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Early Vasoactive-Inotropic Score Trajectory as a Marker of Postoperative Recovery After Major Cardiac Surgery: An Exploratory Cohort Study

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Abstract

Background and Objectives: The vasoactive-inotropic score (VIS) is associated with adverse outcomes after cardiac surgery, but most studies have evaluated a single VIS value. We aimed to describe early VIS patterns across three perioperative time points and their concurrent association with early postoperative complications (EPC). *Materials and Methods:* In this exploratory, retrospective, single-center cohort, 90 of 93 adults in a database of patients undergoing major cardiac surgery were analyzed (three were excluded for incomplete VIS data). Peak VIS was recorded intraoperatively, on the day of surgery (Z0), and on postoperative day 1 (Z1). Using a threshold of VIS ≥5, patients were classified as minimal support, rapid responders, persistent vasoactive support, or delayed deterioration (non-elevated intraoperative VIS with VIS ≥5 at Z1). Analyses were descriptive and unadjusted; categorical variables were compared with exact tests. *Results:* The four groups comprised 57, 7, 18, and 8 patients, respectively. Cardiopulmonary bypass and aortic cross-clamp times differed across groups ($p = 0.010$ and $p = 0.005$). EPC occurred in 36 patients (40.0%): in 28%, 43%, 56%, and 88% of the four groups, respectively ($p = 0.004$). Compared with minimal support, crude odds ratios for EPC were 3.15 (95% CI 0.93–11.08) for persistent vasoactive support and 17.11 (95% CI 1.96–827.40) for delayed deterioration; for rapid responders, no association was demonstrable. No between-group difference in stroke was demonstrable (two events; $p = 0.132$). *Conclusions:* In this small exploratory cohort, early VIS patterns, particularly support emerging after a non-elevated intraoperative VIS, were concurrently associated with a more complicated early postoperative course. Because complications may have preceded or coincided with VIS assessment and the estimates were unadjusted and imprecise, these patterns should not be interpreted as predictors.

Keywords: vasoactive-inotropic score; inotropes; cardiac surgery; postoperative complications; vasoactive support

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1. Introduction

Postoperative hemodynamic instability remains an important determinant of morbidity and resource utilization after cardiac surgery. Patients requiring substantial pharmacological cardiovascular support may experience a more complicated postoperative course, including organ dysfunction, prolonged intensive care, and increased mortality. Describing the course of cardiovascular support after surgery is therefore clinically relevant, particularly because postoperative cardiovascular status is dynamic and may evolve substantially during the first hours after surgery.

The vasoactive-inotropic score (VIS) provides a quantitative estimate of the intensity of pharmacological cardiovascular support by combining the doses of commonly used inotropic and vasopressor agents into a single numerical measure. Initially developed in pediatric cardiac surgery [1], VIS has subsequently been investigated as a marker of postoperative severity and adverse outcomes in different clinical settings. Previous studies have demonstrated associations between higher VIS values and mortality, postoperative morbidity, prolonged mechanical ventilation, and longer intensive care unit (ICU) stay [1–3]. More recently, studies in adult cardiac surgery have also suggested that VIS measured at specific perioperative or postoperative time points may provide prognostic information regarding subsequent clinical outcomes [4,5].

However, the hemodynamic information provided by a single VIS measurement may be incomplete. Two patients with an identical VIS at one time point may have markedly different clinical trajectories: vasoactive requirements may rapidly resolve, remain persistently elevated, or increase after an initially stable period. These patterns may reflect different underlying physiological processes and potentially different levels of postoperative risk. In particular, increasing support requirements in a patient with initially modest vasoactive needs would not be captured by an intraoperative or immediate postoperative VIS alone.

Although previous investigations have primarily focused on the absolute value of VIS, its maximum value, or measurements obtained at predefined postoperative time points, the temporal evolution of VIS has received comparatively less attention. A trajectory-based approach may help to distinguish transient postoperative support requirements from persistent or newly developing ones, although whether it adds information to a single VIS value remains to be established. Such an approach is particularly attractive because VIS is derived from routinely collected treatment data and can be assessed repeatedly without additional investigations or specialized equipment.

The clinical relevance of serial VIS assessment remains to be established in adult patients undergoing cardiac surgery. We hypothesized that distinct early perioperative VIS patterns would be accompanied by different early postoperative courses. The aim of this exploratory, descriptive study was therefore to characterize VIS across the intraoperative period, postoperative day 0, and postoperative day 1, to classify patients into trajectory phenotypes using a simple threshold-based rule, and to describe the concurrent association between these phenotypes and early postoperative complications and other postoperative outcomes. The study was not designed to develop or validate a prediction tool.

2. Materials and Methods

2.1. Study Design and Population

This retrospective, single-center, exploratory cohort study was conducted at the Niculae Stăncioiu Heart Institute, "Iuliu Haţieganu" University of Medicine and Pharmacy, Cluj-Napoca, Romania, and covered the period from 1 October 2021 to 28 February 2022. Clinical, perioperative, and postoperative data were obtained from the institutional database assembled for our previous study of preoperative vitamin D status and postoperative vasoactive-inotropic requirements in the same population and period [3]. During this

period, 300 patients underwent major cardiac surgery at our institution [3]; the database comprised 93 of these patients, namely those who had a preoperative 25-OH vitamin D measurement. The present cohort is therefore a selected subgroup rather than a consecutive series of all cardiac operations performed during the study period. The 83 patients analyzed in [3] form a subset of this database, while the other 10 were excluded from that analysis because of preoperative vitamin D supplementation. The study period and sample size were thus determined by the existing database, and no a priori sample size calculation was performed.

Major cardiac surgery was defined, as in our previous study [3], as aortic or mitral valve surgery, coronary artery bypass grafting (CABG), aortic valve and ascending aorta surgery, aortic aneurysm repair, or combined CABG and valve surgery. Exclusion criteria were age <18 years, emergency surgery, preoperative hemodynamic instability, transcatheter aortic valve implantation, aortic arch or descending aortic surgery, and transfer to another facility within 24 h of surgery [3]. For the present analysis, VIS data were additionally required at all three predefined assessment time points: intraoperatively, on postoperative day 0 (Z0), and on postoperative day 1 (Z1). Three patients were excluded because of incomplete VIS data at one or more of these time points; all other patients in the database were included, and the final study population therefore comprised 90 patients. The same database was also used for a companion analysis by our group that developed a multivariable prediction model for early postoperative complications from baseline and intraoperative variables (manuscript under review), but the VIS trajectory classification and its association with outcomes have not been reported previously.

The study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the Institutional Ethics Committee of "Iuliu Haţieganu" University of Medicine and Pharmacy, Cluj-Napoca (approval number 259, dated 28 September 2023). Given the retrospective observational design of the study and the minimal risk to participants, the requirement for individual informed consent was waived by the Ethics Committee.

