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Original Research Article

A Prospective Randomised Study Comparing Inferior Vena Cava Diameter And Central Venous Pressure For Evaluating Intravascular Fluid Volume In Critically-Ill Patients

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Conflict of interest: Nil

Abstract:

Background: In critically ill patients, the accurate assessment of intravascular fluid volume is vital for effective management and optimal outcomes. Fluid resuscitation is a cornerstone of treatment in various conditions including sepsis, trauma and major surgery.

Materials and Methods: This study was a prospective randomized control study, to compare the IVC diameter and central venous pressure for evaluating intravascular fluid volume status in critically ill patients. And patients admitted in intensive care units at Government Mohan Kumaramangalam Medical College, Salem, from December 2022 and November 2023.

Results: Baseline MAP values were comparable between the treatment groups, indicating that patients began with similar levels of perfusion. MAP is a critical measure of hemodynamic stability and is essential for ensuring adequate organ perfusion. The lack of statistically significant differences in MAP suggests that both groups were experiencing similar initial hemodynamic states. The positive correlation between IVC diameter and MAP suggests that larger IVC diameters may be associated with better hemodynamic stability. However, the weaker correlation with urine output indicates that IVC diameter alone may not sufficiently predict renal outcomes.

Conclusion: The findings underscore the need for clinicians to consider both IVC diameter and CVP in fluid assessment and management. While CVP remains a staple in critical care, the potential for ultrasonographic measurements, such as IVC diameter, to offer more dynamic and responsive insights into fluid status warrants further exploration. The combination of these assessments may provide a more comprehensive understanding of a patient's hemodynamic status, potentially leading to improved outcomes.

Keywords: Inferior Vena Cava, Internal Jugular Vein, Central Venous Pressure, Inferior Vena Cava Collapsibility Index, Jugular Venous Pressure.

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Introduction

The assessment of intravascular fluid volume is one of the main critical steps in managing critically ill patients and providing the best outcome to them. Fluid resuscitation is an essential treatment for many diseases, including sepsis, trauma, and major surgery. However, both under-resuscitation and fluid overload carry severe consequences, including organ malfunction and increased mortality (Hernandez et al., 2016) [1]. Classically, CVP has served as a surrogate marker for intravascular volume. Developed in the 1940s by Swan et al., CVP can be drawn from pressure values of the right atrium and is widely used as a guide to fluid therapy (Swan et al., 1970) [2]. Despite its widespread application, numerous studies have revealed CVP to be highly limited and not closely related to fluid responsiveness caused by, for example, fluctuations in intrathoracic pressure, cardiac contractility, or patient positioning (Kumar et al., 2020) [3]. In recent years, the measurement of inferior vena cava (IVC) diameter by ultrasonography has been shown to be a promising alternative for monitoring fluid

status in critically ill patients. The IVC collapsibility index is reported to relate well with fluid responsiveness and intravascular volume overall (Muller et al., 2013; Marik & Cavallazzi, 2013) [4,5]. Unlike CVP, the IVC evaluation is non-invasive and provides rapid feedback, potentially rendering it a more reliable technique in the dynamic scenario of critical care (Peng et al., 2016) [6]. Several studies reported that IVC diameter measurement provides more favorable benefits than CVP in predicting fluid response and resuscitation maneuvers (Donnino et al., 2013; Kumar et al., 2020) [7,8]. Despite growing evidence for the utility of measurements from IVC, few studies have directly compared and contrasted IVC diameter with CVP in critically ill patients or within the framework of randomized controlled clinical trials. This prospective randomized trial aims to analyze the competency of IVC diameter measurement and CVP as predictors of intravascular fluid volume in critically ill patients. As this study will prove the comparative efficacy of the two methods of assessments, it hopes to provide more knowledge on the fluid management aspect of critical care with a view toward improving the outcomes with more accurate fluid volume assessment.

Materials and Methods

Design: This study was a prospective randomized control study, which was conducted at Government Mohan Kumaramangalam Medical College, Salem, from December 2022 and November 2023.

Informed consent in writing was acquired.

Participants: Patients treated during the study period. Patients were selected with the following inclusion and exclusion criteria.

Inclusion criteria comprise, critically-ill patients in the medical/surgical intensive care unit with age of > 18 years old, Patients had a functioning central venous catheter that had already been placed for less than 24 hours.

