Conductivity Meter as a Novel Device for Real-Time Urinary Electrolyte Monitoring

Ami Mayo, MD[1]; Avishay Manos, BSc[2]; Itzik Barnett, RN, MSc[2] ; Aliza Goldman, RN, MSc[2]; Lital Katz, BSc[2]; Hagar Azran, MSc[2]

[1]Assuta Hospital, Ashdod, Israel, [2]RenalSense, Jerusalem, Israel

Introduction

Acute kidney injury (AKI) is a complex syndrome characterized by a decrease in renal function, associated with numerous etiologies and pathophysiological mechanisms. It is a common diagnosis in hospitalized patients and is associated with increased patient morbidity and mortality (1). Classification of AKI includes prerenal AKI, postrenal AKI and intrinsic renal disease. Of these, only intrinsic renal AKI indicates kidney disease with damage to the renal parenchyma, while prerenal and postrenal AKI are the result of extrarenal disease that leads to a decreased glomerular filtration rate (GFR). If these pre or postrenal conditions continue, they will ultimately develop into renal cellular damage and hence intrinsic renal disease (2). An early diagnosis of AKI, as well as the differentiation between prerenal, intrinsic renal, and postrenal AKI, are significant, as each case not only requires a different therapeutic approach but is also associated with a different prognosis (3).

Although AKI identification and classification have improved greatly over the years, methods to distinguish between renal AKI and prerenal AKI are still lacking. Considering the consequences of misdiagnose and mistreatment of different classes of AKI, a monitoring system that will allow to assess the kidney's ability to concentrate or dilute urine in response to injury or treatment is highly required. *RenalSense* has developed a novel urine real-time conductivity monitoring system that monitors the concentration of urine electrolytes, integrated with Urine Output (UO) measurements. The objective of this study was to establish the reliability and accuracy of the urine conductivity monitoring device.

Materials and Methods

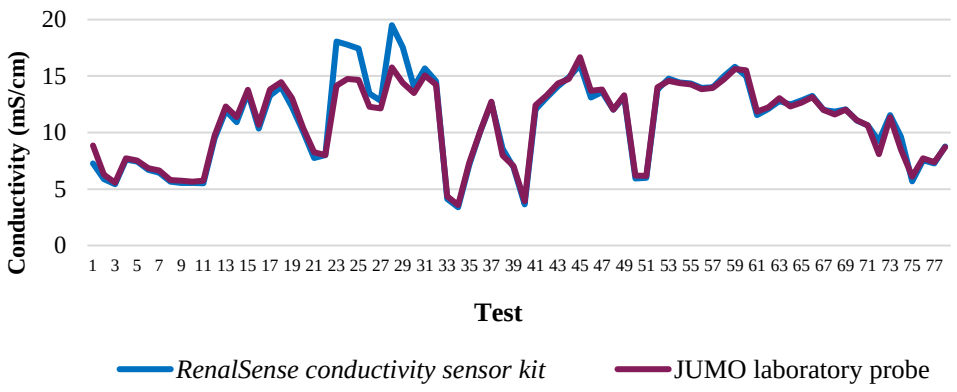
The clinical trial was performed on the premises of the ICU at Assuta Ashdod Hospital, where ICU patients were connected to the *RenalSense Conductivity Sensor Kit™*. Medical information was gathered for each patient and included age, gender, weight, fluid balance, medical history, medications, cause of admission, urine conductivity values and UO. Conductivity values were measured by the sensor kit, displayed, and documented by JUMO BlackLine CR-GT and JUMO logger, respectively. The validation procedure comprised extracting urine samples from the patients' sample port in order to compare the conductivity values measured in the laboratory with those measured by the kit, as well as to indicate a correlation between the concentration of ions in urine to the measured conductivity values. The urine samples were tested for conductivity (JUMO lab probe), electrolytes (Roche 9180 Electrolyte Analyzer) and urine analysis in the laboratory.

We studied 24 patients that were admitted to the ICU between November 29th, 2020, and July 22nd, 2021. Age average was 65.3 years, 12 Males and 12 Females. The median duration of sensor connection per patient was 3 days (STDEV 1.82), total of 74 connection days. Fourteen patients (58.3%) received diuretics, with a median of 3 days, total of 41 diuretic days. During diuretic administration, we found that significant changes occur rapidly and sharply to urine conductivity. Therefore, accuracy tests during diuretic days, specifically, are valuable for validating the accuracy and credibility of the device under these conditions.