2.2. Data Collection and Study Variables

Demographic and clinical data collected included age, sex, body mass index (BMI), place of residence, diabetes mellitus, insulin-dependent diabetes mellitus, hypertension, chronic anemia, chronic respiratory disease, and chronic kidney disease. Left ventricular ejection fraction (EF) was recorded before and after surgery. The type of surgery was categorized, as in our previous study [3], as lower complexity (single-valve surgery or isolated CABG) or higher complexity (combined or aortic procedures). EuroSCORE II, right ventricular function, and redo status were not available in the database.

Intraoperative variables included cardiopulmonary bypass (CPB) time and aortic cross-clamp time. Preoperative ionized calcium and vitamin D levels were also recorded. Postoperative data included mechanical ventilation duration, ICU length of stay, hospital length of stay, red blood cell transfusion, hemostasis reintervention, acute kidney injury, stroke, extracardiac hemorrhagic complications, and in-hospital mortality. Acute kidney injury was defined according to the Kidney Disease: Improving Global Outcomes (KDIGO) criteria, using serum creatinine and urine output. Mechanical ventilation duration referred to the total ventilation time, including any reintubation.

2.3. Vasoactive-Inotropic Score Assessment

VIS was assessed in three predefined windows: the intraoperative period, from induction of anesthesia to transfer to the ICU, including separation from CPB; postoperative day 0 (Z0) and postoperative day 1 (Z1). Infusion rates were obtained from the anesthesia

record and the ICU charts, in which they were documented at every change in rate. For each window, VIS was calculated from the continuous infusion rates administered simultaneously at the time of the highest total support (peak VIS within the window), rather than from a single prespecified time point or from the maximum dose of each agent taken separately; bolus doses were not included, and doses were expressed per kilogram of actual body weight. VIS was calculated according to the standard formula:

VIS = dopamine dose + dobutamine dose + 100 × epinephrine dose + 10 × milrinone dose + 10,000 × vasopressin dose + 100 × norepinephrine dose, expressed using the standard dose units (μg/kg/min for dopamine, dobutamine, epinephrine, milrinone, and norepinephrine; units/kg/min for vasopressin).

For trajectory classification, a VIS ≥5 was considered to represent elevated vasoactive-inotropic support at a given time point, and the same threshold was applied at all three time points. The threshold was intended to separate the absence of clinically meaningful support from its presence, not to identify high-intensity support: a VIS of 5 corresponds, for example, to norepinephrine or epinephrine at 0.05 μg/kg/min, to dobutamine or dopamine at 5 μg/kg/min, or to milrinone at 0.5 μg/kg/min. Higher cut-offs, such as the threshold of 15 used in our previous analysis of this population [3], identify high-intensity support and serve a different purpose. The threshold was set before the outcome analyses and no alternative thresholds were evaluated.

2.4. VIS Trajectory Classification

Patients were classified into four predefined VIS trajectory phenotypes according to the presence of elevated support (VIS ≥5) at the intraoperative, Z0, and Z1 time points, using the following hierarchical, mutually exclusive rules:

- Rapid responders: elevated intraoperative VIS (≥5) that resolved by both Z0 and Z1 (VIS <5 at Z0 and at Z1).
- Persistent vasoactive support: elevated intraoperative VIS (≥5) that remained elevated at Z0 and/or Z1.
- Delayed deterioration: non-elevated intraoperative VIS (<5), with VIS ≥5 at Z1, irrespective of the Z0 value.
- Minimal support: non-elevated intraoperative VIS (<5), with VIS <5 at Z1, irrespective of the Z0 value.

The Z0 value was therefore used only to distinguish rapid responders from persistent vasoactive support among patients with an elevated intraoperative VIS. Among patients with a non-elevated intraoperative VIS, classification depended on the Z1 value alone, so the minimal support group could include patients with a transient VIS ≥5 at Z0 that had resolved by Z1, and the delayed deterioration group could include patients whose VIS was already ≥5 at Z0. Accordingly, "minimal support" denotes non-elevated support during surgery and on postoperative day 1, and "delayed deterioration" denotes elevated support that emerged after a non-elevated intraoperative period, not necessarily a late increase after an initially stable postoperative course. The labels are descriptive shorthand for these rules and do not imply a specific mechanism.

2.5. Study Outcomes

The primary outcome was the occurrence of early postoperative complications (EPC). EPC was defined as a composite outcome including one or more of the following: in-hospital mortality, stroke, acute kidney injury, extracardiac hemorrhagic complications, mechanical ventilation lasting >24 h, hemostasis reintervention, or ICU stay >5 days. Because ICU stay >5 days is a component of EPC, it is not regarded as confirmation independent of the EPC results; in a sensitivity analysis, EPC was redefined without this component.

Secondary outcomes included the individual components of the composite endpoint, duration of mechanical ventilation, ICU length of stay, hospital length of stay, and red blood cell transfusion.

The timing of each complication relative to the VIS assessment windows was not analyzed. Complications could therefore have occurred before, during, or after the windows in which VIS was assessed, and the associations reported here are concurrent rather than predictive.

2.6. Statistical Analysis

The analysis was exploratory and descriptive. Continuous variables are presented as median and interquartile range (IQR) and were compared across the four VIS trajectory groups using the Kruskal–Wallis test. Categorical variables are presented as number and percentage; because every comparison included cells with expected counts below five, they were compared across the four groups using the Fisher–Freeman–Halton exact test. For analyses comparing the delayed deterioration group with the remainder of the cohort, continuous variables were compared using the Mann–Whitney U test and categorical variables using Fisher's exact test.

Crude associations between VIS trajectory groups and adverse postoperative outcomes were expressed as odds ratios (ORs) with 95% confidence intervals (CIs), using the minimal support group as the reference category. Because of small cell counts, ORs were estimated as conditional maximum-likelihood estimates from 2 × 2 contingency tables with exact 95% CIs, and *p*-values were derived using Fisher's exact test; when a group had no events, the estimated OR is 0 and only the upper confidence limit is informative. Because the exact CI and the Fisher *p*-value are obtained by different procedures, they may disagree when *p* is close to 0.05. Multivariable adjustment was not performed: with 36 EPC events across four groups and near-complete separation in the delayed deterioration group (7 of 8 patients with EPC), even a penalized (Firth) logistic model including CPB time and a few baseline covariates would have relied on very few events per parameter, and several relevant confounders were not available (Section 2.2). All associations are therefore reported as crude and descriptive.

For the comparison of VIS values between patients with and without EPC at each predefined time point, the Mann–Whitney U test was used; because complications may have preceded the VIS assessments (Section 2.5), these comparisons are descriptive. VIS values were not compared statistically across the trajectory groups, and no mixed-effects model with a time × group interaction was fitted, because group membership was defined from the same VIS values, so that between-group differences over time are determined by construction. All tests were two-sided, with $p < 0.05$ used as a nominal threshold; *p*-values were not adjusted for multiple comparisons and should be interpreted as descriptive. Statistical analyses were performed with SPSS Statistics, version 23 (IBM Corp., Armonk, NY, USA); exact tests and exact confidence intervals were computed in Python (SciPy, version 1.18).