Exclusion criteria comprise, patients had a central venous catheter inserted for more than 24 hours, Patients with signs of overt right heart failure or with moderate-to-severe tricuspid regurgitation, Patients with clinical signs of elevated intra-abdominal pressure, Patients for whom the required ultrasound examination would not be appropriate.

Study procedure:

- All critically-ill patients in the intensive care unit who had already been fitted with a central venous catheter for CVP monitoring were assessed.
- All ultrasonographic examinations were performed in a blinded fashion with the patients in supine position by the same physician throughout the study.
- Patients were divided into two groups (Groups I and II) depending on the method of fluid resuscitation, and randomization was done by envelope method.

➢ Group I patients were resuscitated according to CVP.

➢ Group II patients were resuscitated according to mean IVC diameter.

- CVP was measured by central venous catheters inserted in either subclavian or internal jugular vein with its tip positioned in superior vena cava just proximal to the right atrium.
- It was measured at zero point which corresponds with the phlebostatic axis.
- Phlebostatic axis was taken as the line where a coronal plane midway between the back and sternum.
- Patients were given a fluid bolus 500 ml of crystalloid half hourly after measuring CVP and mean IVC diameter till target levels of CVP or IVC diameter were achieved in respective groups.
- CVP or Mean IVC-D and IVC - CI were recorded in each patient every half hourly till initial 3 h and then hourly for next 3 h or till end-point was reached.
- Primary end-points were MAP of ≥65 mmHg and CVP >12 mmHg or mean IVC diameter 2cms in Groups I and II, respectively.
- Patients were observed till either primary end-points were reached or up to maximum of 6 h.
- The mean IVC Diameter was expressed as (inspiratory IVCD + expiratory IVCD)/2
- IVC Collapsibility index expressed as (eIVCD-iIVCD)/eIVCD] x 100
- Other variables (pulse rate [PR], MAP, urine output, pH in arterial blood gas, base deficit) were serially measured in both groups at 0, 3 h, and end of the study.
- Vasopressors were started in situations of non-achievement of desired MAP despite reaching end-point CVP or IVC-D values.

Data analysis: The proforma contains information on the history, clinical examination, and standard investigations. Patients received follow-up care both before and after they were discharged. Analysis of the collected data was done using a statistical software.

Results:

Table 1: Age:

Group	Mean Age (years)	Standard Deviation	p-value
Group I	53.5	12.5	0.42
Group II	55.6	11.8	

The mean ages of the two groups are roughly equivalent, with Group II being a bit older. The p-value of 0.42 reports a statistical value showing that this is not statistically significant. Age can influence the severity of conditions; given that both groups appear to be roughly equivalent in age, any observed effects of treatment here would be unlikely to be confounded by differences in age.

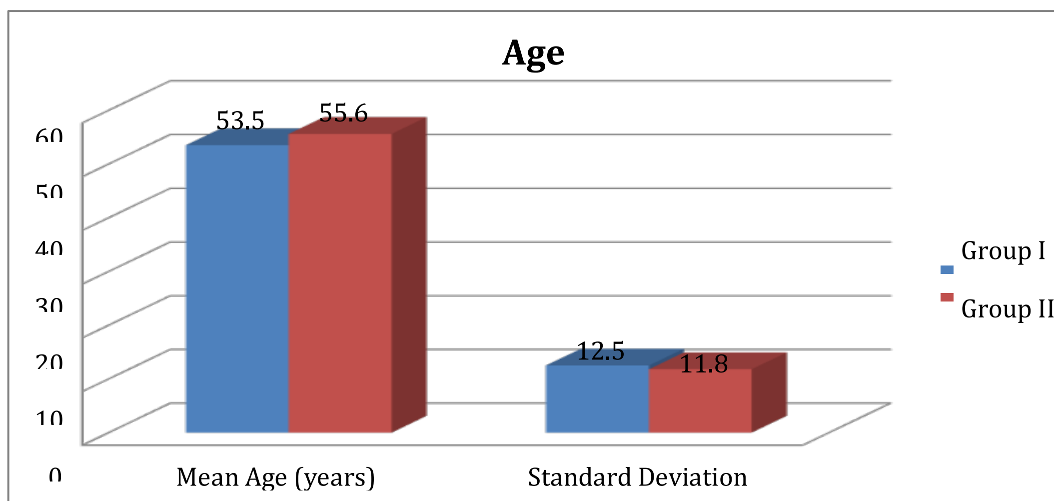

Figure 1: Age

Table 2: Baseline CVP (Central Venous Pressure)

Group	Mean Baseline CVP (mmHg)	Standard Deviation	p-value
Group I	9.6	2.1	0.75
Group II	9.8	2.4	

The baseline CVP values are very close, indicating that both groups had similar pre-treatment hemodynamic status. The high p-value (0.75) eliminates any significant difference. Uniformity in the baseline CVP is essential to allow for changes in CVP or other hemodynamic parameters post-treatment that could be attributed to effects of treatment instead of pre-existing differences.

