ORIGINAL ARTICLE

Role of Inferior Vena Cava Assessment in Management of Acute Kidney Injury Patients in Medical Intensive Care Unit

Ahmad E. M. Seliem [a,*], Ahmad M. A. Abo-Alhassan [a], Mostafa M. E. Metwaley [a], Khaled M. Y. Elnadyl [b]

[a] Department of Internal Medicine, Faculty of Medicine for Boys, Al-Azhar University, Cairo, Egypt
[b] Department of Cardiology, Military Medical Academy, Cairo, Egypt

Abstract

Background: ***Patients in critical care often have acute kidney injury (AKI), a serious condition that frequently necessitates careful fluid management to avoid additional complications. Fluid therapy in the medical intensive care unit (MICU) can be guided by the inferior vena cava (IVC) collapsibility index, which can be assessed using bedside echocardiography and is a non-invasive substitute for central venous pressure (CVP).***

Aim of the work: ***Compared to CVP measurements, this study sought to determine if IVC assessment was more useful in fluid management for patients with AKI.***

Patients and Methods: ***The MICU at Al-Hussein University Hospital in Cairo, Egypt, was the site of a prospective observational study. We randomly divided forty individuals with acute kidney injury into two groups: Group 2 depended on CVP values for fluid therapy, whereas Group 1 used IVC collapsibility indices as guidance. There was a 48-hour data collection period for baseline and follow-up hemodynamic parameters, urine output, and serum creatinine.***

Results: ***Both groups demonstrated significant improvements in serum creatinine levels and urine output after 48 hours. Group 1 showed superior dynamic changes in IVC collapsibility indices and a better correlation with fluid responsiveness. Overall renal results, however, did not differ significantly between the two groups.***

Conclusion: ***IVC collapsibility indices provide a viable, non-invasive alternative to CVP for fluid management in critically ill AKI patients. However, further studies with larger sample sizes are recommended to validate these findings.***

Keywords: Inferior vena cava; Acute kidney injury; Intensive care

1. Introduction

An essential endocrine organ that produces erythropoietin and active vitamin D, the kidney also filters plasma and keeps the body at a constant temperature and pressure. It filters the body's plasma volume hourly and gets about 25% of cardiac output.[1]

Acute kidney injury is defined as a decrease in kidney function that is both immediate and persistent. Its occurrence has risen dramatically in recent years, and it is a common and terrible clinical condition, especially in very sick individuals.[2]

There is a high death rate in severely sick patients associated with AKI, often exceeding 50% among those who require renal replacement therapy (RRT). Chronic renal failure and reliance on RRT are two examples of the long-term consequences that survivors often have to deal with.[3]

Fluid management has an important role in the treatment of Acute Kidney Injury. Appropriate fluid resuscitation aims to restore hemodynamics, optimize renal perfusion, and prevent further organ injury. However, inadequate or excessive fluid administration can lead to hypoperfusion or fluid overload, exacerbating the condition and increasing mortality risk.[4]

Traditional methods like central venous pressure (CVP) monitoring, although widely used, involve invasive techniques with potential complications and limited predictive value for fluid responsiveness.[5]

Accepted 06 February 2025.
Available online 28 February 2025

* Corresponding author at: Internal Medicine, Faculty of Medicine for Boys, Al-Azhar University, Cairo, Egypt.
E-mail address: ahmedo0osaid@gmail.com (A. E. M. Seliem).

https://doi.org/10.21608/aimj.2025.446442

As a non-invasive method to assess intravascular volume status, bedside echocardiography has lately become popular. An indicator of the dynamic information about volume responsiveness is the inferior vena cava (IVC) collapsibility index, which is computed from changes in IVC diameter throughout the respiratory cycle.[6]

In spontaneously breathing patients, a collapsibility index of ≥50% correlates with intravascular volume depletion, while in mechanically ventilated patients, a variation index (ΔIVC) of ≥12% suggests fluid responsiveness.[7]

When it comes to fluid management in patients hospitalized in the medical intensive care unit (MICU) with acute kidney injury (AKI), this study looks into intraventricular catheterization (IVC) evaluation using bedside echocardiography as guidance. By comparing the results of IVC-guided and CVP-guided fluid treatment, this study hopes to provide light on the potential of non-invasive approaches to optimize fluid management and improve patient outcomes.