3. Results

3.1. Patient Selection and VIS Trajectory Classification

Of the 93 patients included in the database, 3 were excluded because of incomplete VIS data at one or more of the predefined assessment time points, resulting in a final cohort of 90 patients for trajectory analysis. Based on the predefined threshold-based classification, patients were assigned to one of four VIS trajectory phenotypes: minimal support ($n = 57$, 63.3%), rapid responders ($n = 7$, 7.8%), persistent vasoactive support ($n = 18$, 20.0%), and

delayed deterioration ($n = 8$, 8.9%). The distribution of patients across the four trajectory groups is presented in Figure 1.

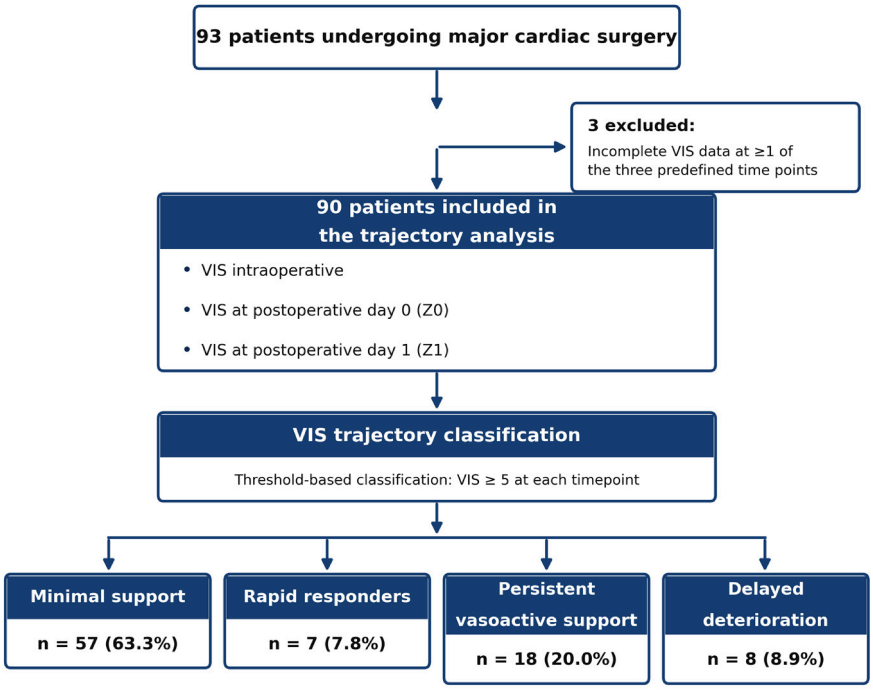

Figure 1. Flowchart of patient selection and vasoactive-inotropic score (VIS) trajectory classification. Of the 93 patients in the study database (Section 2.1), 3 were excluded because of incomplete VIS data at one or more of the three predefined time points (intraoperative, postoperative day 0 [Z0], postoperative day 1 [Z1]), leaving 90 patients for analysis. Elevated support was defined as VIS ≥5 at a given time point. Rapid responders: elevated intraoperative VIS, with VIS <5 at both Z0 and Z1; persistent vasoactive support: elevated intraoperative VIS, with VIS ≥5 at Z0 and/or Z1; delayed deterioration: non-elevated intraoperative VIS, with VIS ≥5 at Z1, irrespective of Z0; minimal support: non-elevated intraoperative VIS, with VIS <5 at Z1, irrespective of Z0.

3.2. Baseline Characteristics According to VIS Trajectory

No statistically significant differences across the four VIS trajectory groups were observed for age, BMI, urban residence, diabetes mellitus, insulin-dependent diabetes, hypertension, chronic anemia, chronic respiratory disease, chronic kidney disease, preoperative ejection fraction, ionized calcium, or vitamin D levels. Given the small size of several groups, however, these non-significant comparisons do not demonstrate that the groups were comparable at baseline. The distribution of sex and procedure complexity by group is shown in Table 1. In contrast, cardiopulmonary bypass time ($p = 0.010$) and aortic cross-clamp time ($p = 0.005$) differed across the four groups. The longest median durations were observed in the persistent vasoactive support group (126.5 and 96.5 min, respectively), whereas the minimal support group had the shortest median cardiopulmonary bypass and cross-clamp times (89.0 and 67.0 min, respectively) (Table 1). Because longer operative times may increase both vasoactive requirements and the risk of complications, these differences are potential confounders of the associations reported below.

Table 1. Baseline Characteristics of the Study Population According to VIS Trajectory.

Variable	Minimal Support (n = 57)	Rapid Responders (n = 7)	Persistent Vasoactive Support (n = 18)	Delayed Deterioration (n = 8)	p
Demographics					
Age, years, median (IQR)	66.0 (61.0–71.0)	65.0 (61.5–67.5)	65.5 (60.2–69.0)	66.0 (61.0–69.2)	1.000
BMI, median (IQR)	28.7 (25.3–31.1)	25.7 (23.6–31.7)	28.3 (25.2–31.1)	31.7 (30.4–37.9)	0.097
Urban residence, *n* (%)	37 (65%)	5 (71%)	7 (41%)	2 (25%)	0.072
Comorbidities					
Diabetes mellitus, *n* (%)	17 (30%)	1 (14%)	4 (22%)	3 (38%)	0.746
Insulin-dependent DM, *n* (%)	7 (12%)	1 (14%)	2 (11%)	2 (25%)	0.722
Hypertension, *n* (%)	47 (82%)	6 (86%)	12 (67%)	7 (88%)	0.516
Chronic anemia, *n* (%)	22 (39%)	3 (43%)	2 (11%)	4 (50%)	0.092
Chronic respiratory disease, *n* (%)	9 (16%)	2 (29%)	2 (11%)	2 (25%)	0.605
Chronic kidney disease, *n* (%)	9 (16%)	1 (14%)	3 (17%)	0 (0%)	0.839
Cardiac Function and Intraoperative Parameters					
Preoperative EF, %, median (IQR)	55.0 (45.0–64.0)	52.0 (46.0–58.0)	55.0 (46.0–60.0)	55.0 (37.5–65.5)	0.985
CPB time, min, median (IQR)	89.0 (67.0–107.0)	93.0 (43.0–110.5)	126.5 (98.8–174.2)	118.5 (88.0–173.8)	0.010
Aortic cross-clamp time, min, median (IQR)	67.0 (45.0–84.0)	74.0 (34.5–87.5)	96.5 (83.5–145.5)	88.0 (55.2–135.8)	0.005
Preoperative ionized calcium, mmol/L, median (IQR)	1.2 (1.2–1.2)	1.2 (1.2–1.3)	1.2 (1.2–1.2)	1.2 (1.2–1.3)	0.665
Preoperative vitamin D, ng/mL, median (IQR)	15.8 (14.5–19.2)	14.7 (14.4–15.6)	17.4 (14.6–20.9)	16.2 (15.3–17.0)	0.478

