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# Vasoactive Inotropic Score for Predicting Pediatric Tracheostomy

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**Abstract**

**Background:** Although tracheostomy is not performed as frequently as in adults, it is also used in children. There is no clear consensus on timing and risk factors, especially in early infancy and in cases who underwent cardiac surgeries. In the early infancy period, pediatric cardiac surgery patients have to receive an inotropic agent after the cardiac surgery due to poor general condition or hemodynamic instability. As a result of prolonged intubation, tracheostomy is required to be performed in some of these patients.

**Objectives:** The present study aimed to investigate the relationship between vasoactive inotropic scores (VIS) and tracheostomy in pediatric cardiac surgery patients.

**Methods:** A total of 47 patients, 21 with tracheostomy and 26 without tracheostomy, who underwent cardiac surgery were included in this retrospective study. The VIS and inotrope score (IS) values were calculated and recorded hourly for 48 h postoperatively. Scores were calculated by multiplying the inotropes infusion rate of the patients with certain coefficients. It was attempted to determine objective formalized models and cut-off values that may benefit the relationship between VIS values and tracheostomy.

**Results:** The median weight was 3,630 g (range, 2,040-13,400), and the median age was 69 days (range, 1-1,081) on the surgery day. The majority (93.6%) of the patients were aged < 1 year. Preoperative C-reactive protein measurements were significantly higher by 50% in patients who underwent tracheostomy (P=0.005). The albumin levels in the tracheostomy group (TG) were low, although not significantly (P=0.057). The VIS values of TG had 50% higher values than the non-tracheostomy group (NTG) (P<0.001). In addition, formula 1 predicted with 57% accuracy that a tracheostomy could be performed (VIS =18.170-0.170* HOUR; P < 0.001), and formula 2 predicted with 72% accuracy that a tracheostomy could not be performed (VIS =17.170-0.170* HOUR; P < 0.001). Hospital stay (P<0.001), mechanical ventilation duration (P<0.001), and the number of ongoing intubation on the 7th day post-surgery were significantly higher in TG.

**Conclusion:** After pediatric cardiac surgery, VIS values can predict tracheostomy status and help intensive care professionals make decisions.

*Keywords:* Intensive care, Pediatric cardiac surgery, Tracheostomy, Vasoactive inotropic score

## 1. Background

Tracheostomy is a surgical procedure used to maintain safe airway continuation and remove lung secretions resulting from prolonged intubation, except for emergency conditions in intensive care units (ICUs). In an ICU, especially in pediatric cardiac ICUs, a prolonged period of mechanical ventilation is unavoidable, and these patients may often have increased sedation requirements to avoid self-extubation, which frequently needs reintubation in suboptimal conditions (1). Although the optimal timing of tracheostomy is still controversial, tracheostomy is performed within ICUs to facilitate weaning from mechanical ventilation, restore the upper airway function, continue tracheobronchial toileting, and minimize injury to the vocal cords (2, 3). Tracheostomy is widely performed in ICUs due to the mentioned benefits.

Cardiac failure and output, associated with tissue oxygenation and cellular oxygen demand, are among the most critical issues for postoperative cardiac surgeries in ICUs (4). Evaluation of cellular oxygen demand and tissue hypoxia is challenging. Because some parameters (e.g., blood lactate levels, blood gas parameters, arterial blood pressure, and urine output) are impaired in the advanced stages of shock, intensivists use these parameters to assess the progression of the patient's clinical condition. Most pediatric cardiac surgery patients have to take inotropes during the perioperative period. Therefore, the need to evaluate the level of inotropics administered led to the development of a scoring system. The inotrope score (IS) was first introduced by Wernovsky et al. as a means to assess more quantitative support levels after cardiac surgeries (5). Gaieset al. recently introduced the vasoactive inotropic score (VIS), which expanded the IS to include other vasoactive agents commonly used in ICUs (6). The VIS is calculated easily and has proven to be a valuable tool in predicting mortality and morbidity, such as length of hospital stay (7, 8). These scores were used to predict mortality and morbidity in various disease groups in pediatric and adult patients.

