Correlation between perfusion index and vasoactive-inotropic score with the incidence of acute kidney injury in post-emergency laparotomy patients in the Intensive Care Unit

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Abstract

***Objective*: Acute kidney injury (AKI) is one of the complications caused by laparotomy surgery with general anesthesia. Perfusion index (PI) and vasoactive-inotropic score (VIS) have the potential to be predictors of post-laparotomy acute kidney injury. The aim of this study was to investigate the correlation between PI and VIS with the incidence of AKI in post-emergency laparotomy patients in the Intensive Care Unit (ICU).**

***Design*: This cohort study evaluated PI and VIS during and after emergency laparotomy and the incidence of AKI in post-emergency laparotomy patients in the ICU.**

***Setting*: This study was conducted in the ICU of Dr. Wahidin Sudirohusodo Hospital, Makassar, Indonesia, from June 2024 to December 2024.**

***Patients and participants*: A total of 30 post-emergency laparotomy patients in the ICU were included in this study.**

***Measurement and results*: The total sample of this study was 30 patients, consisting of 17 patients with AKI. In patients with AKI, the median PI was significantly lower than in patients without AKI (0.85 [0.29-3.76] vs 2.02 [0.34-3.42], p<0.01). Additionally, the median VIS in patients with AKI was significantly higher than in those without AKI (25 [5-55] vs 10 [5-30], p<0.01). Based on the area under the curve (AUC), VIS had a higher predictive value (83.40%) than PI (79.60%). The optimal cut-off for PI was 1.62 (odds ratio [OR] = 10.83 [95% CI: 1.96-59.83], p<0.01), and for VIS was 12.5 (OR=25.66 [95% CI: 3.63-181.43], p<0.01).**

***Conclusion*: A low PI and high VIS are associated with the incidence of post-emergency laparotomy acute kidney injury and might be used as sensitive and specific markers.**

Keywords: Acute kidney injury, emergency laparotomy, critical care, perfusion index, vasoactive-inotropic score.

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Introduction

Laparotomy is the most common surgical procedure performed routinely. (1) General anesthesia is usually required in laparotomy to provide relaxation and organ paralysis. (2) Induction of anesthesia produces dose-dependent vasoplegia by suppressing sympathetic tone, which accentuates preload response and leads to vasoconstriction. (3) If this condition continues, some complications might occur. One of the possible complications is acute kidney injury (AKI). (4)

The perfusion index (PI) is an indicator of perfusion status and is mainly determined by cardiac output and the balance of sympathetic and parasympathetic

status, which affects vascular tone. (5) Kang et al. reported that the risk of postoperative acute renal failure increased when the perfusion index was <0.5. (6) In addition, PI and vasoactive-inotropic score (VIS) might also reflect the overall pharmacological support of the cardiovascular system. The highest VIS value (VISmax) within 24 hours has been shown to be a valuable scoring system for predicting morbidity and mortality in patients with cardiac surgery and myocardial infarction. (7,8)

The use of PI and VIS as predictors of post-emergency laparotomy AKI has never been conducted. In addition, research on diagnostic accuracy in the form of sensitivity, specificity, and cut-off values of PI and VIS scores in predicting post-emergency laparotomy AKI is still scarce. Therefore, this study aimed to evaluate the correlation between PI and VIS with the incidence of post-emergency laparotomy AKI in the ICU.

Materials and methods

This cohort study evaluated PI and VIS of intra and post-emergency laparotomy and the incidence of AKI in the ICU of Dr. Wahidin Sudirohusodo Hospital, Makassar, Indonesia. The study was conducted from June to December 2024. The inclusion criteria in this study were patients undergoing emergency laparotomy surgery, American Society of Anesthesiologists (ASA) physical status = 1-3, aged 18-64 years, and body mass index (BMI) 18.50-29.99 kg/cm^2. Exclusion criteria in this study were patients with dialysis dependence, kidney transplantation, renal artery stenosis, and renal anatomical abnormalities, experiencing severe acute or chronic renal insufficiency, having a history of previous cardiac disorders, laparoscopic surgery which was then converted to laparotomy, experiencing central hypothermia, limb ischemia caused by blood vessel occlusion, inaccessible peripheral perfusion, and patients with regional anesthesia.

Patients in this study underwent a preoperative serum creatinine examination, and the patients maintained normothermia and euvolemia. The patients were recorded for the peripheral PI using the Mindray® device from when they arrived in the operating room (before induction) until 48 hours post-surgery. VISmax was calculated using the maximum dose levels of vasoactive and inotropic drugs during the first 24 hours after surgery. Urine output was calculated per hour during the patient's stay in the ICU at 6 hours, 12 hours, 24 hours, and 48 hours after laparotomy. After completing the research, all data were collected and statistically processed using SPSS 26 for Windows.

