intra-assay precision of the Nova-1 (blood mode) was tested by analyzing a frozen serum quality-control material at least 15 consecutive times on four different occasions over a two-month period. The coefficient of variation ranged from 0.28 to 0.67% for sodium and 0.62 to 0.91% for potassium. The intra-assay precision for pooled whole blood was 0.71 and 0.92% for sodium and 1.22 and 0.78% for potassium on two different occasions. The more relevant interassay precision is shown in Table 2 and indicates that the Nova-1 (blood mode) is more precise than the Beckman KLiNa flame, but that the Orion SS/30 is slightly more precise than the Nova-1. The intra-assay precision for urine (23 consecutive analyses of frozen pooled urine) was 1.2 and 1.5% for Na and K in

Table 2. Comparison of the Interassay Precision for Electrolyte Analysis in Serum and Urine

Control pool [a]	Instrument	No. days	n	Sodium Mean mmol/L	Sodium SD mmol/L	Sodium CV, %	Potassium Mean mmol/L	Potassium SD mmol/L	Potassium CV, %
Serum A	Nova-1	22	139	128.4	1.16	0.8	3.07	0.045	1.5
	Orion SS-30	6	36	129.4	1.02	0.8	3.08	0.020	0.6
	Flame	18	142	131	2.6	2.0	3.1	0.07	2.2
Serum B	Nova-1	8	34	123.7	1.22	1.0	3.40	0.037	1.1
	Orion SS-30	7	32	124.3	1.04	0.8	3.38	0.35	1.0
Serum C	Nova-1	16	84	148.8	1.23	0.8	6.32	0.076	1.2
	Orion SS-30	9	45	149.1	0.74	0.5	6.38	0.104	1.6
	Flame	10	80	150	2.8	1.9	6.4	0.14	2.2
Serum D	Nova-1	12	166	156.7	1.61	1.0	6.79	0.115	1.7
	Flame	8	58	147	3.4	2.3	6.6	0.13	2.0
Urine E	Nova-1	40	176	15.1	0.84	5.6	22.0	1.5	6.7
	Flame	43	258	14.8	0.49	3.3	21.6	0.7	3.1
Urine F	Nova-1	41	195	41.0	1.21	2.9	15.9	0.9	5.9
	Flame	43	249	41.2	1.06	2.6	15.8	0.5	3.2

[a] Pooled and filtered frozen controls. The Nova-1 results for serum were obtained with the instrument operated in the blood mode and for urine in the urine mode.

control E and 1.9 and 1.7% in control F. The interassay precision of the Nova-1 (urine mode) is shown, compared to the Beckman KLiNa flame for these same controls, in Table 2. In contrast to the Nova-1 blood mode, it is evident that the KLiNa flame is more precise than the Nova-1 for urine analysis.

Whole Blood Vs. Plasma

We made 86 comparisons of results for whole blood and plasma on specimens from 46 different patients. The samples had hematocrits ranging from 26 to 65%. The results for sodium in whole blood were slightly (0.5 mmol/L, $p < 0.001$) lower than those in plasma; the results for potassium were not significantly different. The ratio of results for whole blood to those for plasma averaged 0.996 ± 0.011 (SD) for sodium and 0.993 ± 0.021 for potassium. These are similar to the values of 0.997 and 0.998 previously reported from this laboratory for the Orion SS/30 (*16*) and indicate that the Nova-1, like the Orion SS/30, may validly be used to measure plasma sodium and potassium in whole blood.