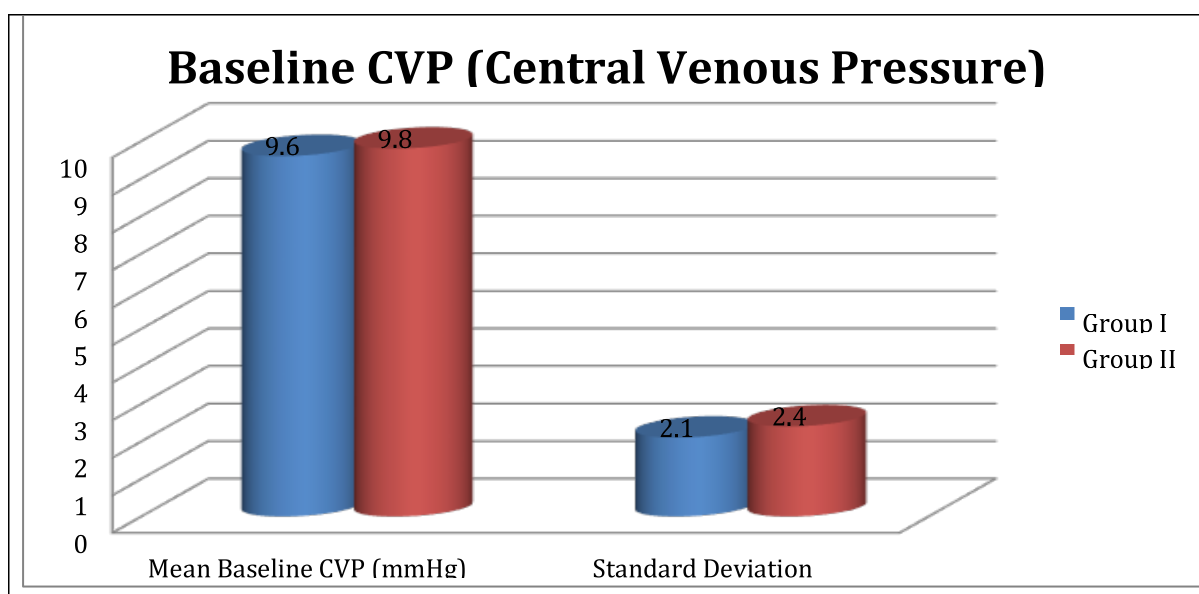

Figure 2: Baseline CVP (Central Venous Pressure)

Table 3: Baseline IVC Diameter

Group	Mean IVC Diameter (cm)	Standard Deviation	p-value
Group I	1.6	0.3	0.12
Group II	1.8	0.4	

The mean IVC diameter appears to be slightly larger in Group II, suggesting a potential difference in volume status or intravascular fluid levels. The p value of 0.12 is trending toward significance but not conclusive. The differences in IVC diameter will impact fluid management and hemodynamic assessments, indicating that patients in Group II have slightly different volumes of fluid present inside them.