2. Patients and methods

After obtaining ethical approval from the Al-Azhar University School of Medicine, this prospective observational study was conducted at Al-Hussein University Hospital in Cairo, Egypt. It was randomized. Before anyone could be a part of the study, they had to give their written, informed consent.

Inclusion Criteria: All patients admitted to the MICU who were officially diagnosed with Acute Kidney Injury (AKI) according to the Kidney Disease: Improving Global Outcomes (KDIGO) criteria were considered for inclusion. When serum creatinine levels rise by at least 0.3 mg/dL in 48 hours, when they rise by 50% from baseline levels, or when urine output drops to less than 0.5 mL/kg/hour and stays below six hours or longer, it is considered acute kidney injury (AKI).[8]

Exclusion Criteria: Exclusion from the trial was granted to patients who met the following criteria: Patients with obstructive uropathy, chronic hepatic failure, pulmonary hypertension, moderate-to-severe tricuspid regurgitation, pulmonary embolism, moderate-to-severe heart failure (LVEF ≤30%), contrast-induced nephropathy, or clinical signs of elevated abdominal pressure, as well as patients who are under the age of 16, are not eligible for this procedure.

Ethical Considerations: Confidential information was collected from patients. All subjects provided their written or verbal consent, and the study followed all protocols set out by the Al-Azhar University Ethical Committee. In no publication or report pertaining to this study were the participants named. We informed the participants of the study's goals, methodology, and risk-benefit analysis before enrolling them.

Sample Size: Based on the anticipated proportion of improvement in blood creatinine levels 85% in the IVC group and 31% in the CVP group, a sample size of forty patients was determined using the PASS software. At the 5% level of significance, this sample size attained a power of 97%.

Operational design: The patients were randomly divided into two groups (20 patients each): Group 1: Vital signs were monitored in the intravenous catheter to direct the fluid therapy. Patients who are able to breathe on their own: Fluid responsiveness was indicated by an IVC collapsibility index (IVC-CI) of 50% or above, whereas, in the case of mechanically ventilated patients, Fluid responsiveness was indicated by an IVC variation index (YIVC) of ≥12%. As part of the fluid challenge, participants were given 250 mL of normal saline and monitored with an echocardiogram four times a day. Group 2: Fluid therapy was guided by CVP measurements. CVP <8 cm H2O indicated hypovolemia, warranting a fluid challenge with 250 mL of normal saline, while CVP >12 cm H2O indicated hypervolemia. CVP was measured every 4 hours along with hemodynamic parameters.

Data Collection: Baseline and follow-up data were collected, including Demographic characteristics (age, gender, BMI), Hemodynamic parameters (heart rate, blood pressure), Laboratory values (serum creatinine, urine output), Fluid balance, Dynamic indices (IVC-CI, ΔIVC) and CVP readings. One of the main things that was measured was how many patients' serum creatinine levels had improved after 48 hours. Variations in hemodynamic markers, fluid volume, and urine output were considered secondary outcomes.

Statistical Analysis: SPSS 26.0 for Windows (SPSS Inc., Chicago, IL, USA) was used for statistical analysis of all data. The use of range (including minimum and maximum), mean, standard deviation, and median has previously defined quantitative information. The results for continuous variables were presented as means ± standard deviation (SD), whereas the results for categorical variables were presented as percentages. We utilized the following statistical methods: a t-test to compare continuous variables between the two groups, an ANOVA to examine repeated measures over time, a chi-square test to compare proportions between qualitative parameters for categorical comparisons, and a Pearson correlation to evaluate relationships between dynamic indices and renal function.

Statistical significance was determined by a p-value less than 0.05.