## 2. Objectives

The present study aimed to evaluate the relationships among IS, VIS, and tracheostomy in pediatric patients undergoing cardiac surgery who were mainly aged under one year.

## 3. Methods

This retrospective observational study was conducted in the ICU of (hidden for review), a congenital heart surgery center where 200 heart surgeries are performed annually, 90% of the patients are under one year, and 45% are aged under one month. The study was conducted following the principles of the Declaration of Helsinki.

### *3.1. Study Design and Sample Collection*

The patients data were retrospectively obtained from the Hospital data system and archive records. The sample included patients who underwent tracheostomy after cardiac surgery in the ICU in the last five years (tracheostomy group (TG), n=21). The patient-matched control group had a similar number of similarly aged patients with congenital heart disease who did not undergo tracheostomy (non-tracheostomy group (NTG), n=26). The examined medical records included: age at the time of surgery, sex, congenital heart disease diagnosis, preoperative hemoglobin level, preoperative C-reactive protein (CRP) level, preoperative albumin, albumin-hemoglobin index (which is calculated by multiplying albumin by hemoglobin), intubation, and inotrope infusion state at admission, preoperative leukocyte count, postoperative maximum fraction of inspired oxygen ($FiO_2$) at the 48$^{th}$ h, tracheostomy day after surgery, length of hospital stay, mortality, proven sepsis, mechanical ventilation duration, the presence of cardiac arrest during the hospital stay, aortic cross-clamp time, cardiopulmonary bypass time, pulmonary abnormalities, postoperative diaphragm paralysis, dysmorphic features, and additional major abnormalities.

### *3.2. Vasoactive Inotropic Scores (VIS) and Inotrope Score (IS) Calculation*

The IS and VIS of all patients were calculated using the patients medical records. The hourly doses of the inotropic and vasoactive medications, including dopamine, dobutamine, epinephrine, norepinephrine, and milrinone, were recorded for the first 48 h after postoperative admission to the ICU. In the current analysis, the IS was calculated as described by Wernovsky (5). The VIS and IS were calculated as shown in the following formula:

IS: Dopamine dosage (μg/kg/min) + dobutamine dosage (μg/kg/min) +100 × epinephrine dosage (μg/kg/min), VIS: IS + 10 × milrinone dosage (μg/kg/min) + 10,000 × vasopressin dosage (U/kg/min) + 100 × norepinephrine dosage (μg/kg/min).Vasopressin could not be used for calculations because it is not available in our country.

### *3.3. Inotrope Titration and Tracheostomy Decision*

Postoperatively, the inotropic and vasopressor agent was determined according to the underlying disease and surgical procedure by a team that included a pediatric cardiac surgeon and pediatric cardiologist. The pediatric cardiac intensive care team performed titration of inotropes and vasoactive drugs and stopped medications by taking into account the patients blood gases, blood pressure status, urine output, and echocardiographic findings, if necessary. In the post-operative period, inotropic titration was adjusted according to invasive arterial blood pressure measurements.

The date of tracheostomy was defined as the date on which the patients were deemed medically stable for the surgery by the primary Department, and legal guardians consents were obtained. The decision to perform a tracheostomy was made with the family based on the consensus of the pediatric cardiovascular surgery team and otolaryngologist.

### *3.4. Statistics*

When appropriate, descriptive statistics of scale variables are presented as means ± standard deviations (SD) or medians (range). Demographic and clinical continuous variables were compared using independent Student t-tests for normally distributed values (e.g., albumin hemoglobin index) and the Mann-Whitney U test for non-normally distributed values (e.g., weight at operation, postoperative oxygen requirement, hospital, and mechanical ventilation, cardiopulmonary bypass time, cross-clamp time). Categorical variables, including gender, ongoing intubation on the 3$^{rd}$ and 7$^{th}$ day, intubation at first admission, inotrope infusion before admission, sepsis, mortality rate, observed cardiac arrest event, and malformation rate, were compared using Fisher's exact test. A nonparametric Wilcoxon test for two dependent groups was used to compare the values of IS and VIS. The nonparametric Mann-Whitney U test for two independent groups was used to compare the VIS values of TG and NTG. Linear regression models for TG and NTG and 95% and 99% confidence intervals were constructed to estimate VIS values as a function of time. Two separate linear models based on time were proposed for classification of tracheostomy and nontracheostomy, and their correct classification rates were presented. For all tests, the level of statistical significance was set at $P<0.05$. The collected data were analyzed using SPSS software (version 25).