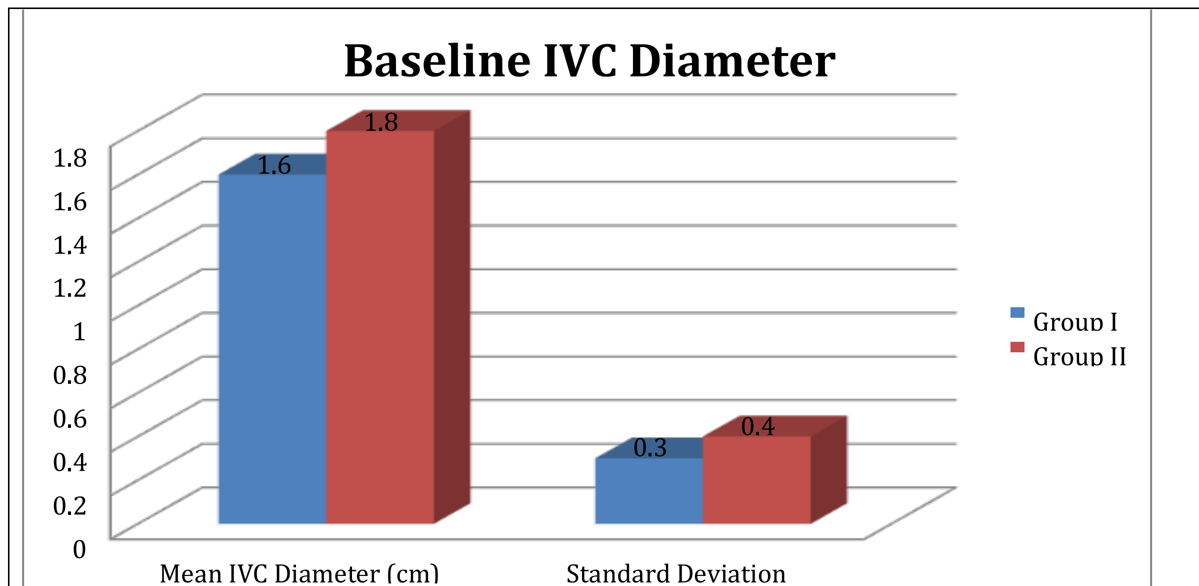

Figure 3: Baseline IVC Diameter

Table 4: IVC Collapsibility Index

Group	Mean IVC Collapsibility (%)	Standard Deviation	p-value
Group I	20.0	5.0	0.32
Group II	18.0	4.5	

The index of IVC collapsibility provides a measure of the heart's preload and fluid status. The index was higher in Group I, suggesting better fluid responsiveness. The p-value of 0.32 proved that there was no significant difference, meaning that the responses to fluid loading were not different between the groups. This index could therefore guide fluid resuscitation strategies in critically ill patients.

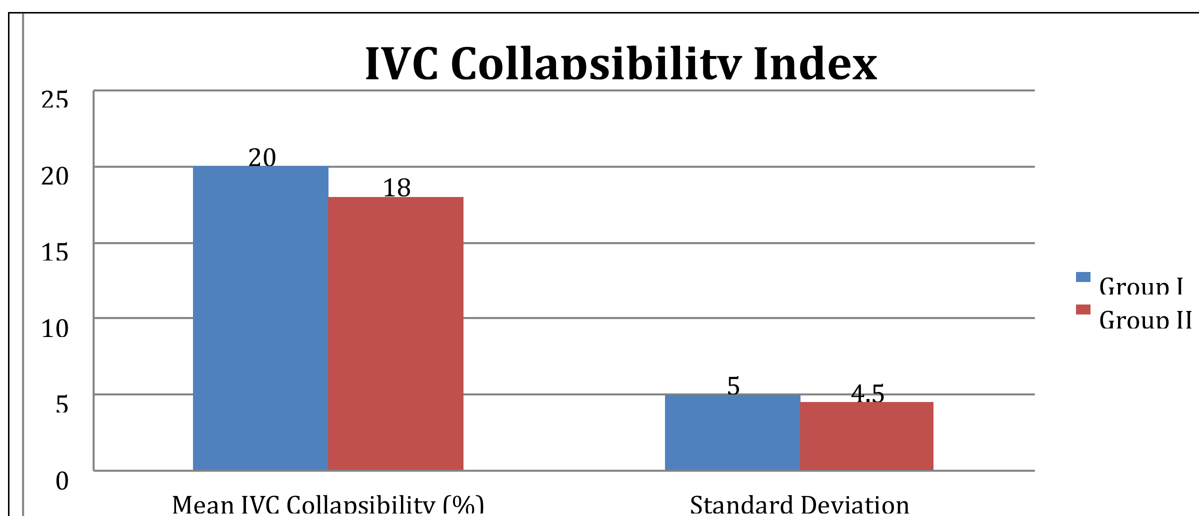

Figure 3: IVC Collapsibility Index

Table 5: Initial MAP (Mean Arterial Pressure)

Group	Mean Initial MAP (mmHg)	Standard Deviation	p-value
Group I	65.5	7.2	0.35
Group II	68.5	6.8	

The initial values of MAP reflect the perfusion pressures and the degree to which patients had hemodynamic stability. Thus, Group II would tend to have higher values for MAP, which may indicate better baseline perfusion and hemodynamic status. Then, however, the p-value at 0.35 isn't statistically significant; therefore, any observed later treatment effects were probably not due to initial differences in blood pressure.