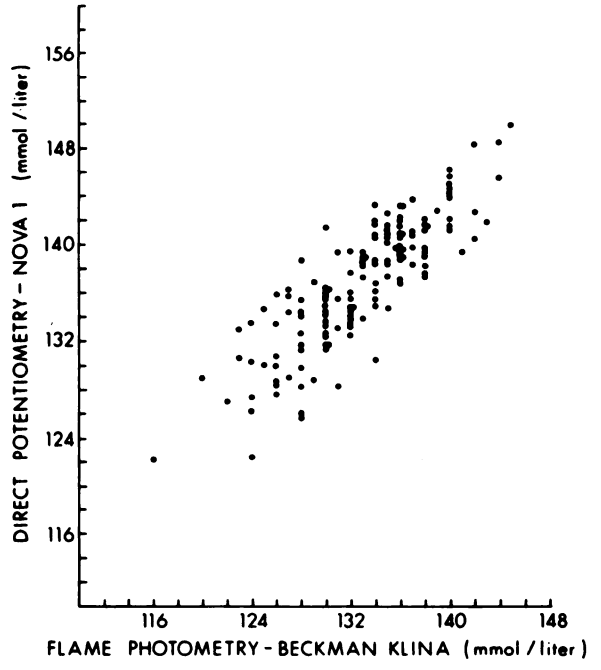

Fig. 1. Comparison of results for Na in plasma: Nova-1 and the Beckman KLiNa flame-photometer

Data shown are the median of triplicate measurements of each specimen by each method. Samples were selected without conscious bias from those submitted from patients for electrolyte analyses. The number of samples compared was 148 and the correlation coefficient was 0.846. Least-squares analysis indicated the Nova values =0.838 flame values + 25.4. Flame-photometric values were 97.2 ± 2.1% of direct potentiometric values, and the Nova-1 values averaged 3.9 mmol/L higher than the Beckman KLiNa flame-photometric values (paired *t*, $p < 0.001$)

Comparisons with Use of Patients' Samples

Plasma. Plasma samples from 148 patients were assayed by Nova-1 (blood mode) and flame photometry during 21 working days over a two-month period (Figures 1 and 2). Flame-photometric values as compared to Nova-1 values were

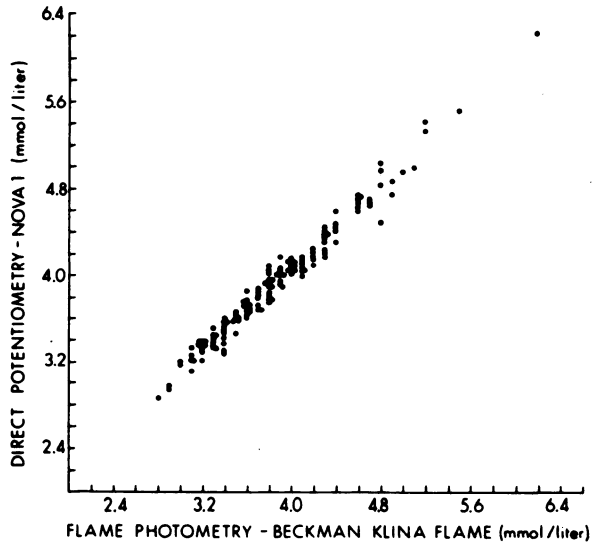

Fig. 2. Comparison of results for K in plasma: Nova-1 and the Beckman KLiNa flame-photometer

Conditions as in Figure 1. The number of samples was 148 and the correlation coefficient was 0.987. Least-squares analysis indicated the Nova values = 0.940 flame values + 0.30. Flame photometric values were 98.1 ± 2.4% of direct potentiometric values, and the Nova-1 values averaged 0.07 mmol/L higher than the Beckman KLiNa flame-photometric values (paired *t*, $p < 0.001$)

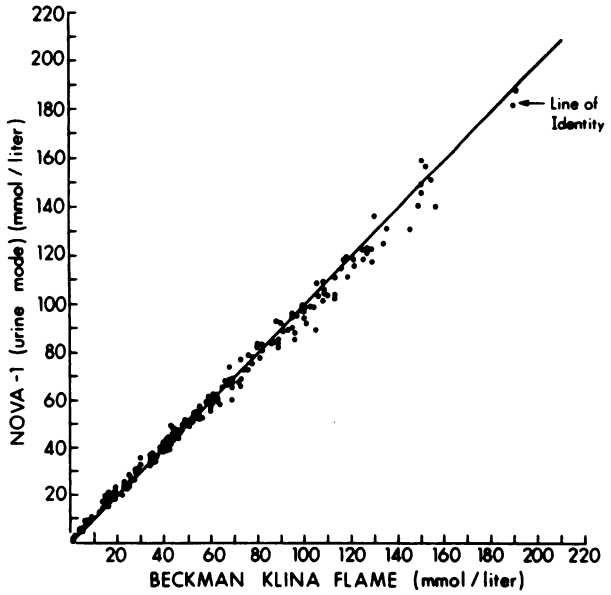

Fig. 3. Comparison of values for Na in urine: Nova-1 (urine mode) and the Beckman KLiNa flame-photometer