## 4. Results

No statistically significant differences were observed between the two groups regarding sex, age at cardiac surgery, and weight on the day of surgery (Table 1). In addition, no significant difference was found between the groups in terms of dysmorphic features, thoracic abnormalities, other major malformations, and diaphragm paralysis.

**Table 1**. Baseline characteristics of the groups

| | (NTG) (n=26) | (TG) (n=21) | P-value |
|---|---|---|---|
| **Sex; Male; n (%)** | 13(44.8) | 16(55.2) | 0.066* |
| **Weight at surgery: (g) median(min-max)** | 3,875(2,825-13,400) | 3,460(2,040-10,000) | 0.093** |
| **Age at cardiac surgery:(days) median(min-max)** | 70(1-1,081) | 53(4-452) | 0.923** |
| **CRP (mg/L); mean±SD** | 110.69±75.4 | 173.49±62.98 | 0.005*** |
| **Albumin gr/dl, mean±SD** | 3.8±0.5 | 3.47±0.5 | 0.057*** |
| **Albumin-hemoglobin index mean±SD** | 44.5±13 | 38.7±7.7 | 0.08*** |
| **Intubation at first admission: n(%)** | 5(35.7) | 9(64,3) | 0.112* |
| **Inotrope infusion before ICU admission; n(%)** | 0(0) | 1(100) | 0.447* |
| **Cardiopulmonary bypass time(minute) median(min-max)** | 93(38-225) | 120(67-257) | 0.495** |
| **Cross-clamp time(minute) median(min-max)** | 62(26-160) | 71(38-164) | 0.533** |
| **Ongoing intubation on 3rd PO day; n(%)** | 20(51.3) | 19(48.7) | 0.269* |
| **Ongoing intubation at 7th PO day; n(%)** | 9(31) | 20(69) | <0.001* |
| **Postoperative max FiO2 at 48 hours: median (min-max)** | 70(45-100) | 60(40-85) | 0.856** |
| **Hospital duration; median (min-max)** | 17(5-174) | 180(36-345) | <0.001** |
| **MV duration; median (min-max)** | 4(0-167) | 131(7-229) | <0.001** |
| **Proven sepsis: n(%)** | 3(16.7) | 15(83.3) | <0.001* |
| **Cardiac arrest event after surgery: n(%)** | 3(37.5) | 5(62.5) | 0.437* |
| **Dysmorphism: n(%)** | 5(33.3) | 10(66.7) | 0.059* |
| **Thorax and lung malformations: n(%)** | 0(0) | 2(100) | 0.194* |
| **Other major malformation: n(%)** | 2(28.6) | 5(71.4) | 0.217* |
| **Diaphragm paralysis** | 1(50) | 1(50) | 1* |
| **Mortality: n(%)** | 4(57.1) | 3(42.9) | 1* |

Abbreviations: TG: Tracheostomy group, NTG: Non-tracheostomy group, MV: Mechanical ventilation, PO: Postoperative, SD: Standard deviation, ICU: Intensive care unit, $FiO_2$: Fraction of inspired oxygen, CRP: C-reactive protein. *Fischer's exact test or Chi-square test where appropriate, ** Man-Whitney U test, *** Student T-Test.

