Improving awareness of kidney function through electronic urine output monitoring: a comparative study

Omar Murad, MD[1]; Daniel F Orjuela Cruz, MD[1]; Aliza Goldman, RN, MSc[2]; Tal Stern[2]; Peter Vernon van Heerden MD, PhD[1]
[1]General Intensive Care Unit, Hadassah University Hospital and Faculty of Medicine, [2]RenalSense Ltd.

Introduction

Intensive monitoring of a patient's vital signs and physiological parameters in the ICU (intensive care unit) provides timely information and enables rapid response by the attending medical staff.[1] The KDIGO (Kidney Disease Improving Global Outcomes) guidelines suggest a 'bundle' approach for treating patients at risk of developing acute kidney injury (AKI). This bundle includes (along with other monitoring) the maintenance of volume status and monitoring of serum creatinine (SCr) and urine output (UO).[2] One of the few parameters still monitored manually in the ICU is UO.

Study goal: To study the effect that department-wide use of electronic UO monitoring has on improving medical staff awareness of patient kidney function and response to treatment for oliguric patients.

Materials and Methods

RenalSense Clarity RMS Consoles (pic 1) were installed in the General ICU at the Hadassah Medical Center, Israel, from Dec 2019 to Nov 2020. Using its Sensor Kit, the system continuously monitors UO in real-time.[3] 100 patients were randomly selected from this period as the study group ($\mathbf{UO_{real\text{-}time}}$) and compared to a matched control group ($\mathbf{UO_{manual}}$) from the same period two years earlier (Table 1). UO and administration of fluid bolus and diuretics were analyzed during the first 48 hours of hospitalization. Oliguric hours were defined as UO below 0.5ml/kg/hr. *Statistical analysis*: All analyses were repeated for the patients enrolled in the study before and after the COVID-19 pandemic began, and their matched subjects to assure similar trends. Statistical analyses were performed using R 3.5.0.

Table 1. patient information	2018		2020		P-value
Cause of admission					
surgical	48	48%	48	48%	
neuro logical/surgical	13	13%	13	13%	
sepsis/septic shock	11	11%	11	11%	
trauma	14	14%	14	14%	
burn trauma	4	4%	4	4%	
other	10	10%	10	10%	
Gender- n (%)					
F	29	29.0%	38	38.0%	0.1771
M	71	71.0%	62	62.0%	
Age- Mean (SD)	60.9 (20.0)		61.0 (20.6)		0.9708
Median (IQR)	67.0 (47.8, 74.9)		65.6 (45.6, 75.2)		
Range (Min, Max)	(18.9, 93.9)		(18.5, 99.7)		
Weight- Mean (SD)	77.4 (14.7)		76.87 (15.0)		0.7624
Median (IQR)	75.0 (70.0, 85.0)		77.5 (67.5, 85.5)		
Range	(48.0, 120.0)		(50.0, 110.0)		
APACHE- Mean (SD)	21.4 (9.1)		20.4 (7.5)		0.4021
Median (IQR)	21 (14, 28)		20 (16,25)		
Range	(2, 42)		(0, 43)		
APACHE≥25	35	35%	30	30%	0.4506
receiving vasopressors Y/N- n (%)					
N	42	42.0%	48	48.0%	0.3940
Y	58	58.0%	52	52.0%	

Pic. 1 RenalSense™ Clarity RMS™ Console and Sensor Kit™

Table 2	Study group UO_{manual}	Control group $UO_{real\text{-}time}$
Correlation of Oliguria Day 1, Treatment Day 1	0.081	0.123
Correlation of Oliguria Day 2, Treatment Day 2	-0.032	**0.281**
Summary correlation of Day 1 and Day 2		
Pearson's correlation	0.009	**0.246**
***P* value**	0.932	**0.017**

Table 2. Pearson's correlation comparing treatment response to oliguria in the study group versus the matched control. Bolded numbers represent statistical significance.

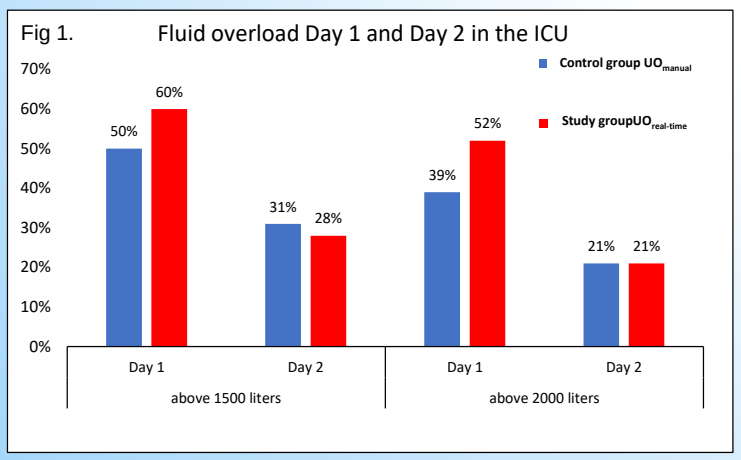

Fig 1. the rate of patients with daily fluid overload[4]: >1500 and >2000 liter in the study group , $\mathbf{UO_{real\text{-}time}}$ compared to the matched control $\mathbf{UO_{manual}}$

Results

Fluid bolus and diuretic administration: a negative correlation was found between furosemide treatment and fluid bolus (i.e., if the patient received one of the treatments, they are less likely to receive the other). Oliguria on Day 1 was strongly correlated with oliguria on Day 2 in both patient groups. The summary of correlation between the sum of all oliguric hours on Day 1 and 2 with the sum of any treatment (bolus or furosemide) for the study group $\mathbf{UO_{real\text{-}time}}$ showed a significant correlation, while the matched control group $\mathbf{UO_{manual}}$ showed no such correlation (P = 0.017, and 0.932, respectively) (Table 2).