Comparisons made during four months. Excluded from the data are 11 samples for which values were off-scale on the KLiNa flame and 21 samples with values >50 mmol/L that could not be repeated on dilution. 193 samples were compared. The Nova-1 values averaged 64.2 ± 38.9 and the KLiNa values 64.9 ± 40.8 (paired t, $p < 0.02$). The correlation coefficient was 0.996; least-squares analysis gave the relationship $y = 0.950x + 2.6$

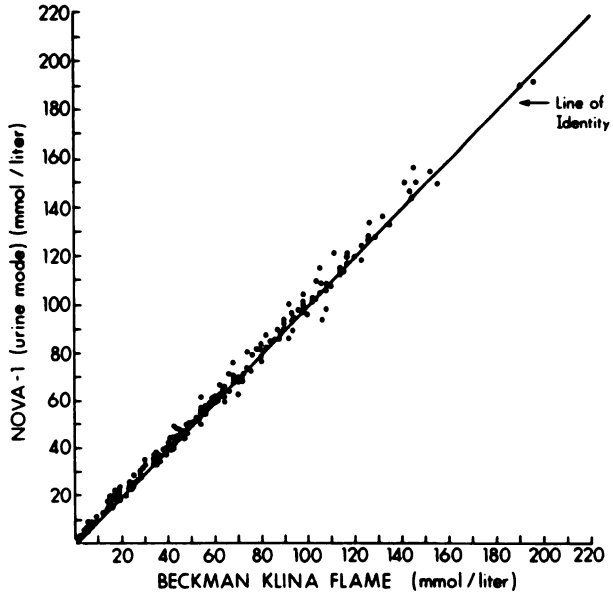

Fig. 5. Comparison of values for Na in urines with Na concentrations >50 mmol/L repeated on dilution

Conditions and samples identical with Figure 3 except that samples with values >50 mmol/L were diluted sufficiently to ensure that the measured value was <50 mmol/L. Nova-1 values are now 65.3 ± 39.6 and the Beckman KLiNa flame values 64.2 ± 39.6 (paired t, $p < 0.001$). The correlation coefficient is 0.997; least-squares analysis gave the relationship $y = 0.997x + 1.3$

97.2 ± 2.1% as great for sodium and 98.1 ± 2.4% for potassium. These were close to the percentages previously reported (*15*) for the Orion SS/30 (98.8 ± 1.3% for sodium and 96.0 ± 2.0% for potassium). We directly compared the Nova-1 and Orion SS/30 for 181 additional plasma samples. The correlation coefficient for Na was 0.950, for K 0.935. The Nova-1 gave slightly lower values for sodium (0.8 mmol/L, $p < 0.001$) and potassium (0.016 mmol/L, $p < 0.001$) than the Orion SS/30. Although some of these samples were grossly lipemic, they showed a similar relationship.

Urine. The flame-photometric and Nova-1 (urine mode) values for urine samples analyzed over a four-month period are shown in Figures 3 and 4. For both electrolytes, but particularly for potassium, there is a tendency to obtain lower values with the Nova-1 at higher electrolyte concentrations. After initially noting this phenomena, I sought urine samples with higher values and repeated all samples with potassium or sodium values greater than 50 mmol/L, after diluting with de-ionized water so that the measurement would be made at a value under 50 mmol/L. These diluted samples were also