In our center, the overall rate of tracheostomies in operated heart patients was 1.68%. Of the 47 patients, 29(63%) were male. The median weight was 3,630 g (range, 2,040-13,400), and the median age on the day of surgery was 69 days (range, 1-1,081). The majority (93.6%) of the patients were aged < 1 year. Although preoperative hemoglobin and leukocyte counts did not differ between the groups, CRP measurements, in particular, were observed to be significantly higher by 50% in TG (P=0.005). By contrast, the albumin levels of TG were low, although not significantly (P=0.057). There were no statistically significant differences between the groups regarding cardiopulmonary bypass and cross-clamp time. On the 7th postoperative day, 63% of the patients were still intubated. The median length of post-tracheostomy hospital stay was 62 days (range, 12-128). Culture-proven sepsis was significantly higher in TG (P<0.001). As expected, the length of hospital stay (P<0.001), mechanical ventilation duration (P<0.001), and the duration of intubation on the 7th-day post-surgery were significantly higher in TG. Furthermore, no difference was found between the groups regarding the number of still-intubated patients on 3rd-day post-surgery (P=0.269). Post-surgery cardiac arrest and mortality rates showed no difference between the groups. Tracheostomy status can also be predicted from IS and VIS values calculated from postoperatively administered inotropic and vasopressor drugs. For this purpose, the tracheostomy status was evaluated using the IS and VIS values calculated for each hour over 48 h.

While analyzing the VIS and IS values, three patients in NTG were excluded from the statistical analysis due to severe postoperative hemodynamic instability and extreme scores. For these statistical analyses, the data of 21 patients in TG and 23 patients in NTG were used. It was observed that the IS and VIS values continuously downward over time. It was revealed that VIS values were consistently five points higher than IS values and represented parallelism over time (Figure 1, Table 2). In this respect, using IS or VIS values does not change the findings. However, a larger scale of VIS values will provide more advantages in classification. It was determined that the VIS values of TG were 50% higher than those of NTG (P<0.001, Table 2). A time-based function would be more meaningful because the majority of patients required high-dose inotrops in the early postoperative period. The time-dependent change in VIS values in Figure 2 was modeled separately for both groups (Figure 2, Table 3).

Table 3 indicates a significant negative linear relationship between VIS values over time. Although both models were statistically significant, they were not strong in terms of explanatory power. The scores showed a wide distribution among patients over time, and the insufficient number of patients reduced the prediction ability of the models. We tried to find cut-off values to predict tracheostomy status based on linear regression modeling. Figure 3 displays a graphical representation of 95% and 99% confidence intervals for the mean VIS values for both groups and cut-off values for both models to predict tracheostomy status (Figure 3). From these two

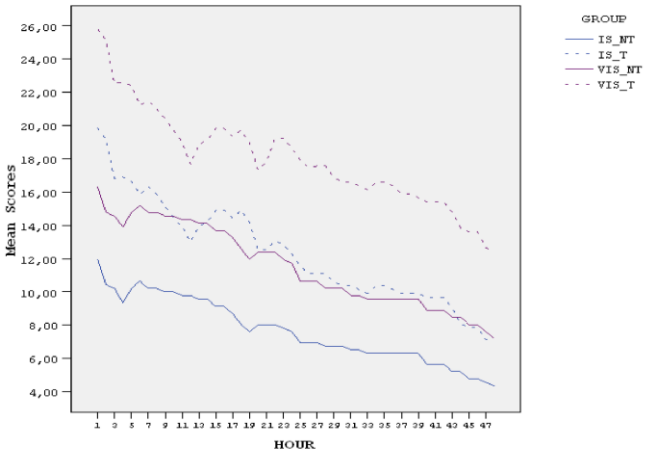


**Figure 1.** Postoperative IS and VIS values for each hour in both groups
Abbreviations: IS: Inotrope score, VIS: Vasoactive inotropic score, T: Tracheostomy, NT: Non-tracheostomy

**Table 2.** Difference between IS and VIS values and the effect of VIS on the tracheostomy state

| SCORE | n | Mean | SD | Min. | Median | Max. | P-value |
|---|---|---|---|---|---|---|---|
| **IS** | 2112 | 9.89 | 9.01 | 0.0 | 5.0 | 45.00 | <0.001* |
| **VIS** | 2112 | 14.64 | 11.87 | 0.0 | 10.0 | 70.00 | |
| **VIS values for tracheostomy state** | | | | | | | |
| **NO** | 1104 | 11.56 | 8.05 | 0.00 | 10.0 | 40.00 | <0.001* |
| **YES** | 1008 | 18.01 | 14.23 | 0.00 | 15.0 | 70.00 | |