Patients were classified into four vasoactive-inotropic score (VIS) trajectory groups using a threshold-based rule (VIS ≥5 considered elevated support at a given timepoint; definitions in Section 2.4) applied to VIS values at the intraoperative, postoperative day 0, and postoperative day 1 timepoints (N = 90). Continuous variables are reported as median (interquartile range, IQR) and compared using the Kruskal–Wallis test; categorical variables are reported as *n* (%) and compared using the Fisher–Freeman–Halton exact test. Urban residence was unknown for one patient in the persistent vasoactive support group (percentage based on 17 patients). Given the small group sizes, non-significant *p*-values do not establish baseline comparability. BMI, body mass index; DM, diabetes mellitus; EF, ejection fraction; CPB, cardiopulmonary bypass.

3.3. Postoperative Outcomes According to VIS Trajectory

Early postoperative complications (EPC) occurred in 36 of 90 patients (40.0%); their frequency was 28% in the minimal support group, 43% in rapid responders, 56% in persistent vasoactive support, and 88% in the delayed deterioration group ($p = 0.004$). ICU stay >5 days ($p = 0.005$), ICU length of stay ($p = 0.001$), and hospital length of stay ($p = 0.001$) also differed across groups. The delayed deterioration group had the highest frequency of ICU stay >5 days (50%) and the longest median ICU (5.5 days) and hospital (15.0 days) stays, compared with medians of 3.0–4.0 and 9.0–13.0 days, respectively, in the other three groups. Because ICU stay >5 days is itself a component of EPC, these findings are not independent of the EPC result. No between-group difference was demonstrable for in-hospital mortality, acute kidney injury, stroke, extracardiac hemorrhagic complications, hemostasis reintervention, duration of mechanical ventilation, or red blood cell transfusion (Table 2). Stroke occurred in two patients, both in the persistent vasoactive support group ($p = 0.132$). The seven in-hospital deaths occurred in the minimal support (5/57) and delayed deterioration (2/8). No patient required mechanical ventilation for more than 24 h.

Table 2. Postoperative Outcomes According to VIS Trajectory.

Outcome	Minimal Support (n = 57)	Rapid Responders (n = 7)	Persistent Vasoactive Support (n = 18)	Delayed Deterioration (n = 8)	p
Primary Composite Outcome					
Early postoperative complications (EPC), *n* (%)	16 (28%)	3 (43%)	10 (56%)	7 (88%)	0.004
Individual Complications					
In-hospital mortality, *n* (%)	5 (9%)	0 (0%)	0 (0%)	2 (25%)	0.173
Acute kidney injury (any), *n* (%)	11 (19%)	1 (14%)	7 (39%)	4 (50%)	0.115
Stroke, *n* (%)	0 (0%)	0 (0%)	2 (11%)	0 (0%)	0.132
Extracardiac hemorrhagic complications, *n* (%)	1 (2%)	0 (0%)	2 (11%)	1 (12%)	0.168
Hemostasis reintervention, *n* (%)	4 (7%)	1 (14%)	1 (6%)	0 (0%)	0.691
ICU stay >5 days, *n* (%)	3 (5%)	1 (14%)	1 (6%)	4 (50%)	0.005
Resource Utilization					
Mechanical ventilation, hours, median (IQR)	5.0 (3.0–8.0)	5.0 (3.5–9.0)	5.0 (3.0–7.5)	6.5 (2.8–12.5)	0.980
ICU length of stay, days, median (IQR)	3.0 (2.0–3.0)	4.0 (3.0–4.5)	3.0 (2.0–4.0)	5.5 (4.0–9.5)	0.001
Hospital length of stay, days, median (IQR)	9.0 (8.0–11.0)	13.0 (10.5–15.0)	10.0 (8.2–12.0)	15.0 (12.2–16.2)	0.001
Red blood cell transfusion, *n* (%)	17 (30%)	3 (43%)	6 (33%)	4 (50%)	0.623

Patients were classified into four vasoactive-inotropic score (VIS) trajectory groups using a threshold-based rule (VIS ≥5 considered elevated support at a given timepoint; definitions in Section 2.4) applied to VIS values at the intraoperative, postoperative day 0, and postoperative day 1 timepoints (N = 90). Early postoperative complications (EPC) were a composite of in-hospital death, stroke, acute kidney injury, extracardiac hemorrhagic complications, mechanical ventilation >24 h, hemostasis reintervention, or ICU stay >5 days; ICU stay >5 days is therefore not independent of EPC. Continuous variables are reported as median (interquartile range, IQR) and compared using the Kruskal–Wallis test; categorical variables are reported as *n* (%) and compared using the Fisher–Freeman–Halton exact test.

3.4. Comparison of Delayed Deterioration Versus the Rest of the Cohort

When the delayed deterioration group (n = 8) was compared with the remaining cohort (n = 82), patients with delayed deterioration had a higher BMI (31.7 vs. 28.5 kg/m^2, p = 0.014), whereas no difference was demonstrable in age, comorbidities, preoperative or postoperative ejection fraction, intraoperative CPB time, aortic cross-clamp time, or preoperative biochemical parameters. During the postoperative course, delayed deterioration was associated with a longer ICU stay (5.5 vs. 3.0 days, $p < 0.001$), a longer hospital stay (15.0 vs. 9.0 days, p = 0.003), and a higher frequency of EPC (88% vs. 35%, p = 0.006). No difference was demonstrable for mechanical ventilation duration, red blood cell transfusion, hemostasis reintervention, or in-hospital mortality (Table 3).

Table 3. Comparison of the Delayed Deterioration Group Versus the Rest of the Cohort.