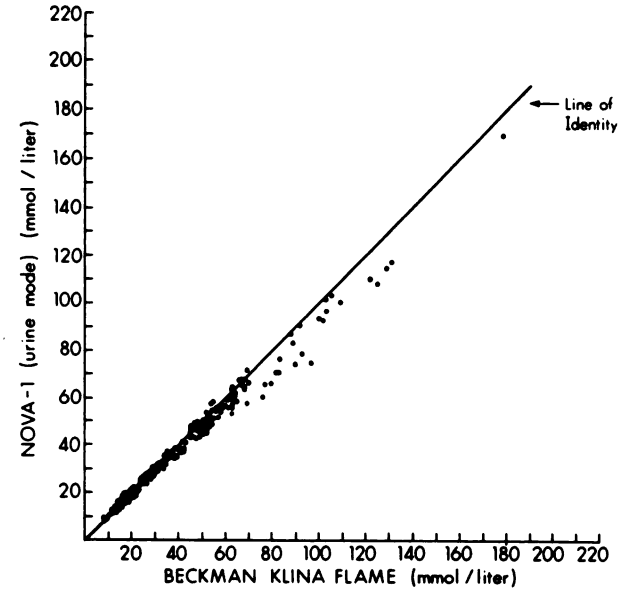

Fig. 4. Comparison of values for K in urine: Nova-1 (urine mode) and the Beckman KLiNa flame-photometer

Comparisons made during four months. Excluded from the data are six samples with values >50 mmol/L that could not be repeated on dilution. 219 samples were compared. The Nova-1 values averaged 41.5 ± 24.4 and the KLiNa flame values 43.6 ± 26.8 (paired t, $p < 0.001$). The correlation coefficient was 0.993; least-squares analysis gave the relationship $y = 0.902x + 2.2$

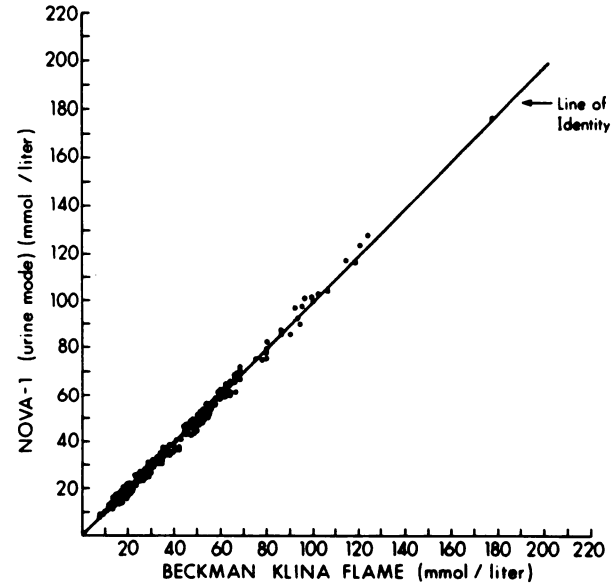

Fig. 6. Comparison of values for K in urines with K concentrations >50 mmol/Liter, repeated on dilution

Conditions and samples identical with Figure 4 except that samples with values >50 mmol/L were diluted sufficiently to ensure that the measured value was <50 mmol/L. The Nova-1 values are now 42.8 ± 26.2 and the Beckman KLiNa flame values 43.1 ± 25.9 (paired t, $p < 0.005$). The correlation coefficient is 0.998; least-squares analysis gave the relationship $y = 1.010x - 0.8$

assayed with the flame photometer and, after correcting for the dilution, these data are shown in Figures 5 and 6. Excellent agreement between the two methods, for both sodium and potassium, is now found.