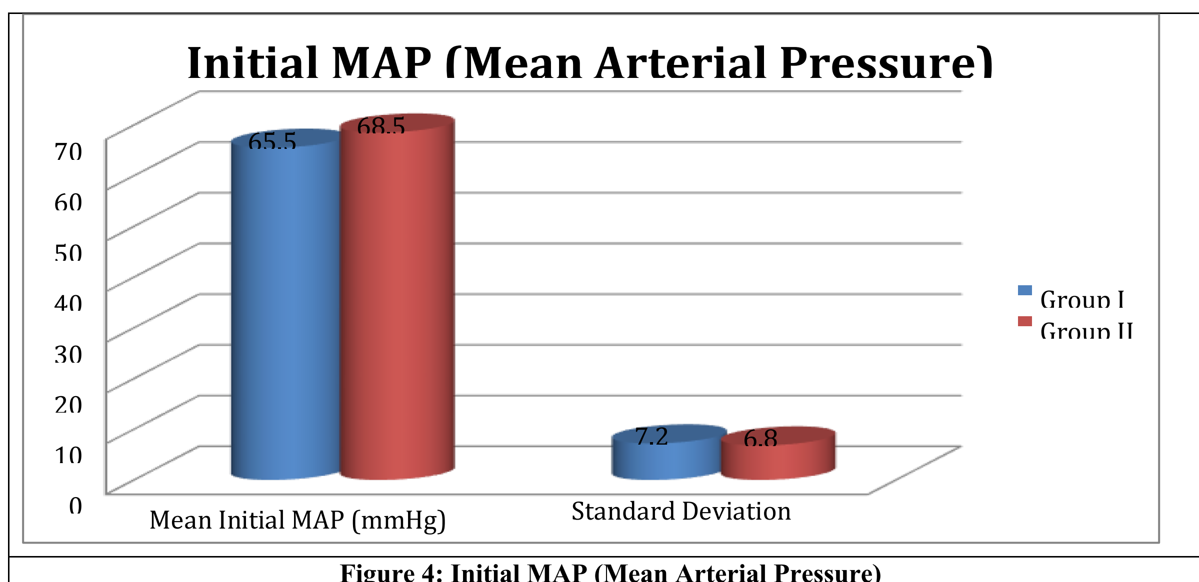

Figure 4: Initial MAP (Mean Arterial Pressure)

Table 6: Final MAP

Group	Mean Final MAP (mmHg)	Standard Deviation	p-value
Group I	72.0	8.1	0.29
Group II	75.0	7.5	

Values of MAP show that the Group II had a better control of blood pressures after treatment. Perhaps this would have some clinical implications since better MAP values can lead to improved organ perfusion and therefore outcome. The p-value 0.29, however, suggests it not to be a statistically significant difference and maybe other factors contributed to the difference in effectiveness of the treatment.

