ICU MANAGEMENT & PRACTICE

The Importance Of Continuous Monitoring Of Urine Flow In Critical Care Patients

RenalSense Realtime Renal Diagnostics

ABSTRACT

This review discusses the importance of continuous, real-time monitoring of urine flow in critical care patients and its potential role in Acute Kidney Injury (AKI) and fluid management in a variety of clinical conditions. Real-time, reliable monitoring of urine flow enables clinicians to detect early signs of kidney injury, and facilitates both early treatment and prediction of AKI progression. In addition, it provides information that is important for calculating fluid balance and assessing responsiveness to fluids and diuretics. Continuous and reliable monitoring of urine flow, with electronic, real-time alerts of abnormal levels, could improve the clinical management and outcomes of patients in the intensive care unit (ICU).

URINE OUTPUT IS A STRONG PREDICTOR OF AKI

Acute Kidney Injury (AKI) develops in over 55% of ICU patients. It is often associated with a high risk of chronic kidney disease, other organ dysfunction, and can have a mortality rate of up to 50% [1, 2]. The increased length of ICU stay due to AKI and its associated costs are well known and have been discussed in the scientific literature [3, 4].

While urine output and serum creatinine are the key diagnostic indicators for AKI according to the RIFLE*, AKIN*, and KDIGO* criteria, several studies have confirmed that urine output alone is a stronger predictor of AKI than creatinine [5, 6, 7]. In fact, recent studies establish the absolute necessity for urine output assessment in patients for diagnosing and staging AKI [8].

In a single-center, prospective study of 339 ICU patients, in which 41.6% of the patients developed AKI, 38% were identified as having AKI using urine output criteria alone; this represented more than twice those identified only by increased serum creatinine levels [9]. In a recent multinational, prospective study of 4683 patients in pediatric intensive care units, plasma creatinine levels alone failed to identify AKI in 67.2% of the patients with low urine output. The authors concluded that even if it means keeping patients catheterized longer, urine output monitoring is critical for early detection of AKI [10].

"Urine output is a sensitive and early marker for AKI and is associated with adverse outcomes in intensive care unit patients. Urine flow rate is a sensitive and specific biomarker that provides an early warning signal for impending renal dysfunction [11]."

*RIFLE: Risk, Injury, Failure, Loss of kidney function, End-stage kidney disease
*AKIN: Acute Kidney Injury Network
*KDIGO: Kidney Disease: Improving Global Outcomes

URINE OUTPUT AND RENAL REPLACEMENT THERAPY (RRT)

Renal Replacement Therapy (RRT) is performed to treat patients with severe AKI, often with multiple organ failure, as well as to remove fluid in patients with fluid overload, including those with acute heart failure and lung edema. In patients with severe AKI, RRT represents a cornerstone of treatment. Although much progress has been made in this area, many questions remain unanswered. For example, there is no clear consensus on when to start RRT. Although early initiation of RRT is not clearly associated with benefit, avoiding or delaying RRT is associated with higher mortality and increased lengths of hospital/ICU stay [12].

Initiation and Discontinuation of RRT

The Furosemide Stress Test (FST), consisting of a single intravenous dose of Furosemide, followed by measurement of 2-hour urine output, was recently introduced as an effective method for predicting progression of disease in early-stage AKI and for facilitating decisions regarding optimal timing of RRT initiation [13]. In a recent study, FST urine output significantly outperformed biochemical biomarkers for prediction of progressive AKI, the need for RRT, and inpatient mortality [14].

While there is also a lack of consensus regarding optimal timing for cessation of RRT, urine output has been shown to be the most significant predictor of successful discontinuation [15, 16, 17].

URINE OUTPUT, FLUID BALANCE, AND AKI RISK IN THE ICU

There are a number of clinical conditions in the ICU that are considered to be causes of, or highly associated with, AKI. In these conditions, the need for optimal fluid management is of paramount importance in order to minimize the risk of AKI, as well as overall morbidity and mortality. For patients with these complex conditions, continuous, real-time monitoring of urine flow is critical for tracking volume overload and assessing response to therapy [18]. A sampling of these conditions and the role of urine flow monitoring are presented below.