Variable	Delayed Deterioration (n = 8)	Rest of Cohort (n = 82)	p
Demographics			
Age, years, median (IQR)	66.0 (61.0–69.2)	65.5 (61.0–69.8)	0.921
BMI, median (IQR)	31.7 (30.4–37.9)	28.5 (25.2–31.1)	0.014
Urban residence, *n* (%)	2/8 (25%)	49/81 (60%)	0.069
Comorbidities			
Diabetes mellitus, *n* (%)	3/8 (38%)	22/82 (27%)	0.680
Insulin-dependent DM, *n* (%)	2/8 (25%)	10/82 (12%)	0.289
Hypertension, *n* (%)	7/8 (88%)	65/82 (79%)	1.000
Chronic anemia, *n* (%)	4/8 (50%)	27/82 (33%)	0.439
Chronic respiratory disease, *n* (%)	2/8 (25%)	13/82 (16%)	0.616
Chronic kidney disease, *n* (%)	0/8 (0%)	13/82 (16%)	0.597

Table 3. *Cont.*

Variable	Delayed Deterioration (n = 8)	Rest of Cohort (n = 82)	p
Cardiac Function			
Preoperative EF, %, median (IQR)	55.0 (37.5–65.5)	55.0 (45.2–62.0)	0.943
Postoperative EF, %, median (IQR)	56.0 (46.8–65.5)	50.0 (40.0–55.8)	0.242
Intraoperative Parameters			
CPB time, min, median (IQR)	118.5 (88.0–173.8)	97.0 (68.5–115.5)	0.196
Aortic cross-clamp time, min, median (IQR)	88.0 (55.2–135.8)	76.0 (52.0–92.5)	0.310
Preoperative ionized calcium, median (IQR)	1.2 (1.2–1.3)	1.2 (1.2–1.2)	0.273
Preoperative vitamin D, median (IQR)	16.2 (15.3–17.0)	15.9 (14.5–19.6)	0.859
Postoperative Course			
Mechanical ventilation, hours, median (IQR)	6.5 (2.8–12.5)	5.0 (3.0–8.0)	0.694
ICU length of stay, days, median (IQR)	5.5 (4.0–9.5)	3.0 (2.0–4.0)	<0.001
Hospital length of stay, days, median (IQR)	15.0 (12.2–16.2)	9.0 (8.0–11.8)	0.003
Red blood cell transfusion, n (%)	4/8 (50%)	26/82 (32%)	0.433
Hemostasis reintervention, n (%)	0/8 (0%)	6/82 (7%)	1.000
In-hospital mortality, n (%)	2/8 (25%)	5/82 (6%)	0.116
Early postoperative complications (EPC), n (%)	7/8 (88%)	29/82 (35%)	0.006

The delayed deterioration group (n = 8) was defined using a threshold-based rule as patients with a non-elevated intraoperative vasoactive-inotropic score (VIS <5) and a VIS ≥5 on postoperative day 1, irrespective of the day 0 value. Continuous variables were compared using the Mann–Whitney U test and are reported as median (interquartile range, IQR); categorical variables were compared using Fisher's exact test and are reported as n/N (%). Given the small size of the delayed deterioration group, all p-values—including the significant results—should be interpreted with appropriate caution and regarded as hypothesis-generating. BMI, body mass index; EF, ejection fraction; CPB, cardiopulmonary bypass.

3.5. Association Between VIS Trajectory and Adverse Postoperative Outcomes

Using the minimal support group as the reference category, the crude odds of EPC were higher in the delayed deterioration group (OR 17.11, 95% CI 1.96–827.40; p = 0.002) and, with less precision, in the persistent vasoactive support group (OR 3.15, 95% CI 0.93–11.08; p = 0.047), for which the exact confidence interval included 1. Delayed deterioration was also associated with ICU stay >5 days (OR 16.41, 95% CI 2.05–158.01; p = 0.003), which is a component of EPC. No association was demonstrable between persistent vasoactive support and ICU stay >5 days (OR 1.06, 95% CI 0.02–14.21), or between the rapid responder group and any of the evaluated outcomes; with only seven patients in this group, the confidence intervals were very wide (for EPC, OR 1.90, 95% CI 0.25–12.66) and compatible with both lower and substantially higher odds. No association with acute kidney injury or in-hospital mortality was demonstrable for any group (Table 4). All estimates were unadjusted and are descriptive.

Table 4. Crude Associations Between VIS Trajectory and Adverse Postoperative Outcomes.

VIS Trajectory Group	Odds Ratio	95% CI	p
Early Postoperative Complications (EPC)			
Minimal support (n = 57)	Reference	—	—
Rapid responders (n = 7)	1.90	0.25–12.66	0.415
Persistent vasoactive support (n = 18)	3.15	0.93–11.08	0.047
Delayed deterioration (n = 8)	17.11	1.96–827.40	0.002

Table 4. *Cont.*

VIS Trajectory Group	Odds Ratio	95% CI	*p*
ICU Stay >5 Days			
Minimal support ($n = 57$)	Reference	—	—
Rapid responders ($n = 7$)	2.93	0.05–44.05	0.378
Persistent vasoactive support ($n = 18$)	1.06	0.02–14.21	1.000
Delayed deterioration ($n = 8$)	16.41	2.05–158.01	0.003
Acute Kidney Injury (Any)			
Minimal support ($n = 57$)	Reference	—	—
Rapid responders ($n = 7$)	0.70	0.01–6.78	1.000
Persistent vasoactive support ($n = 18$)	2.62	0.70–9.64	0.116
Delayed deterioration ($n = 8$)	4.07	0.65–25.70	0.075
In-Hospital Mortality			
Minimal support ($n = 57$)	Reference	—	—
Rapid responders ($n = 7$)	0.00	0.00–9.91	1.000
Persistent vasoactive support ($n = 18$)	0.00	0.00–3.48	0.329
Delayed deterioration ($n = 8$)	3.37	0.27–27.39	0.203

Crude (unadjusted) odds ratios (ORs) with exact 95% confidence intervals (CIs) for each vasoactive-inotropic score (VIS) trajectory group relative to the minimal support group (reference), for each outcome (N = 90). ORs are conditional maximum-likelihood estimates from 2 × 2 contingency tables; *p*-values were derived from two-sided Fisher's exact test. Because the exact CI and the Fisher *p*-value are obtained by different procedures, they may disagree near $p = 0.05$ (persistent vasoactive support, EPC). For groups without events (in-hospital mortality), the estimated OR is 0 and only the upper confidence limit is informative. ICU stay >5 days is a component of EPC. Given the small size of several trajectory groups (rapid responders, $n = 7$; delayed deterioration, $n = 8$), confidence intervals are wide; these associations are descriptive and hypothesis-generating rather than confirmatory. EPC, early postoperative complications; ICU, intensive care unit.

3.6. VIS Trajectory Across the Four Trajectory Phenotypes

The VIS values of the four groups across the intraoperative, postoperative day 0, and postoperative day 1 time points are shown in Figure 2. The minimal support group maintained low VIS values throughout the observation period (median ≤2 at every timepoint), whereas rapid responders showed an early decline in vasoactive-inotropic support after surgery, from a median intraoperative VIS of 7.0 to approximately 2 by postoperative day 1. In contrast, the persistent vasoactive support group maintained elevated VIS values from the intraoperative period through postoperative day 0, with only a partial decline by day 1, while in the delayed deterioration group VIS increased after surgery, from a low intraoperative median to elevated levels that were already present at Z0 and were sustained through postoperative day 1; at Z0, the interquartile range of this group lay entirely above the threshold of 5 (Figure 2). Because the groups were defined from these values, the between-group differences in Figure 2 are expected by construction and were not tested statistically.