*Student T-test
Abbreviations: VIS: Vasoactive inotropic score, IS: Inotrope score

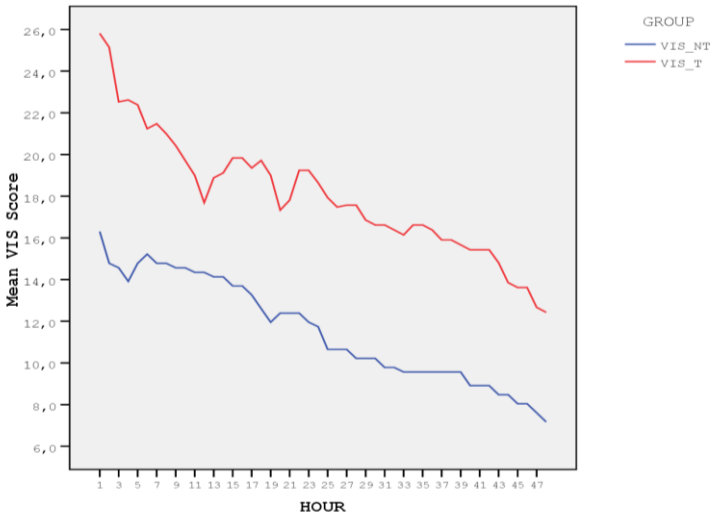


**Figure 2.** Mean VIS values for both groups per hour in the postoperative period
Abbreviations: VIS: Vasoactive inotropic score; T: Tracheostomy, NT: Non-tracheostomy

**Table 3.** Linear regression models to predict time and VIS values association in non-tracheostomy and tracheostomy groups

| Tracheostomy | | Unstandardized Coefficients | | R-square | t | P-value | 95% Confidence Interval for B | |
|---|---|---|---|---|---|---|---|---|
| **NO** | Constant | 15.874 | 0.470 | 0.303 | 33.799 | <0.001* | 14.953 | 16.796 |
| | HOUR | -0.176 | 0.017 | | -10.546 | <0.001* | -0.209 | -0.143 |
| **YES** | Constant | 22.897 | 0.894 | 0.194 | 25.622 | <0.001* | 21.144 | 24.651 |
| | HOUR | -0.199 | 0.032 | | -6.280 | <0.001* | -0.262 | -0.137 |

*: Linear regression analysis

linear models, an equation was formulized to predict tracheostomy status and is presented in Table 4. The correct classification rates of the two separately created regression models are also shown. (Table 4).

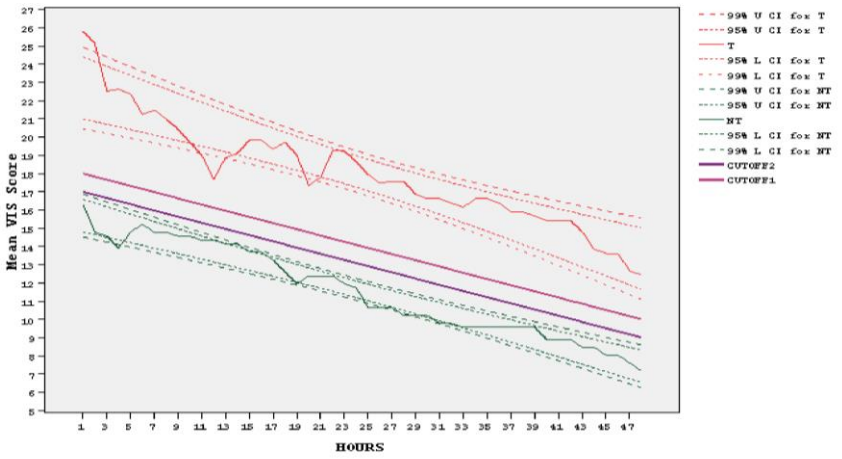


**Figure 3.** Confidence intervals of regression models for VIS values and two cut-off values of the linear model
Abbreviations: VIS: Vasoactive inotropic score, T: Tracheostomy, NT: Non-tracheostomy, U CI: Upper confidence interval, L CI: Lower confidence interval