Results

The total sample of this study was 30 patients, consisting of 17 patients who had AKI. There was a significant correlation between PI and VIS (**Table 1**) with the incidence of AKI ($p<0.01$). In patients with AKI, the median PI was lower (0.85 [0.29-3.76]) than in patients without AKI (2.02 [0.34-3.42]). Besides that, the median VIS in patients with AKI was higher (25 [5-55]) than in patients without AKI (10 [5-30]).

There was a significant relationship between PI and VIS with urine output (**Table 2**) ($p<0.01$). PI had a strong positive correlation ($\rho=0.73$) (**Figure 1A**), where increasing PI was associated with higher urine output, reflecting optimal tissue perfusion and supporting kidney function. In contrast, VIS showed a strong negative correlation ($\rho=-0.78$) (**Figure 1B**), where increasing VIS was associated with decreasing urine output, indicating the impact of vasoactive agent use on impaired renal function.

Based on the area under the curve (AUC), VIS had a higher predictive value (83.40%) compared to PI (79.60%), with both showing statistical significance ($p<0.01$) (**Table 3**). The optimal cut-off for PI was 1.62, with a sensitivity of 76.90%, specificity of 76.50%, positive predictive value (PPV) of 81.60%, and negative predictive value (NPV) of 71.40% (**Figure 2A**). VIS had an optimal cut-off of 12.5 with a sensitivity of 82.40%, specificity of 84.60%, PPV of 87.50%, and NPV of 78.60% (**Figure 2B**). At PI<1.62, 81.20% of patients experienced AKI, with an odds ratio (OR) of 10.83 (95% CI: 1.96-59.83, $p<0.01$), indicating a significant risk compared to PI>1.62, where only 28.60% of patients experienced AKI. Meanwhile, VIS>12.50 showed a prevalence of AKI of 87.50%, with a much higher OR of 25.66 (95% CI: 3.63-181.43, $p<0.01$), compared to VIS<12.50 which only had a prevalence of 21.40% (**Table 4**). These results confirmed that PI and VIS were significant predictors of AKI, with VIS indicating a greater risk.

Discussion

In this study, the median PI (0.85) in patients with AKI was lower than in the group without AKI (2.02). Decreased PI indicated renal hypoperfusion, which increased the risk of AKI due to ischemia-reperfusion stress and impaired renal vascular autoregulation. (9-11) Other studies have highlighted that low PI (<1.5) was consistently an independent predictor of AKI due to impaired renal oxygenation, especially in operations with significant hemodynamic instability, such as emergency laparotomy. (9,12) Decreased PI is often exacerbated by the use

of vasoactive agents, which reduce renal perfusion, leading to an increased incidence of AKI. (13) A study on cardiopulmonary bypass has also shown that low PI increases the risk of AKI due to tissue oxygenation imbalance. (14)

PI showed a sensitivity of 76.90% and specificity of 76.50% at a cut-off of 1.62 in predicting AKI in emergency laparotomy patients, as shown in the receiver operating characteristic (ROC) curve (AUC=79.60%). High sensitivity reflects the ability of PI to detect patients at risk for AKI, while specificity indicates accuracy in identifying patients who do not experience AKI. This is pathophysiologically relevant because PI reflects peripheral tissue perfusion, where lower values indicate hypoperfusion and increased risk of renal ischemic injury due to impaired renal vascular autoregulation. Other studies support these findings. Studies on cardiopulmonary bypass showed a PI cut-off of <1.5 with comparable sensitivity and specificity, indicating a risk of impaired oxygen perfusion to the kidneys. (14-16) This correlation is strengthened by using vasoactive agents, which could worsen renal hypoperfusion and further decrease PI values, and finally reduce the ability of renal autoregulation to maintain adequate perfusion. (13)

VIS had a significant negative correlation with urine output in emergency laparotomy patients (ρ=-0.78, $p<0.01$). High VIS reflects the use of aggressive vasoactive agents, which often cause renal vasoconstriction and hypoperfusion, leading to an increased risk of AKI. The use of vasopressors or inotropic, or a combination of both, is used to maintain hemodynamic stability in patients admitted to the ICU. (17) Other studies support this finding, who reported that high VIS (>32) was associated with severe kidney injury in various emergency and critical surgical procedures. (8,18) High VIS is a major pathophysiological marker of impaired renal autoregulation that fails to maintain perfusion under low perfusion pressures. (19,20) Studies have shown that VIS is a reliable predictor of the need for renal replacement therapy and mortality in severe AKI. (21) These mechanisms make VIS an important tool for monitoring the risk of AKI in critically ill patients, especially during emergency laparotomy.