3.7. Early VIS Trajectory According to Postoperative Complication Status

Patients who developed EPC had higher VIS values than those without EPC at each of the three predefined time points: intraoperatively ($p = 0.012$), on postoperative day 0 ($p = 0.003$), and on postoperative day 1 ($p < 0.001$). The difference was the largest, in relative terms, on postoperative day 1 (Figure 3). Because the timing of complications relative to the VIS assessments was not analyzed, the higher postoperative VIS values in patients with EPC may partly reflect the treatment of complications that had already occurred.

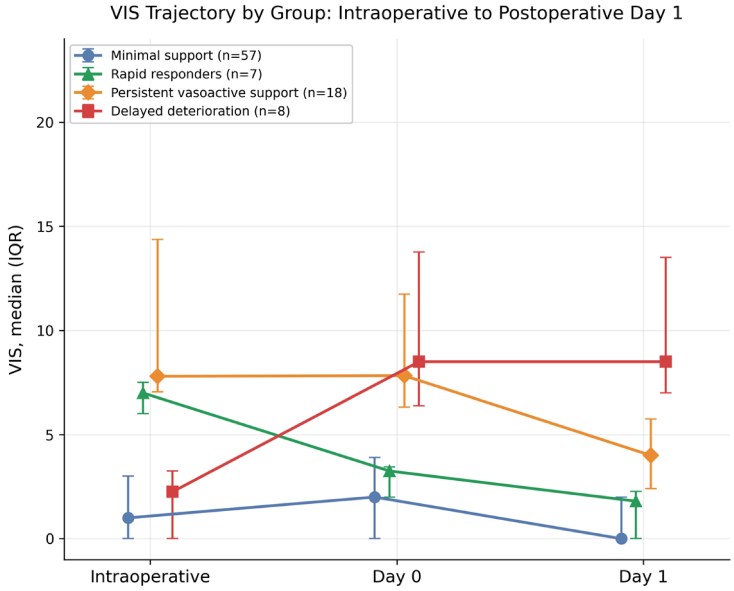

Figure 2. VIS trajectory by group, from intraoperative to postoperative day 1. Trajectory of the vasoactive-inotropic score (VIS), shown as median (interquartile range), across the three predefined time points (intraoperative, postoperative day 0, postoperative day 1) for each of the four VIS trajectory groups: minimal support ($n = 57$), rapid responders ($n = 7$), persistent vasoactive support ($n = 18$), and delayed deterioration ($n = 8$). N = 90. Groups were defined from these VIS values (Section 2.4); between-group differences are therefore expected by construction and were not tested.

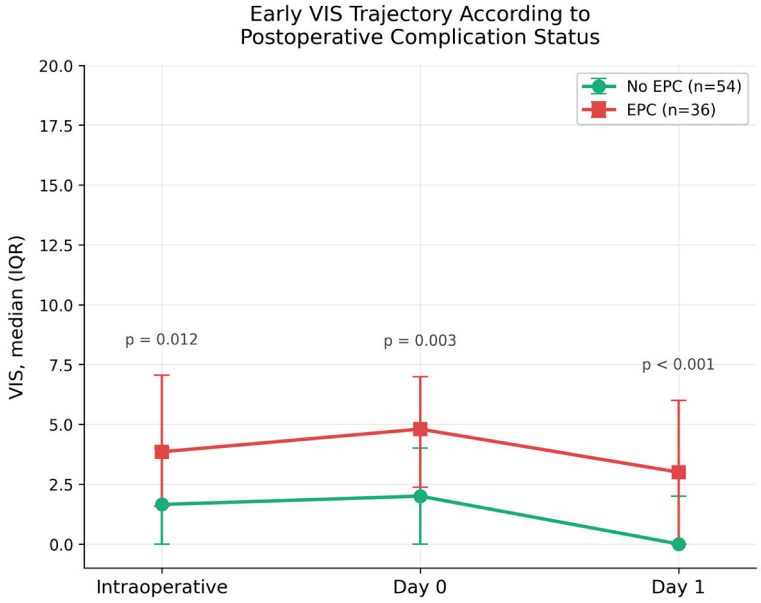

Figure 3. Early VIS trajectory according to postoperative complication status. Trajectory of the vasoactive-inotropic score (VIS), shown as median (interquartile range), across the three predefined time points (intraoperative, postoperative day 0, postoperative day 1), stratified by the occurrence of early postoperative complications (EPC). Patients who developed EPC ($n = 36$) had higher VIS values than those who did not ($n = 54$) at all three timepoints (intraoperative: $p = 0.012$; day 0: $p = 0.003$; day 1: $p < 0.001$; Mann–Whitney U test). N = 90. These comparisons are descriptive and do not establish that VIS elevation preceded the complications.

3.8. Clinical Outcomes Across VIS Trajectory Phenotypes

Figure 4 illustrates the distribution of EPC, acute kidney injury, ICU stay >5 days, and in-hospital mortality across the four trajectory phenotypes. Each of these outcomes was

most frequent in the delayed deterioration group; the corresponding statistical comparisons are presented in Tables 2 and 4.

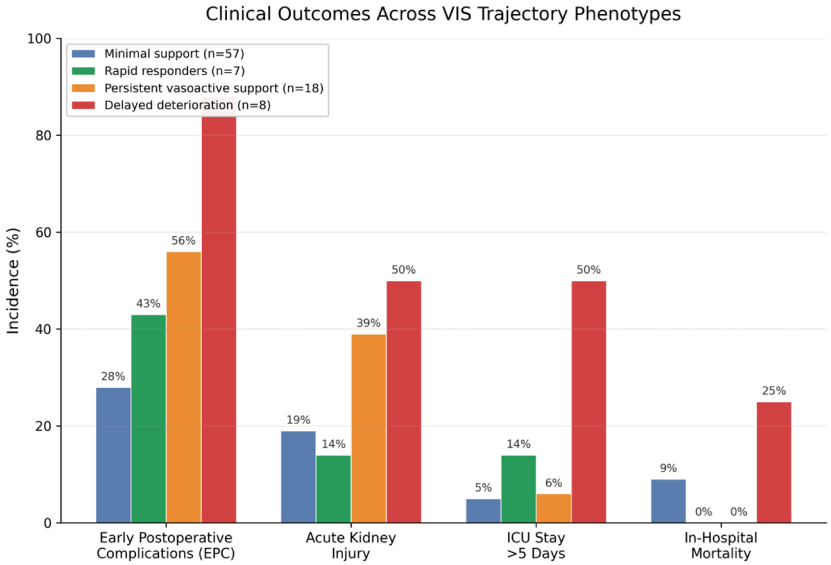

Figure 4. Clinical outcomes across VIS trajectory phenotypes. Incidence of four postoperative outcomes—early postoperative complications (EPC), acute kidney injury (any), ICU stay >5 days, and in-hospital mortality—across the four vasoactive-inotropic score (VIS) trajectory phenotypes: minimal support ($n = 57$), rapid responders ($n = 7$), persistent vasoactive support ($n = 18$), and delayed deterioration ($n = 8$). N = 90. Corresponding statistical comparisons are presented in Table 2 (across all four groups) and Table 4 (odds ratios versus the minimal support reference group). ICU stay >5 days is a component of EPC.