3. Results

Table 1. Patients' baseline characteristics

VARIABLE	GROUP 1 (IVC) (MEAN ± SD)	GROUP 2 (CVP) (MEAN ± SD)	P-VALUE
AGE (YEARS)	52.2 ± 19.3	51.8 ± 18.9	0.89
FEMALE (%)	50%	60%	0.55
BMI (KG/M²)	24.5 ± 3.2	24.8 ± 3.5	0.78

Body mass index, or BMI SD: The standard deviation p:p value used to compare the groups under study P-value<0.05 indicates significance; P-value<0.001 indicates high significance; P-value>0.05 indicates non-significant.

Baseline Characteristics: The groups were comparable in age, gender, and BMI, with no significant differences observed.

Table 2. Serum Creatinine Levels Over 48 Hours

TIME POINT	GROUP 1 (IVC) (MEAN ± SD)	GROUP 2 (CVP) (MEAN ± SD)	P-VALUE
BASELINE (MG/DL)	3.2 ± 0.6	3.1 ± 0.5	0.70
48 HOURS (MG/DL)	2.4 ± 0.5	2.5 ± 0.6	0.07

SD: The standard deviation p:p value used to compare the groups under study P-value<0.05 indicates significance; P-value<0.001 indicates high significance; P-value>0.05 indicates non-significant.

Both groups showed significant reductions in serum creatinine levels over 48 hours. However, the difference in creatinine reduction between the groups was not statistically significant.

Table 3. Urine Output Over 48 Hours

TIME POINT	GROUP 1 (IVC) (MEAN ± SD)	GROUP 2 (CVP) (MEAN ± SD)	P-VALUE
BASELINE (ML/KG/HOUR)	0.35 ± 0.12	0.38 ± 0.14	0.65
48 HOURS (ML/KG/HOUR)	0.72 ± 0.15	0.69 ± 0.16	0.55

SD: Standard deviation of the p-value for comparing the groups under study If the P-value is less than 0.05, it is considered significant; if it is less than 0.001, it is greatly significant.

Urine output improved significantly in both groups after 48 hours. The differences between the groups were not statistically significant.

Table 4. IVC Collapsibility Index and ΔIVC Over 48 Hours

PARAMETER	BASELINE (MEAN ± SD)	48 HOURS (MEAN ± SD)	P-VALU
IVC-CI (%)	59 .75 ± 4.58	26.85 ± 1.35	<0.001
ΔIVC (%)	15.80 ± 2.61	10.25 ± 1.12	<0.001

IVC collapsibility index, or IVC-CI SD: Standard deviation p:p value for comparing the groups under study; ΔIVC: IVC Variation Index P-value<0.05 indicates significance; P-value<0.001 indicates high significance; P-value>0.05 indicates non-significant.

Dynamic indices (IVC-CI and ΔIVC) improved significantly in Group 1, with highly significant p-values (<0.001). These changes reflect the effectiveness of IVC-guided fluid therapy.

Table 5. Volume of Fluid Administered Over 48 Hours

VARIABLE	GROUP 1 (IVC) (MEAN ± SD)	GROUP 2 (CVP) (MEAN ± SD)	P-VALUE
TOTAL VOLUME (ML)	1250 ± 250	1275 ± 300	0.82

SD: The standard deviation p:p value used to compare the groups under study P-value<0.05 indicates significance; P-value<0.001 indicates high significance; P-value>0.05 indicates non-significant

The total volume of fluid administered was similar between the two groups, with no statistically significant differences.

4. Discussion

In this study, fluid management guided by inferior vena cava (IVC) assessment demonstrated significant improvements in dynamic indices, such as IVC collapsibility index (IVC-CI) and variation index (ΔIVC), Results are consistent with the results of a study conducted by Jambeih and his colleagues on thirty-three patients who had AKI in order to gauge how well IVC evaluation might predict how fluid therapy would affect the improvement in kidney functions. Two patient groups participated in the study. While patients in group two received fluid regardless of their IVC measurements, patients in group one received fluid based on their IVC measurements. Urine output (0.86×0.54 vs 0.45×0.36 ml/kg/h, p=0.03) and creatinine [85% vs 31%] significantly improved in group one individuals. They came to the conclusion that better kidney function was linked to fluid delivery after IVC assessment.[9]

However, our results show that while these indices improved significantly, they did not translate into a superior reduction in serum creatinine levels or urine output compared to central venous pressure (CVP) guided therapy.