Fluid balance: Although not statistically significant (P = 0.1046), it is of clinical interest to note that our study group showed a 31% decrease in the rate of patients with fluid overload from Day 1 to 2, versus 18% in the matched control (Fig 1).

Length of Stay: Median LOS in the ICU of $\mathbf{UO_{real\text{-}time}}$ versus $\mathbf{UO_{manual}}$ was 69.46 (44.7, 125.9) hours and 116.5 (62.46, 281.3) hours, respectively (P = 0.0002) (Fig 2a and 2b).

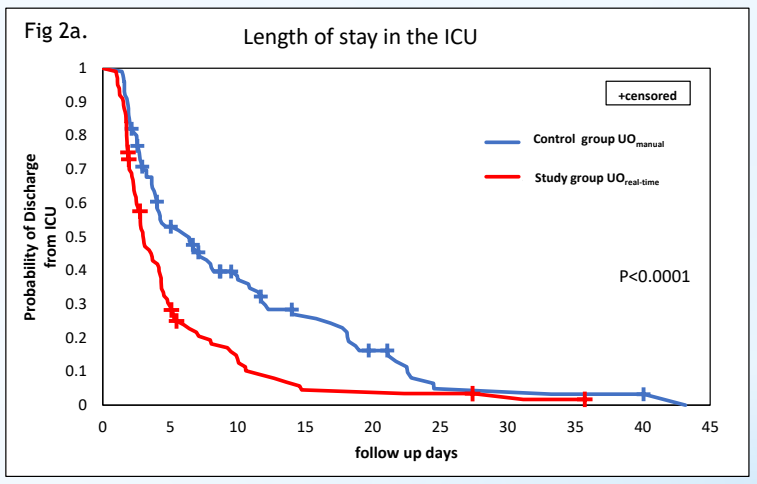

Fig 2a. Kaplan-Meier curve comparing length of stay (mortality-free) between the study group and the matched control.

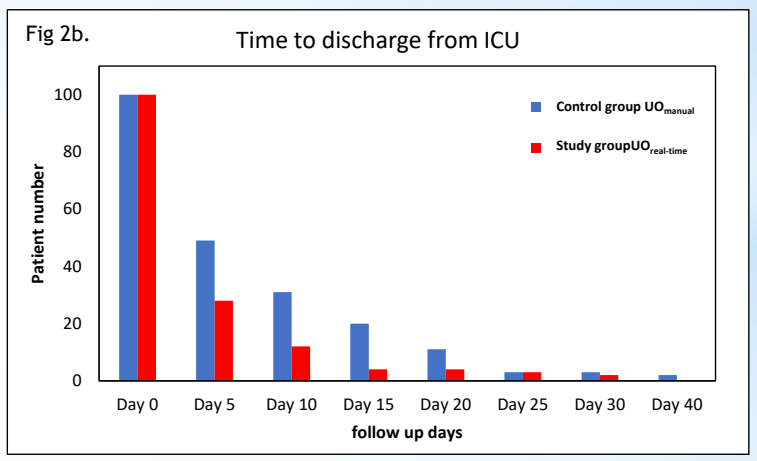

Fig 2b. Comparison of time to discharge between the study group and the matched control.

Discussion and Conclusion

AKI increases length of stay and the risk of morbidity and mortality in ICU patients. Research in this field has focused on predicting those at risk for AKI to improve patient care and lower healthcare costs.[5] Studies have shown that close monitoring of UO and patient fluid status, is central to identifying those at risk of developing AKI.[6] The results of our study strongly suggest that the use of electronic UO monitoring contributed to increased staff awareness and correspondingly meaningful medical intervention in the ICU.

Conclusion: Real-time electronic UO monitoring can promote earlier intervention and better application of goal-directed patient treatment.

References:
1. Maslove, D. M., Dubin, J. A., Shrivats, A., & Lee, J. Errors, omissions, and outliers in hourly vital signs measurements in intensive care. *Crit Care.* 2016; *44*(11): e1021–e1030.
2. Koyner, J. L., Zarbock, A., Basu, R. K., & Ronco, C. The impact of biomarkers of acute kidney injury on individual patient care. *Nephrol Dial Transpl.* 2020; *35*(8): 1295–1305.
3. Goldman A, Azran H, Stern T, et al. A novel electronic device for measuring urine flow rate: a clinical investigation. *Clinical Medicine Insights: Trauma and Intensive Medicine*. 2017; 8: 1–6.
4. Hatton, G. E., Du, R. E., Wei, S., Harvin, J. A., Finkel, K. W., Wade, C. E., & Kao, L. S. Positive Fluid Balance and Association with Post-Traumatic Acute Kidney Injury. *J Am Coll Surg.* 2020; *230*(2): 190–199.e1.
5. Song, X., Liu, X., Liu, F., & Wang, C. Comparison of machine learning and logistic regression models in predicting acute kidney injury: A systematic review and meta-analysis. *Int J Med Inform.* 2021; *151:* 104484.
6. Jin K, Murugan R, Sileanu FE, Foldes E, et al. Intensive Monitoring of Urine Output Is Associated With Increased Detection of Acute Kidney Injury and Improved Outcomes. *Chest*. 2017; 152(5): 972-979.