Results

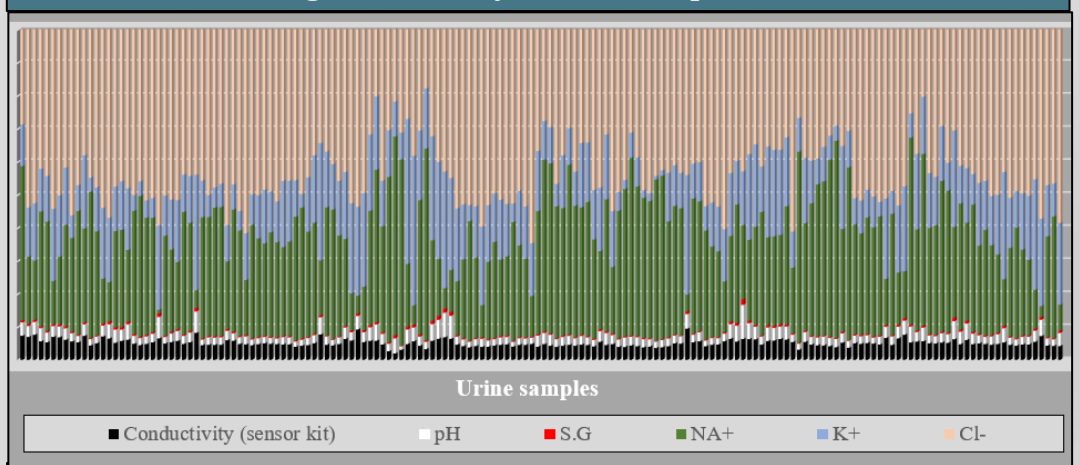
A high correlation was found between lab conductivity measurements to those conducted by the novel conductivity monitoring system (r=0.95).

Fig 1: Conductivity tests measured in the laboratory using a probe vs. measurements taken by the *RenalSense Conductivity Sensor Kit*



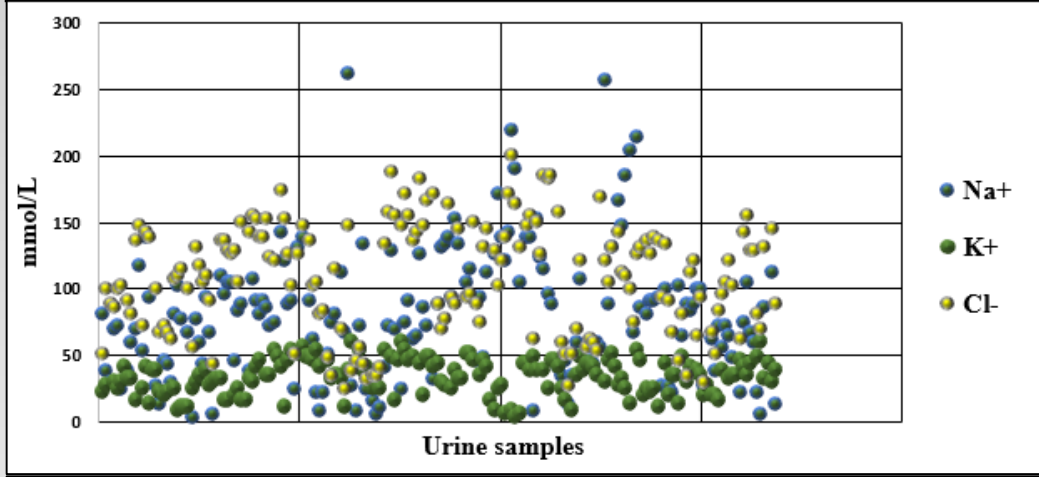
Urine samples were extracted via the sample port and tested by the JUMO lab probe**.** The results received by the probe were compared to the results given by the *RenalSense Conductivity Sensor Kit*. A high correlation was observed between lab conductivity results and real-time patient monitoring results using the device (r = 0.95) .

Fig 2: Variability of urine composition



Accuracy tests were performed on 170 urine samples with a variety of urine compositions. This figure shows the diversity of the urine samples across 4 components: electrolyte concentration, conductivity values, pH, and specific gravity. The RenalSense system measured conductivity accurately, regardless of the variability of urine samples. It also preserved accuracy during diuretic administration, which affects urine composition significantly and rapidly.