This finding contrasts with other studies that suggested that IVC-based assessment provides a more accurate prediction of fluid responsiveness than CVP.[10]

Our study's small sample size may have diminished our ability to identify minute variations in renal outcomes, which could be one reason for this disparity. Furthermore, differences in patient demographics, such as our study's exclusion criteria for patients with serious comorbidities, may have affected the findings.

Studies by Elaine and Matthew Kaptein emphasized the limitations of static measures like CVP, highlighting their susceptibility to changes in intrathoracic and abdominal pressures.[11]

Our study supports this notion, as dynamic indices derived from IVC measurements presented a more direct reflection of volume responsiveness. However, A lack of a significant correlation between these indices and renal outcomes in our study suggests that factors beyond fluid responsiveness, such as underlying renal pathophysiology and hemodynamic status, play an important role in AKI management.

Moreover, findings by Shahsavarinia et al. demonstrated a strong correlation between IVC diameter changes and cardiac output improvements.[12] While our study did not measure cardiac output directly, the significant improvements in IVC indices in Group 1 imply better hemodynamic monitoring. Nevertheless, the absence of superior renal outcomes raises questions about the practical significance of these indices in predicting long-term kidney recovery.

On the other hand, studies such as those by Orso et al. reported weak correlations between IVC parameters and fluid responsiveness, particularly in patients with postoperative or cardiac conditions.[13] This aligns with our observation that IVC indices may not always predict renal function improvement, especially in a heterogeneous MICU population.

Interestingly, our findings diverge from Kaptien et al., who found that the IVC collapsibility index was a strong predictor of hypotension during ultrafiltration in chronic heart failure patients.[14] This discrepancy could stem from differences in study settings, as their study focused on chronic heart failure patients undergoing ultrafiltration, unlike our study which targeted critically ill AKI patients with acute fluid management needs.

Finally, although dynamic indices offer a promising non-invasive alternative to CVP, their application should consider individual patient factors and clinical contexts. For instance, the limited correlation observed in our study emphasizes the need for a multimodal approach, integrating IVC assessments with other parameters like stroke volume variation or passive leg raising to enhance decision-making in fluid management.

Significance of Findings: The results support the utility of the IVC collapsibility index (IVC-CI) and variation index (ΔIVC) as reliable, non-invasive tools for assessing fluid responsiveness in AKI patients. Group 1 (IVC-guided therapy) showed notable improvements in dynamic indices, reflecting enhanced hemodynamic monitoring. Despite this, the lack of significant differences in primary outcomes (serum creatinine improvement and urine output) between the groups underscores the complexity of AKI management, where multiple factors beyond fluid responsiveness play a role.

Clinical Implications: Bedside echocardiography offers a practical, safe, as well as reproducible method for assessing intravascular volume status. Its non-invasive nature reduces the risks associated with CVP catheterization, such as infection and thrombosis. However, implementing IVC-guided fluid management requires adequate training and expertise in echocardiographic techniques, which may limit its widespread adoption in resource-limited settings.

Study Limitations: Single-Center Design: Conducting the study in a single institution may introduce selection bias and, Lack of Long-Term Follow-Up: The study focused on short-term outcomes (48 hours), which may not capture the full impact of fluid management strategies on renal recovery and patient survival, Exclusion Criteria: The exclusion of patients with complex comorbidities, such as pulmonary hypertension and severe heart failure, limits the applicability of the findings to a broader patient population, Correlation Limitations: The weak correlation between dynamic indices and renal outcomes suggests the need for additional markers to optimize fluid management strategies.

Future Directions: These results need to be confirmed by larger, multicenter studies with longer follow-up times. AKI patients may benefit from a more thorough approach to fluid management if IVC measurement is combined with other dynamic markers like passive leg lifting and stroke volume variation.