VIS has a strong correlation with the incidence of AKI in emergency laparotomy, with an AUC of 83.40% indicating a reliable predictor. A VIS cut-off 12.5 resulted in a sensitivity of 82.40% and a specificity of 84.60%, reflecting its accuracy in predicting the risk of AKI. A high VIS reflects a dependence on vasoactive agents that could reduce renal perfusion through systemic vasoconstriction and tissue hypoperfusion. (8,18) The mechanism of VIS as a predictor of AKI involves a direct effect on renal autoregulation, which fails to maintain perfusion under low-pressure conditions, making VIS an important tool for early detection and intervention in emergency laparotomy patients.

The study's limitations included the relatively small sample size and the lack of exploration of other earlier predictors of AKI.

Conclusion

Low PI and high VIS are associated with the occurrence of AKI after laparotomy and can be used as sensitive and specific markers. The optimal cut-off PI was 1.62 (sensitivity=76.90%, specificity=76.50%), while the optimal cut-off VIS was 12.5 (sensitivity=82.40%, specificity=84.60%). The use of PI and VIS could be optimized by establishing a standard protocol for real-time hemodynamic monitoring during emergency laparotomy, thus allowing earlier intervention. For research development, prospective studies with multivariate methods can be performed to explore the complex interactions between PI, VIS, and other physiological parameters.

Table 1. Bivariate test of PI and VIS on the incidence of acute kidney injury in patients with post-emergency laparotomy in ICU

Variable	Acute kidney injury, median (min-max)		p-value
	Yes (n=17)	No (n=13)	
PI	0.85 (0.29-3.76)	2.02 (0.34-3.42)	<0.01*
VIS	25 (5-55)	10 (5-30)	<0.01*

Legend: PI=perfusion index; VIS=vasoactive-inotropic score; ICU=intensive care unit.
*Significant.

Table 2. Correlation test of PI and VIS to urine output in patients with post-emergency laparotomy in ICU

Variable	ρ	p-value
PI	0.73	<0.01*
VIS	-0.78	<0.01*

Legend: PI=perfusion index; VIS=vasoactive-inotropic score; ICU=intensive care unit.
*Significant.

Table 3. Testing of cut-off PI and VIS as predictors of acute kidney injury

Variable	AUC	Cut-off	Sensitivity	Specificity	PPV	NPV	p-value
PI	79.60%	1.62	76.90%	76.50%	81.60%	71.40%	<0.01*
VIS	83.40%	12.5	82.40%	84.60%	87.50%	78.60%	<0.01*

Legend: PI=perfusion index; VIS=vasoactive-inotropic score; AUC=area under the curve; PPV=positive predictive value; NPV=negative predictive value.
*Significant.

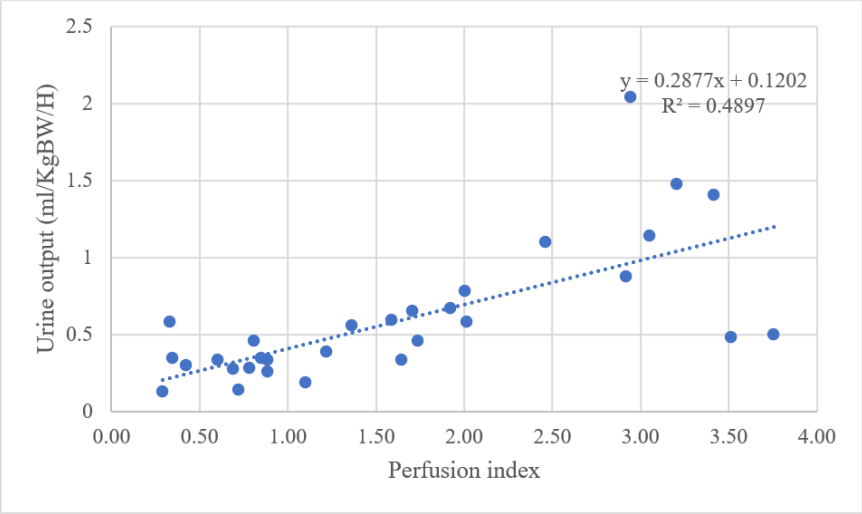
Table 4. Correlation between cut-off PI and VIS to the incidence of acute kidney injury in patients with post-emergency laparotomy in ICU