Fig 3: Variability of urine electrolytes concentrations



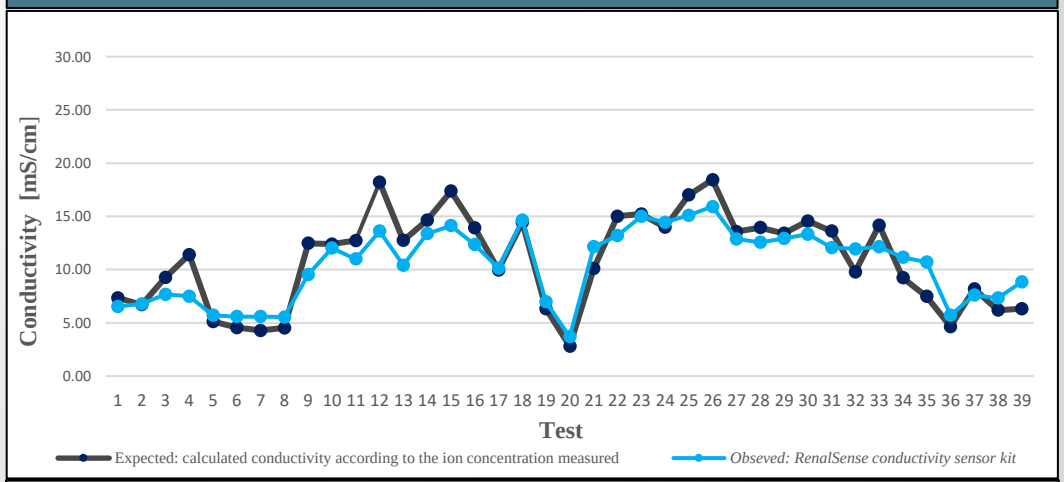
Dispersion of ion concentration for the urine samples that underwent accuracy tests. Concentrations are shown for Na^+ , K^+ and Cl^-. The wide variety of concentrations reflects the constant monitoring. It is especially evident from the tests conducted during diuretic administrations, which dramatically changes the urine ion concentrations.

Second generation Clarity RMS **Dual sensor**

Second generation Clarity RMS: Displays UO and conductivity values simultaneously on the screen.

The Dual sensor: Contains flow sensor and conductivity sensor

Fig 4: Comparing conductivity values taken by the device and conductivity values derived from measured ionic concentrations.



Conductivity values measured by *RenalSense Conductivity Sensor Kit* were compared to electrolyte values that were measured for the same sample using Roche 9180 Electrolyte Analyzer. Electrolyte concentrations were converted to conductivity values using a formula* that calculates the contribution of each ion to the conductivity of the solution. As expected, a correlation was observed between conductivity values given by the *RenalSense Conductivity Sensor Kit* and those received by electrolyte concentrations calculated by the formula* (r = 0.92).

*$D_{Na} = 1.33 \times 10^{-9} m^2/s$, $D_K = 1.96 \times 10^{-9} m^2/s$, $D_{Cl} = 2.03 \times 10^{-9} m^2/s$.

The correlation between conductivity measurements made by the *RenalSense Conductivity Sensor Kit* to those made in the laboratory, and the correlation between the conductivity values to the urine ion concentrations, were seen for all 24 patients. The strong correlations were seen despite the wide-ranging variability of the urine compositions and regardless of the administration of diuretics (which rapidly and dramatically changes urine composition).

Conclusions

Although the establishment of KDIGO (Kidney Disease Improving Global Outcomes) criteria and the clinical use of automatic devices for UO measurements have advanced the diagnosis of AKI, a reliable tool for AKI classification is still lacking. The conductivity monitoring system was tested and found to be reliable, safe, accurate, and consistent.

The conductivity results given by the *RenalSense Conductivity Sensor Kit* showed high correlation to the measurements performed in the laboratory. Furthermore, we showed that conductivity values do reflect the urine electrolyte concentration, as expected.

Real-time measurements of urine electrolytes can provide valuable insight into a wide range of clinical conditions. Conductivity measurements allow ongoing real-time close monitoring of urine electrolytes and can be a significant tool for fluid balance management and assessing responsiveness to diuretic administration relying on urine electrolytes concentration.

References

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