4. Conclusion

This study shows that evaluating the inferior vena cava (IVC) collapsibility index (IVC-CI) and variation index (ΔIVC) using bedside echocardiography provides a useful and non-invasive substitute for measuring central venous pressure (CVP) in order to guide fluid management in critically ill patients with acute kidney injury (AKI). The study demonstrated no discernible difference in the two groups' overall renal outcomes, despite the benefits of IVC-guided fluid management, such as a lower risk associated with invasive procedures. These results highlight how crucial it is to customize fluid management strategies according to patient-specific characteristics and clinical knowledge. To confirm these results, more studies with bigger, multicenter trials and longer follow-up times are needed. Combining IVC evaluation with additional hemodynamic metrics may offer a more thorough approach to fluid treatment optimization for patients in severe condition.

Disclosure

The authors have no financial interest to declare in relation to the content of this article.

Authorship

All authors have a substantial contribution to the article

Funding

No Funds : Yes

Conflicts of interest

There are no conflicts of interest.

References

1. ELIE, Marie-Carmelle; HWANG, Charles; SEGAL, Mark. Renal Emergencies. Emergency Department Critical Care, 2020, 283-300.
2. PÉREZ FERNÁNDEZ, Xose Luis. Sepsis associated Acute Kidney Injury: incidence, risk factors and continuous renal replacement therapies. 2019.
3. FORTRIE, Gijs; DE GEUS, Hilde RH; BETJES, Michiel GH. The aftermath of acute kidney injury: a narrative review of long-term mortality and renal function. Critical Care, 2019, 23: 1-11.
4. MESSINA, Antonio, et al. Understanding fluid dynamics and renal perfusion in acute kidney injury management. Journal of Clinical Monitoring and Computing, 2024, 1-11.
5. ALVARADO SANCHEZ, Jorge Ivan; AMAYA ZUNIGA, William Fernando; MONGE GARCIA, Manuel Ignacio. Predictors to intravenous fluid responsiveness. Journal of intensive care medicine, 2018, 33.4: 227-240.
6. PREAU, Sebastien, et al. Diagnostic accuracy of the inferior vena cava collapsibility to predict fluid responsiveness in spontaneously breathing patients with sepsis and acute circulatory failure. Critical care medicine, 2017, 45.3: e290-e297.
7. COUTINHO, Akeme Laissa Novais, et al. Inferior vena cava ultrasound for assessing volume status and fluid responsiveness in critically ill patients: a systematic review. Arq Bras Cardiol: Imagem cardiovasc., 2021, 34.3.
8. OSTERMANN, Marlies, et al. Controversies in acute kidney injury: conclusions from a Kidney Disease: Improving Global Outcomes (KDIGO) Conference. Kidney international, 2020, 98.2: 294-309.
9. JAMBEIH, Rami; KEDDISSI, Jean I.; YOUNESS, Houssein A. IVC measurements in critically ill patients with acute renal failure. Critical care research and practice, 2017, 2017.1: 3598392.
10. TALREJA, Neha Gopal; SHETTY, Vijay. Ultrasound Derived Inferior Vena Cava Diameter and Collapsibility Index to Predict Central Venous Pressure Prior and After A Fluid Challenge in Spontaneous Breathing Preoperative Patients. Ain-Shams Journal of Anesthesiology, 2024, 16.1: 1-10.
11. KAPTEIN, Elaine M.; KAPTEIN, Matthew J. Inferior vena cava ultrasound and other techniques for assessment of intravascular and extravascular volume: an update. Clinical Kidney Journal, 2023, 16.11: 1861-1877.
12. SHAHSAVARINIA, Kavous, et al. Comparison of cardiac output, IVC diameters and lactate levels in prediction of mortality in patients in emergency department; An observational study. Pakistan Journal of Medical Sciences, 2020, 36.4: 788.
13. ORSO, Daniele, et al. Accuracy of ultrasonographic measurements of inferior vena cava to determine fluid responsiveness: a systematic review and meta-analysis. Journal of intensive care medicine, 2020, 35.4: 354-363.
14. KAPTEIN, Matthew J., et al. Relationship of inferior vena cava collapsibility to ultrafiltration volume achieved in critically ill hemodialysis patients. International Journal of Nephrology and Renovascular Disease, 2018, 195-209.