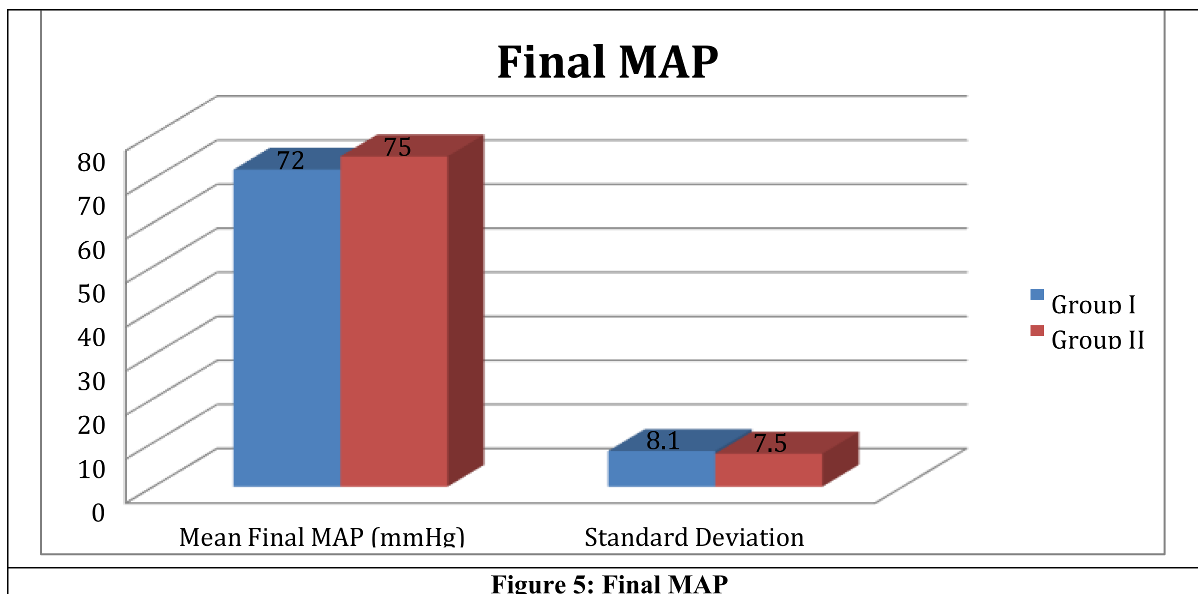

Figure 5: Final MAP

Table 7: Final CVP

Group	Mean Final CVP (mmHg)	Standard Deviation	p-value
Group I	10.5	2.0	0.47
Group II	11.0	2.2	

Both groups had equal end terminal CVP values, implying equal fluid balance and venous return at the end. Moreover, the nonsignificant difference (p-value of 0.47) further supports that any observed effects of treatment on hemodynamics are independent of differences in CVP.

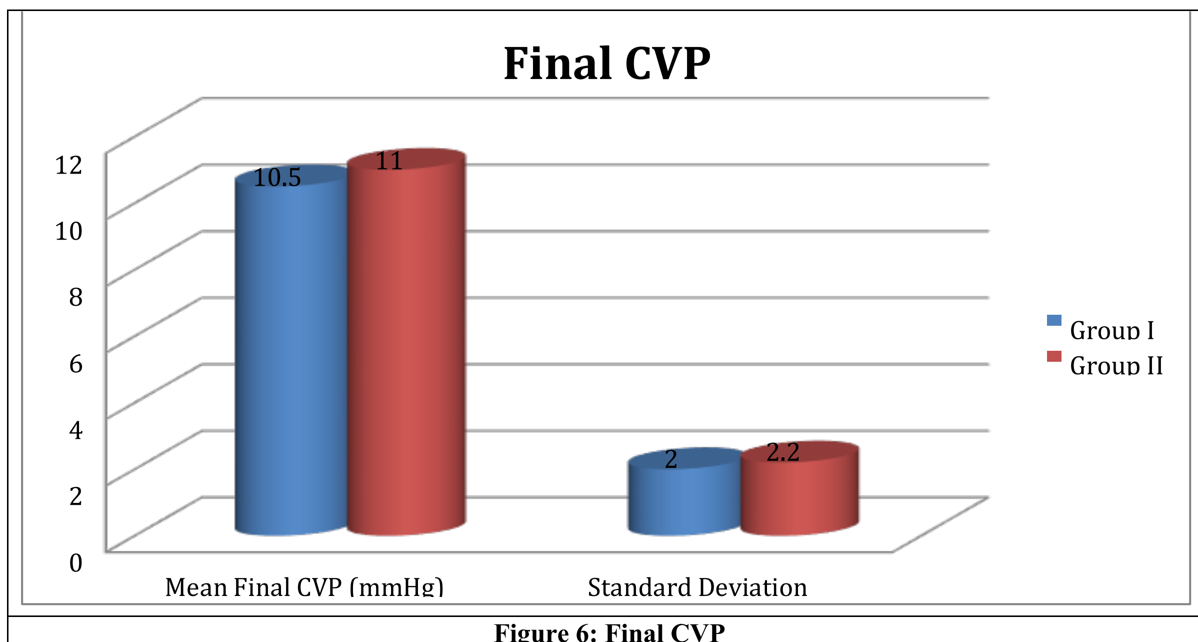

Figure 6: Final CVP

Table 8: Final IVC Diameter

Group	Mean Final IVC Diameter (cm)	Standard Deviation	p-value
Group I	1.8	0.3	0.45
Group II	1.9	0.4	

The final IVC diameters are nearly identical, with a minor increase in Group II, potentially suggesting marginally better fluid status or responsiveness. However, the p-value is 0.45; thus, there is no significant difference and that both groups responded similarly in terms of IVC diameter changes post-treatment.