The differences in electrolyte values for urine between the two methods at values greater than 50 mmol/L were quite surprising, because the standard curve for Nova-1 (urine mode) was linear up to 200 mmol/L, and no interferences were identified that explain this phenomenon. To test the diluting mechanism of the Nova-1 itself, I compared values from 46 samples which were analyzed directly by the Nova-1 (urine mode) with those in which the 1:1.5 dilution with 53 mmol/L $Mg(CH_3COO^-)_2$ was made manually and then the instrument operated in the urine mode with the diluent line pinched off. For both sodium (range of values, 3 to 190 mmol/L) and potassium (range of values, 12 to 101 mmol/L), agreement was excellent. The correlation for sodium was 0.997 with a slope of 1.03 and intercept of −1.4, and for potassium the correlation was 0.991 with a slope of 0.985 and intercept of 1.30. Visual inspection of the data showed no aberrant results. Thus, the dilution technique was not responsible for the lower electrolyte values with the Nova-1 (urine mode). Moreover, the differences in urine values for potassium analyzed by Nova-1 (urine mode) or flame photometer did not correlate with the differences for sodium. This was true for absolute or relative differences and for samples in which the flame photometric values exceeded 50 mmol/L for both electrolytes.

Discussion

My data on whole blood and plasma with the Nova-1 are very similar to my previous experience with the Orion SS/30 (*15*). Both direct potentiometric instruments are precise, linear, and specific, and are not affected by changes in plasma water owing to increases in protein or lipid. This latter finding is in contrast to the apparently low sodium values that occur in the presence of increased protein (*12–14*) or lipids (*11, 12*) when sodium is measured by techniques that require dilution of the sample, such as flame photometry or indirect potentiometry (*15*). Thus in patients with increased protein values (as in multiple myeloma or patients with hyperlipemia) the direct potentiometric analysis of sodium and potassium via either the Nova-1 or Orion SS/30 can be expected to be more accurate than those using flame photometry or indirect potentiometry.

Analyses of whole blood give results virtually identical to those of plasma, so samples can be analyzed as soon as obtained, without centrifugation, in a similar manner to measurement of blood pH and blood gases. This ability to analyze whole-blood samples makes the Nova-1 or Orion SS/30 extremely attractive for urgent analyses. The only drawback in this regard is the lack of a ready means to detect hemolysis, which would falsely increase potassium values by these or any other methods for potassium.

The major functional differences between the Nova-1 and Orion SS/30 are the manner of presenting the sample and the ability of the Nova-1 to measure urine samples. The samples for the Orion SS/30 are injected via a syringe with a blunt needle; with the Nova-1 a sample probe enters the sample, which then is aspirated into the instrument. This difference in sampling approach gives more flexibility to the Nova-1 with respect to the type of sample that can be analyzed, and should permit automation.[1]

The agreement between urinary electrolyte values between the Nova-1 and flame photometry is excellent if samples giving values over 40–50 mmol/L are re-analyzed on dilution (Figures 5 and 6). Figures 3 and 4 show that sodium agreement might be acceptable without dilution of the samples with higher values, but potassium samples with values greater than 50 mmol/L must be diluted to obtain answers that agree with flame photometry. Examination of the urinary electrolytes performed at Barnes Hospital during a year and a half indicates that 24% of the urinary potassium values and 50% of the urinary sodium values exceeded 45 mmol/L, so 25 to 75% of samples will require predilution to obtain results in agreement with flame photometry. The cause for the lower electrolyte values when the sample is not prediluted is as yet unknown. In previous studies of urinary sodium and potassium measurements by indirect potentiometry, at least a 10-fold dilution of the urine was used (*9, 10*). An unknown analytical factor could be involved or the discrepancy could reflect a physiological phenomenon such as electrolyte binding in urine that is being detected by the differences in methods. Further work to clarify this discrepancy is in progress, but electrolyte values that agree with flame photometric values can nevertheless be obtained with the Nova-1 (urine mode) if samples with urinary electrolyte values exceeding 40–50 mmol/L are diluted with de-ionized water.

In conclusion, the Nova-1 analyzer can accurately assay sodium and potassium in whole blood or plasma by direct potentiometry and in urine by indirect potentiometry if samples with higher values are first diluted with de-ionized water. The direct potentiometric values of the Nova-1 should be more nearly accurate than the values obtained by flame photometry or indirect potentiometry when plasma is analyzed, owing to errors with the latter techniques when plasma water decreases due to increased concentrations of proteins or lipids.

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[1] I have been informed by Nova Biomedical, Inc. that a turntable–printer system will soon be available, which will allow automation of the Nova-1 at an analysis rate of 80 samples/h.

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