4. Discussion

4.1. Principal Findings

In this exploratory single-center cohort, a simple threshold-based classification of VIS at three perioperative time points identified four patterns of early vasoactive-inotropic support. The frequency of EPC differed across these patterns, from 28% in patients with minimal support to 88% in those with delayed deterioration, and delayed deterioration was also accompanied by longer ICU and hospital stays. These associations were crude, imprecise, and concurrent rather than prospective: complications may have occurred before or during the VIS assessment windows, so that an elevated VIS at Z0 or Z1 may reflect the treatment of an established complication rather than precede it. The findings therefore describe how vasoactive requirements evolved in patients with and without a complicated early postoperative course; they do not show that VIS patterns predict complications, and the incremental value of the classification over a single VIS measurement was not tested.

4.2. Interpretation in the Context of Previous Studies

Higher VIS values after adult cardiac surgery have repeatedly been associated with mortality, morbidity, and prolonged intensive care [2,4,5], and comparable associations have been described for other early postoperative hemodynamic variables, such as low mixed venous oxygen saturation during the early ICU stay [6]. Associations between VIS and outcome have also been reported after left ventricular assist device implantation [7], after heart transplantation [8], and in patients undergoing coronary artery bypass grafting [9]. Most of these studies used a single VIS value, such as the score at the end of surgery, at 24 h, or the maximum within a predefined interval, and the timing of measurement and the thresholds used varied considerably [2]. Our results are consistent with this literature, but

they extend it only descriptively, by showing how support evolved across three predefined time points in patients with and without EPC.

Operative burden is a plausible confounder of these associations. CPB and aortic cross-clamp times were longest in the persistent vasoactive support and delayed deterioration groups, consistent with pediatric and adult studies in which higher VIS was accompanied by longer CPB and cross-clamp times [1,4] and with studies identifying clinical predictors of the need for high-dose postoperative inotropic support [10]. Procedure type, baseline risk scores, and right ventricular function were not adjusted for, and the absence of statistically significant baseline differences in groups of seven or eight patients does not demonstrate comparability. The differences between trajectory groups may therefore reflect surgical complexity and baseline risk rather than the VIS pattern itself.

The composite EPC endpoint also requires cautious interpretation. ICU stay >5 days is one of its components and, in patients who still require vasoactive support on postoperative day 1, partly reflects that treatment; ICU length of stay is, moreover, determined by multiple clinical and organizational factors [11]. The prolonged ICU stay of the delayed deterioration group therefore does not independently confirm the EPC findings. In-hospital mortality did not follow the pattern observed for EPC: five of the seven deaths occurred in patients with minimal support, and no association between VIS pattern and mortality was demonstrable.

Serial assessment of vasoactive support has recently been examined in postcardiotomy cardiogenic shock, where early VIS trajectories were associated with clinical outcomes [12], and in a multicenter cardiogenic shock registry, where serial assessment of aggregate vasoactive support was associated with mortality [13]. Compared with these studies, our classification was simple, relied on three peak values and a single threshold, and was applied to a small surgical cohort. Associations between VIS and outcome have also been described after CABG [14] and in adolescents after cardiothoracic surgery [15], using different thresholds and time points, and the optimal threshold for a trajectory-based classification is unknown. The VIS ≥5 threshold was chosen to mark the presence of clinically meaningful support rather than high-intensity support; alternative thresholds, continuous changes in VIS, and data-driven trajectory models were not examined and should be evaluated in larger cohorts. Within this framework, no association with adverse outcomes was demonstrable for rapid responders, but with only seven patients and very wide confidence intervals, this does not show that rapid resolution of support is benign. In the delayed deterioration group, VIS was low during surgery but already elevated on postoperative day 0 (Figure 2), so this label describes support emerging in the early ICU period rather than deterioration after a stable postoperative course; the higher BMI in this group (Table 3) should be regarded as an exploratory observation.

4.3. Clinical Implications

Because the associations were concurrent, crude, and imprecise, the present findings do not support the use of VIS trajectory classification for risk stratification, early warning, or clinical decision-making. They suggest only that the serial description of vasoactive requirements, which relies on routinely collected data, merits further study. Prospective studies should record VIS at shorter intervals, time-stamp complications so that VIS assessed before an event can be distinguished from the treatment of an established complication (for example, using landmark analyses), adjust for surgical complexity and baseline risk, and formally compare trajectory-based classifications with single VIS measurements in terms of discrimination and calibration.

4.4. Strengths and Limitations

The study used routinely collected data, three predefined assessment time points, and explicit classification rules that can be reproduced in other cohorts, and exact methods were used for all categorical comparisons.

The study has important limitations. First, the sample was small, with only seven and eight patients in two of the groups; the estimates were imprecise, the confidence intervals very wide, and the study was not powered for any specific comparison. Second, the cohort was a selected subgroup of the patients operated on during the study period, drawn from a database assembled for a previous study [3] rather than a consecutive series, and the same database has been used in other analyses by our group; selection bias and limited generalizability are therefore possible. Third, the timing of complications relative to the VIS assessments was not analyzed, so the associations are concurrent and may partly reflect the treatment of established complications; a landmark analysis restricted to events occurring after the VIS assessment windows was not performed. Fourth, all estimates were unadjusted; operative times differed across groups, and procedure type, EuroSCORE II, right ventricular function, and other potential confounders were not adjusted for. Fifth, the classification used peak values at three time points and a single threshold that has not been validated, did not consider the Z0 value in patients with a non-elevated intraoperative VIS, and was not compared with alternative thresholds, continuous or change-based VIS measures, or longitudinal approaches such as mixed-effects or group-based trajectory models. Sixth, the composite EPC endpoint combined complications of differing severity and mechanisms and included ICU stay >5 days, which partly reflects ongoing vasoactive treatment. Finally, numerous comparisons were made without adjustment for multiplicity, so nominally significant *p*-values should be interpreted with caution. External validation in larger, prospective, and preferably multicenter cohorts is required before VIS trajectory phenotypes can be considered for risk stratification or clinical decision-making.

5. Conclusions

In this exploratory cohort, a simple threshold-based classification of the vasoactive-inotropic score at three perioperative time points identified patterns of support that were concurrently associated with the early postoperative course. Support that emerged after a non-elevated intraoperative VIS was accompanied by the highest frequency of early postoperative complications and the longest ICU and hospital stays, whereas no association was demonstrable for the rapid resolution of initially elevated support. Because the estimates were crude, imprecise, and potentially confounded by operative complexity, and because complications may have preceded or coincided with the VIS assessments, these patterns should not be interpreted as predictors or early warning signals, and their incremental value over single VIS measurements remains untested. Prospective studies with time-stamped complications, more frequent VIS recording, adjustment for surgical complexity and baseline risk, and formal comparison with single VIS measurements are needed.