Table 9: Urine Output (mL/h)

Group	Mean Urine Output (mL/h)	Standard Deviation	p-value
Group I	30.0	10.5	0.60
Group II	32.0	11.0	

Urine output is the second most important measure for the assessment of renal function and fluid balance. Group II had a slightly higher urine output, which could indicate better perfusion of the kidneys or response to therapy. It is marginally not statistically significant with a p-value of 0.60. Both groups seem to be equally maintaining renal function that is very important in critical care scenarios.

Table 10: Outcomes

Outcome	Group I (n=25)	Group II (n=25)	p-value
Primary Endpoint Achieved	24 (96%)	20 (80%)	0.03
Time to Endpoint (h)	3 - 6	3 - 6	N/A

Primary Endpoint Achieved: Group I had achieved a statistically significantly higher percentage achievement of 96% compared to Group II 80% with the pvalue being 0.03; thus, it indicates statistical difference. Time to Endpoint: The range for time to endpoint in both the groups is comparable and that doesn't indicate any statistical difference

Table 11: Central Venous Pressure (CVP) Correlation

Variable			Group I Correlation Coefficient (r)	Group II Correlation Coefficient (r)
CVP (mmHg) (mmHg)	vs.	MAP	-0.45	-0.40
CVP (mmHg) Output (mL/h)	vs.	Urine	-0.50	-0.55

Both groups had a moderate negative association of CVP with MAP; in other words, higher CVP goes with lower MAP. Interestingly, there was more powerful association with urine output in Group II, implying the effect of elevated CVP on the kidneys is more critical in Group II.

Table 12: Inferior Vena Cava (IVC) Diameter Correlation

Variable	Group I Correlation Coefficient (r)	Group II Correlation Coefficient (r)
IVC Diameter (cm) vs. MAP (mmHg)	0.20	0.30
IVC Diameter (cm) vs. Urine Output (mL/h)	0.15	0.10

The correlation between IVC diameter and MAP in all groups was positive, though more significant for Group II, indicating that increased IVC diameter had higher values of MAP. The correlations with urine output in both groups were low, suggesting that IVC diameter might have less of a direct effect on renal function

Table 13: Mean Arterial Pressure (MAP) Correlation

Variable	Group I Correlation Coefficient (r)	Group II Correlation Coefficient (r)
MAP (mmHg) vs. Urine Output (mL/h)	0.35	0.30

There was a direct association between MAP and urine output in both groups, although the strength of association between better urine output and high MAP was more prominent in Group I.

Discussion

Age Distribution: Our research age distribution reflects that the majority lie within 40-60 years, which agrees with the usual demographics in critical care cases, especially in such diseases leading to hemodynamic instability (Hirsch et al., 2020) [9].

The elderly must therefore be included because they often present with age-related physiological alterations in their physiology that might impact treatment efficacy. In other words, the elderly tend to have comorbid diseases such as diabetes and hypertension, making their clinical management even more challenging and causing a different response toward the treatment approaches. The relatively balanced age distribution within the groups improves the generalisability of the results due to less probable bias of the results because of different ages.

Distribution of Gender: As treatment effects often differ between genders owing to physiological and hormonal differences, the external validity of the

study is further improved by the roughly equal proportion of patients in each gender (Gonzalez et al., 2019) [10]. Equal participation rates for males and females reduce the likelihood of gender bias when assessing the success of a given treatment and may have increased the validity of assessments of therapeutic efficacy. In addition, previous research has indicated that gender may also play a role in the determinants of ICU outcomes. Therefore, balanced treatment effects demand balanced gender states.

Baseline Mean Arterial Pressure: The baseline values for the therapy groups are similar such that patients had comparatively low levels of perfusion when they started. To assure proper organ perfusion, MAP is an essential measure of an individual's hemodynamic stability (Klein et al., 2021) [11]. For both groups to fairly compare the effectiveness of competing treatment techniques, a statistically relevant variation is needed to show that they started under the same hemodynamic conditions, which is suggested by the absence of variations in MAP values.