Variable	Acute kidney injury		OR CI 95%	p-value
	Yes, n (%)	No., n (%)		
PI - <1.62 - ≥1.62	 13 (81.20) 4 (28.60)	 3 (18.80) 10 (71.40)	 10.83 (1.96-59.83)	 <0.01*
VIS - >12.50 - ≤12.50	 14 (87.50) 3 (21.40)	 2 (12.50) 11 (78.60)	 25.66 (3.63-181.43)	 <0.01*

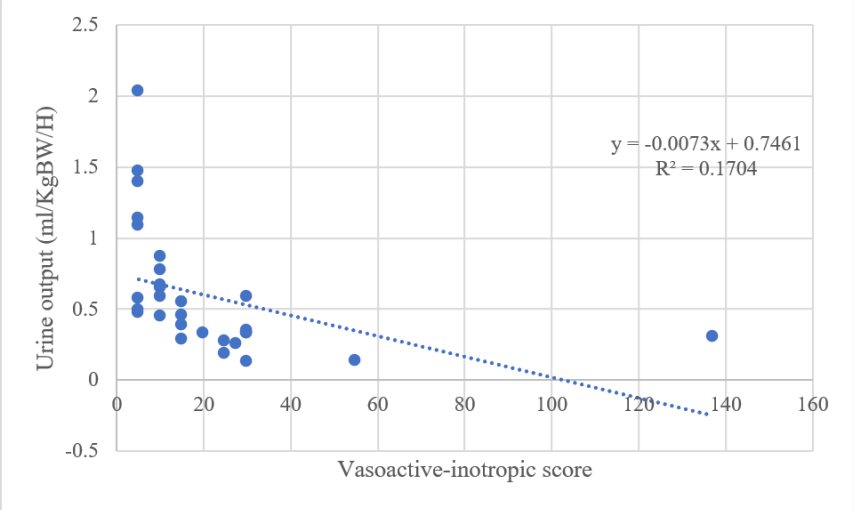
Legend: PI=perfusion index; VIS=vasoactive-inotropic score; ICU=intensive care unit; OR=odds ratio; CI=confidence interval.
*Significant.

Figure 1. Correlation between PI and urine output (A) and correlation between VIS and urine output (B) in post-emergency laparotomy patients in ICU

A

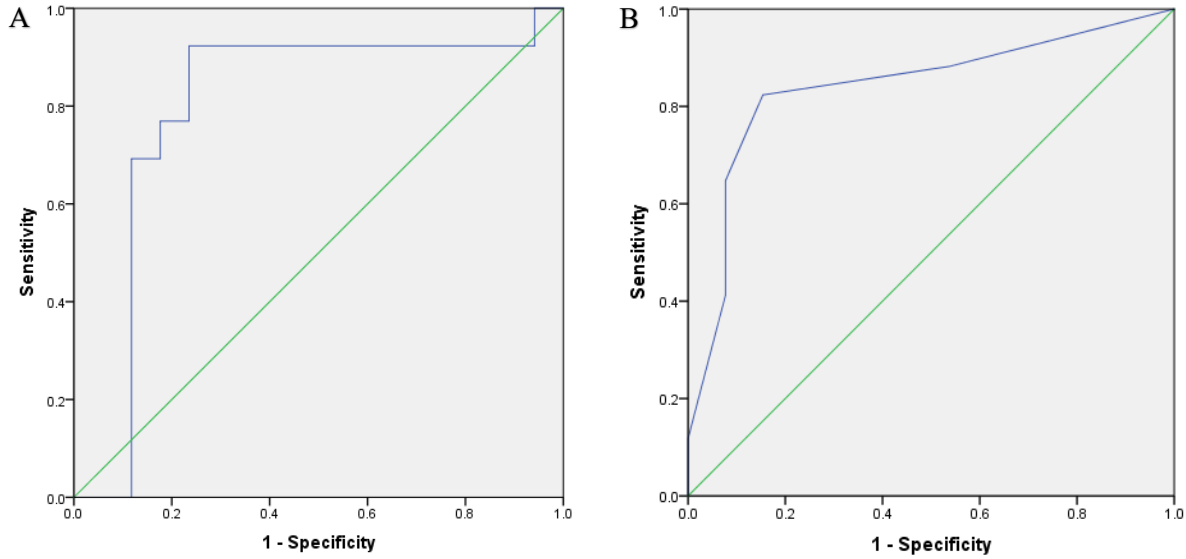


B



Legend: PI=perfusion index; VIS=vasoactive-inotropic score; ICU=intensive care unit.

Figure 2. ROC curve of PI (A) and VIS (B)



Legend: ROC=receiver operating characteristic; PI=perfusion index; VIS=vasoactive-inotropic score.

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