**Table 4.** Cut-off values of models and related correct classification ratios

| CUT-OFF MODEL | | n | The ratio of correct classification |
|---|---|---|---|
| **I. VIS=18.170-0.170*HOUR** | TG HIGHER CUT-OFF1 | 1008 | 0.4881* |
| | NTG LOWER CUT-OFF1 | 1104 | 0.7228* |
| **II. VIS=17.170-0.170*HOUR** | TG HIGHER CUT-OFF2 | 1008 | 0.5704* |
| | NTG LOWER CUT-OFF2 | 1104 | 0.6567* |

Abbreviations: VIS: Vasoactive inotropic score, TG: tracheostomy group, NTG: Non-tracheostomy group *: Linear regression analysis

## 5. Discussion

This study is among the few studies investigating the relationship between tracheostomy and vasoactive inotropic score using objective cut-off values. The results of the study presented objective data for predicting tracheostomy in pediatric cardiovascular surgery patients by formulating two separate time-based cut-off modeling using VIS values in the postoperative period.

Physicians use VIS values to predict mortality and morbidity because they indicate how much inotropic support the patient receives and the seriousness of their condition. In a recently published retrospective research that investigated the outcomes of pediatric tracheostomy with the participation of 53 childrens' hospitals across the United States, significant differences between the groups in terms of the parameters, including region, comorbidities, and age were revealed (9). Comorbidities with a rate of 46% ranked third, after respiratory and gastrointestinal abnormalities. Furthermore, cardiac abnormalities in the group that underwent tracheostomy were significantly lower than in the overall cohort. Possible reasons for this result may be that heart diseases are the most common malformations in the population and that patients with minor congenital heart malformations who did not require surgical correction were included in the study. Considering the length of hospital stay in subgroup analyses, the total length of hospital stay and the length of post-tracheostomy hospital stay of patients with concomitant cardiac abnormalities significantly increased. The mentioned study showed that concomitant cardiac abnormalities were associated with a 33-day and 17-day increase in the total length of hospital stay and the length of post-tracheostomy hospital stay, respectively. The authors also concluded that age contributed significantly to the total length of hospital stay and length of post-tracheostomy hospital stay. Although the analysis was not performed according to IS in the mentioned study, 36% of the patients in our study group were aged under one month at the time of surgery, and 93% were aged under one year, explaining the contribution of the long length of hospital stay to mortality and tracheostomy status.

In the multicenter study conducted by Johnson et al. with patients of age < 18 years to examine the variations in tracheostomy use in patients undergoing cardiac surgery, it was concluded that the incidence of tracheostomy in pediatric patients varied from 0.3% to 2.5% (10). Similarly, the tracheostomy rate was 1.68% in the present study when the patients hospitalized in the last five years were taken into consideration. The authors of the mentioned study found that the median length of hospital stay in patients who underwent tracheostomy was 63 days (Interquartile range (IQR): 36-100) (10). Similarly, we found that the median length of post-tracheostomy hospital stay was 62 days (IQR: 55-83). In the same study, the authors reported that tracheostomy placement for 63 days or more postoperatively increased the mortality risk by

2.2 times. Late tracheostomy placement was represented as one of the mortality risks in patients undergoing congenital heart surgery (10). In the current study, we found no such association, and the reason for this may be the small sample size. No comparison could be made due to the lack of data about the IS values of patients in the said study.

In a study investigating the predictive value of VIS values on mortality in pediatric patients undergoing cardiac surgery, higher VIS values were associated with longer-duration mechanical ventilation and higher mortality rates (11). Contrary to the mentioned study, when the VIS value as 15.5 was considered a cut-off (11), no significant relationship between high VIS values and mortality was observed; however, a significant difference in the duration of mechanical ventilation was observed. These results may be related to variations in the approach and management of hemodynamic compromise or congenital heart diseases of different severity, different weaning strategies, different types of comorbid states such as genetic abnormalities.