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Informed Consent Statement: Patient consent was waived due to the retrospective observational design of the study and the minimal risk to participants, as approved by the Institutional Ethics Committee.

Data Availability Statement: Data supporting the reported results can be found in Mega cloud through the following link: https://mega.nz/fm/yYwzSS6a (accessed on 4 July 2026).

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

VIS	Vasoactive-inotropic score
EPC	Early postoperative complications
ICU	Intensive care unit
CPB	Cardiopulmonary bypass
BMI	body mass index
EF	ejection fraction
DM	diabetes mellitus
IQR	interquartile range
OR	odds ratio
CI	confidence interval
CABG	Coronary artery bypass grafting
KDIGO	Kidney Disease: Improving Global Outcomes

References

1. Gaies, M.G.; Jeffries, H.E.; Niebler, R.A.; Pasquali, S.K.; Donohue, J.E.; Yu, S.; Gall, C.; Rice, T.B.; Thiagarajan, R.R. Vasoactive-inotropic score is associated with outcome after infant cardiac surgery: An analysis from the Pediatric Cardiac Critical Care Consortium and Virtual PICU System Registries. *Pediatr. Crit. Care Med.* **2014**, *15*, 529–537. [CrossRef] [PubMed] [PubMed Central]
2. Sun, Y.T.; Wu, W.; Yao, Y.T. The association of vasoactive-inotropic score and surgical patients' outcomes: A systematic review and meta-analysis. *Syst. Rev.* **2024**, *13*, 20. [CrossRef] [PubMed] [PubMed Central]
3. Stef, A.; Bodolea, C.; Cainap, S.S.; Muntean, M.; Solomonean, A.G.; Tintiuc, N.; Mada, R.O.; Cismaru, G. Lower Levels of Vitamin D Are Associated with Higher Vasoactive-Inotropic Scores in Major Cardiac Surgery. *Life* **2024**, *14*, 1349. [CrossRef] [PubMed] [PubMed Central]
4. Mete, E.M.T.; Bastopcu, M.; Acarel, M. 24th hour vasoactive inotrope score is associated with poor outcome in adult cardiac surgery. *Rev. Assoc. Med. Bras.* **2023**, *69*, e20221433. [CrossRef] [PubMed] [PubMed Central]
5. Yamazaki, Y.; Oba, K.; Matsui, Y.; Morimoto, Y. Vasoactive-inotropic score as a predictor of morbidity and mortality in adults after cardiac surgery with cardiopulmonary bypass. *J. Anesth.* **2018**, *32*, 167–173. [CrossRef]
6. Kaakinen, T.I.; Ikäläinen, T.; Erkinaro, T.M.; Karhu, J.M.; Liisanantti, J.H.; Ohtonen, P.P.; Ala-Kokko, T.I. Association of low mixed venous oxygen saturations during early ICU stay with increased 30-day and 1-year mortality after cardiac surgery: A single-center retrospective study. *BMC Anesthesiol.* **2022**, *22*, 322. [CrossRef]
7. Han, J.; Pinsino, A.; Sanchez, J.; Takayama, H.; Garan, A.R.; Topkara, V.K.; Naka, Y.; Demmer, R.T.; Kurlansky , P.A.; Colombo, P.C.; et al. Prognostic value of vasoactive-inotropic score following continuous flow left ventricular assist device implantation. *J. Heart Lung Transplant.* **2019**, *38*, 930–938. [CrossRef]
8. Tohme, J.; Lescroart, M.; Guillemin, J.; Orer, P.; Dureau, P.; Varnous, S.; Leprince, P.; Coutance, G.; Bouglé, A. Association between vasoactive-inotropic score, morbidity and mortality after heart transplantation. *Interdiscip. Cardiovasc. Thorac. Surg.* **2023**, *36*, ivad055. [CrossRef] [PubMed] [PubMed Central]
9. Damarlapally, N.; Vempati, R.; Vasudevan, S.S.; Mathur, G.; Banda, P.; Mourad, D.; Khan, A.; Polamarasetty, H.; Desai, R.; Nunna, K.R. High vasoactive-inotropic score is associated with poor outcomes in patients undergoing coronary artery bypass grafting: A systematic review and meta-analysis. *Perfusion* **2025**, *Epub ahead of print*. [CrossRef] [PubMed]
10. Belletti, A.; Jacobs, S.; Affronti, G.; Mladenow, A.; Landoni, G.; Falk, V.; Schoenrath , F. Incidence and predictors of postoperative need for high-dose inotropic support in patients undergoing cardiac surgery for infective endocarditis. *J. Cardiothorac. Vasc. Anesth.* **2018**, *32*, 2528–2536. [CrossRef]

11. Michalopoulos, A.; Tzelepis, G.; Pavlides, G.; Kriaras, J.; Dafni, U.; Geroulanos, S. Determinants of duration of ICU stay after coronary artery bypass graft surgery. *Br. J. Anaesth.* **1996**, *77*, 208–212. [CrossRef] [PubMed]
12. Su, Q.; Tang, B.; Li, W.; Liu, S.; Long, Y. Associations between early vasoactive inotrope score trajectories and clinical outcomes in postcardiotomy cardiogenic shock patients: A retrospective cohort analysis. *J. Cardiothorac. Vasc. Anesth.* **2026**, *40*, 2413–2421. [CrossRef]
13. Patel, S.M.; Berg, D.D.; Bohula, E.A.; Baird-Zars, V.M.; Barsness, G.W.; Chaudhry, S.P.; Chonde, M.D.; Cooper, H.A.; Ginder, C.; Jentzer, J.C.; et al. Early serial assessment of aggregate vasoactive support and mortality in cardiogenic shock: Insights from the Critical Care Cardiology Trials Network Registry. *Circ. Heart Fail.* **2024**, *17*, e011218. [CrossRef]
14. Baysal, P.K.; Güzelmeriç, F.; Kahraman, E.; Gürcü, M.E.; Erkılınç, A.; Orki, T. Is Vasoactive-Inotropic Score a Predictor for Mortality and Morbidity in Patients Undergoing Coronary Artery Bypass Surgery? *Braz. J. Cardiovasc. Surg.* **2021**, *36*, 802–806. [CrossRef] [PubMed] [PubMed Central]
15. Garcia, R.U.; Walters, H.L.; Delius, R.E.; Aggarwal, S. Vasoactive inotropic score (VIS) as biomarker of short-term outcomes in adolescents after cardiothoracic surgery. *Pediatr. Cardiol.* **2016**, *37*, 271–277. [CrossRef]

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