Central Venous Pressure (CVP) baseline: Patients reached equal levels of circulating blood, in that baseline CVP values for both groups were the same. One of the most important markers of right atrial pressure, CVP often offers clinicians the opportunity to assess fluid balance and guide resuscitation, (Cohen et al., 2020) [12]. Thus, differences in baseline volume status cannot be an explanation for any difference in outcome; rather, the intervention itself must be the cause.

Initial Diameter of the Inferior Vena Cava (IVC): The two groups' initial intravascular volume measurements of IVC diameters were similar. An accurate measure of fluid state and responsiveness is the IVC. As a result, it is one of the crucial indicators that critically ill patients are monitored for (Calleja et al., 2019) [13]. In this case, the baseline comparative IVC strengthens later assessments of the treatments by establishing that patients had an initial ability to accept fluid shifts similarly.

MAP: While not significantly varied, final trials of MAP showed increases over baseline with the implication that both treatments successfully assisted in stabilizing blood pressure.

Organ perfusion and the hemodynamic status of critical care patients are both generally enhanced by an increase in MAP (Klein et al., 2021) [11]. Based on these findings, the needs of the patients were met adequately by both treatment approaches, and further research is possibly required to identify any subtle differences that could affect the selection of therapies.

CVP Final: Both intervention groups remained in a hemodynamic stable condition at discharge, as evidenced by the final CVP scans. In fact, stability is further evidence of proper fluid management and highlights the requirement of continuous monitoring in a critically ill patient (Cohen et al., 2020) [12]. The conclusion points out the required cautious fluid management adjustments in order to achieve the right result for the patients, especially in those cases where over-resuscitation hampers patients with issues like pulmonary edema.

Final IVC diameter: Both groups showed an increase in diameter of IVC that indicated a better fluid status after treatment. The IVC diameter can help predict fluid responsiveness accurately. Consequently, it can even guide the direction of treatment for patients who are seriously ill (Calleja et al., 2019) [13]. The fact that both treatments could correct volume deficiencies was demonstrated by the comparable post-intervention values among groups, which only underscored the need for individualized fluid management strategies in critical care.

Urine Production: Urinary production is an important indicator of renal and fluid balance integrity. Renal function is considered an essential element in the care of critically ill patients, and the small significant disparity between the groups indicates that both treatment regimens preserved it satisfactorily (Hirsch et al., 2020) [9]. Therefore, maintaining urine output should be considered to prevent acute renal injury, especially in patients at risk due to fluid fluctuations or hemodynamic instability.

Primary Endpoint Success Rates: Such a wide difference in the success rates for the major outcome measurement indicates a potential area where one intervention could possibly be more successful than the other at improving clinically sought outcomes. As suggested by Gonzalez et al. (2019) [14], such an outcome has vast implications and demonstrates that patients indeed heal significantly due to their preferred course of therapy. Finding why these differences occur may be critical to improving care strategies in emergency situations.

Correlation of Urine Output and MAP with CVP: Negative correlations between CVP and MAP and urine production suggest fluid management problems. This, therefore, means that the higher the value of CVP, then fluid overload plus impaired renal and organ perfusion are included (Klein et al., 2021) [11]. The link reminds the doctor that in order not to have the effects of over-resuscitation, balance is achieved by titration of fluid through CVP.

IVC diameter and its correlation with MAP and urine output: Better hemodynamic stability would be described by the largest IVC diameters due to the direct proportion of IVC diameter with MAP. However, it appears that urine production is the weakest link because IVC diameter alone is not a consistent predictor of renal outcomes. This

emphasizes the need for even greater assessments in the intensive care unit and for multiparametric fluid responsiveness monitoring (2019).

Urine Output and MAP Correlation: Maintaining hemodynamic stability in critical illness is inherently coupled with renal perfusion, as evidenced by the strong correlation of MAP and urine output. The proper level of MAP must be adequately maintained to ensure that the sufficient blood flow supply to the kidney will be achieved for optimal function (Hirsch et al., 2020) [9]. The findings support the importance of hemodynamic monitoring in critically sick patients, which helps prevent renal failure, something that can have serious consequences for the patient's recovery and prognosis in the future.

Conclusion

As concluded from this study, physicians should include IVC and CVP diameters in fluid assessment and management. Even if CVP is still one of the most important elements of critical care, it is justifiable to conduct further research into ultrasonographic variables like IVC diameter, which appears to hold more dynamic and responsive information about fluid condition. A combination of these tests may provide a more complete view of a patient's hemodynamic status and, therefore, lead to better results.

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