In a study by Grewan et al. (12), who investigated the safety of tracheal tube placement in adult patients who underwent venovenous and venoarterial extracorporeal membrane oxygenation, it was concluded that tracheostomy placement was a safe procedure and that tracheostomy reduced inotrope and vasopressor requirements. In the present study, the tracheostomy timing and decision were made by an intensivist, and IS values were calculated; however, the relationship between tracheostomy and VIS values was not investigated due to another aim of the study. As can be seen from the boxplots of the mentioned study, the VIS values of the patients were significantly lower than those calculated in our study, which is remarkable. The reason for significant difference of VIS value is that drugs such as adrenaline and noradrenaline, which have a coefficient of 100 in VIS calculations, are associated with aggressive use within the clinical protocol. Similar to the present research, Dilli et al. mentioned a VIS of 140 (11).

In a recent study carried out by Sun et al. investigating the relationship between VIS and short-term outcomes in pediatrics undergoing cardiac surgery, they showed that VIS at the 48$^{th}$ h has better discrimination power for prolonged mechanical ventilation and prolonged hospital stay than other time intervals (13). Although they defined the prolonged mechanical ventilation period as 48 h or later in their study, our patients had a median of 18 days, and the mean was 61 days. In the mentioned study, the median mechanical ventilation duration was only 10 h, and the lowest age and weight were ten months and 7.3 kilograms, respectively (13). It seems that the main reason for this result is that our patient group is younger and has complex congenital heart pathologies that need to be corrected more urgently. The same study showed that VIS scores at 48-h postoperative were valuable in predicting prolonged mechanical ventilation; conversely, we found a weak correlation between tracheostomy and maximum VIS scores in the early hours. The mentioned study reported median VIS scores of 7 in the prolonged mechanical ventilation group (13), while median VIS scores in our patients at 48 h were median of 10 in TG. No difference was observed between the groups regarding the 48$^{th}$ h VIS score in the present research.

In an adult study investigating the relationship between VIS scores and post-cardiac surgery mortalities and morbidities, they found that, contrary to the above-mentioned study, the maximum VIS score in the first 24 h of postoperative was a good predictor in terms of prognosis and morbidities (14). They found that unfavorable outcomes were observed in higher proportions when the VIS max values increased. Similar to this study, VIS values were at the highest level in the early postoperative period in our study. When we examined morbidities similar to this study, we found the mean 16$^{th}$-h VIS values to be high in sepsis cases; however, we found no difference in terms of mortality. Additionally, in cases whose intubation status continued on the 7$^{th}$ day, the mean VIS values in the first 6 and 24 h were significantly higher.

The current research study has some limitations, such as performing the study in a single-center, retrospective nature of the study, and having a small sample size. Additionally, the decision to initiate and continue inotropes was not based on precise rules (i.e., on clearly defined protocols). Although clinical management was performed following general rules, patient progression may have been affected by variations in the practices of the cardiac intensive care team.

## 6. Conclusion

Although tracheostomy is among the most commonly performed procedures in adult ICUs, it has not been widely used for pediatric patients. There is no definite consensus about the length of time a child should remain intubated before performing a tracheostomy. This study presented us with a model from VIS values and formulated equations with a chart to predict postoperative tracheostomy status in pediatric patients undergoing cardiac surgery to facilitate decision-making for intensive care professionals. Using this chart, intensive care physicians can anticipate pediatric cardiac surgery patients who are highly likely to undergo a tracheostomy. By paying attention to these cases, they can reduce the number of tracheostomies with early extubation or gentle ventilation modalities such as high-frequency ventilation and targeted tidal ventilation strategies in appropriate pediatric

cardiovascular surgery cases.

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## Footnotes

**Conflicts of Interest:** The authors declare that they have no conflicts of interest.
**Author contributions:** All authors contributed to the study conception and design. Material preparation, data collection, and analysis were performed by [hidden for review]. [hidden for review] revised it critically for important intellectual content. The first draft of the manuscript was written by [hidden for review], and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.
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**Ethical approval:** This research involved humans. However, since this retrospective study was performed using a hospital database with de-identified patients, the risk to participants was minimal. Patient identity and private images were not shared by following the ethical rules.
**Informed consent:** No consent was required.

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