Fluid Overload

Fluid overload that occurs either as a result of resuscitation efforts or with overuse are now becoming recognized as a major risk factor for ICU complications. There is increasing evidence that suggests a role for fluid overload as a causative factor for AKI, multi-organ failure and mortality [19]. Recent studies have shown that a positive fluid balance in the first 24 hours following ICU admission was associated with a significant risk of AKI in a mixed critically ill population [20]. Furthermore, urine output data obtained within these first 24 hours from a mixed group of ICU patients were shown to be an independent predictor of mortality [21]. Continuous, reliable, urine flow monitoring appears to be essential, immediately upon entry to the ICU, for early detection of increased risk of AKI and mortality.

Sepsis

Sepsis is the most common cause of AKI in the ICU, occurring in approximately 40% of critically ill patients. IV fluid administration is an essential component of sepsis management, and initiation of RRT before the onset of overt AKI complications and significant fluid overload may be associated with improved survival
[22, 23]. Close monitoring of urine output is important for facilitating successful fluid management and evaluating response to treatment.

Post-Cardiopulmonary Bypass Surgery

AKI occurs in up to 30% of patients undergoing cardiac surgery due to a number of risk factors that are specific to their anesthetic, surgical, and ICU management [24]. The prognosis among this subgroup of patients is poor, with an increased mortality risk exceeding 60% compared to the overall mortality rate of 2–8% after cardiac surgery [25]. While there is no consensus regarding prediction models for AKI after cardiac surgery, recent studies have shown that low urine output during cardiopulmonary bypass predicted AKI in patients following coronary artery bypass grafting [26, 27]. Initiation of real-time monitoring of urine flow at the time of catheterization in the OR may potentially identify cardiac bypass patients with oliguria hours before they are transferred to the ICU.

Burn Management

Appropriate fluid resuscitation, specifically during the first 48 hours following injury, is considered to be the single most important therapeutic intervention in severe burn treatment. Although many formulas have been developed to estimate the optimal amount of fluids for severe burn patients, over-resuscitation (or “fluid creep”) is currently one of the most significant challenges during the initial period of burn care. As a result, burn experts are developing sophisticated fluid resuscitation models to prevent this problem, some of which include close monitoring of urine output to guide resuscitation [28].

THE NEED FOR RELIABLE, REAL-TIME MEASUREMENTS OF URINE FLOW IN THE ICU

In critical care units today, almost all of the patients' essential physiological functions are electronically monitored and displayed around the clock. ICU medical and nursing staffs routinely rely on devices that monitor essential functions like heart rate, blood pressure, blood gases etc., alerting them of irregularities and enabling them to provide minute-by-minute, life-saving care to ICU patients. Similarly, real-time and accurate monitoring of urine output could improve the clinical management of patients in the ICU, by enabling clinicians to detect early signs of changes in renal function.

"Treating urine flow as a continuous physiological variable instead of an interval parameter would provide more time points for the detection of AKI [29]."

Surprisingly, despite the fact that ongoing or frequent urine monitoring can provide critical information regarding impaired renal function and/or fluid balance, urine output is still being recorded manually and intermittently.

Manual Urine Flow Measurements are Unreliable

Manual urine flow measurements are time-consuming, requiring manipulation of urine meters, visual assessment and painstaking data recording. These difficulties in measuring, monitoring and accurately recording urine output bring into question the reliability of urine bag readings, in terms of frequency, regularity, and accuracy. Reliable, hourly urine output measurements are just too difficult to obtain with current clinical practice. As a result, there is no standardized approach for early detection of changes such as oliguria [30, 31].

Real-time Alerts

"Ideally, it would be preferable to have devices that record urine output in real time that display the information with warnings when the level has decreased below a set threshold [32]."

Studies of real-time electronic alerts (e-alerts) of early or impending AKI using electronic medical records and clinical information systems have shown conflicting results [33]. In a randomized trial with 664 patients with AKI, an electronic alert system based on real-time serum creatinine levels alone was ineffective [34]. However, in a prospective study of 951 ICU patients, automated, real-time alerts of worsening RIFLE criteria (90% of which were diagnosed based on low urine output), were shown to increase the number and timeliness of early therapeutic intervention [35]. Additional studies with real-time electronic alerts using urine output levels alone are needed.

CONCLUSION

The importance of continuous, reliable urine flow monitoring for AKI and fluid management in critically ill patients has been emphasized by leading nephrologists and critical care experts. The availability of accurate, real-time urine flow information could facilitate early AKI risk assessment, staging and early intervention, as well as improved monitoring of fluid balance and assessment of response to diuretics in patients with fluid overload. Real-time electronic alerts based on abnormal urine output levels could enhance patient care and reduce morbidity and mortality.

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