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Research Article

Renal Injury and Ventilatory Score as Predictors of Morbidity and Mortality in Patients with Complex Congenital Heart Disease in a Tertiary Care Hospital

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Abstract

Introduction: Congenital heart diseases are structural and functional malformations of the heart present at birth, affecting between 0.4% and 1.2% of live newborns. They are among the leading causes of neonatal and pediatric mortality in Mexico. Despite advances in surgical treatments, postoperative complications such as acute kidney injury and prolonged mechanical ventilation remain significant risk factors.

Materials and Methods: This was an observational, analytical, and retrospective study conducted at a tertiary care hospital between 2021 and 2023. Patients with complex congenital heart diseases, such as Tetralogy of Fallot, Aortic Coarctation, and Transposition of the Great Arteries, who underwent surgery with Cardiopulmonary Bypass (CPB) were included. Serum creatinine levels and the duration of phase III ventilation were analyzed to assess their correlation with morbidity and mortality.

Results: Significant correlations were found between acute kidney injury and ventilatory score with postoperative complications. It was demonstrated that patients with prolonged Cardiopulmonary Bypass (CPB) duration and aortic clamping have a higher likelihood of short-term complications, including acute kidney injury and prolonged mechanical ventilation. These factors often lead to extended hospital stays and, in some cases, death.

Discussion: Acute kidney injury and ventilatory score are important predictors of postoperative prognosis. The results of this study can be used to improve morbidity and mortality prediction and to optimize individualized patient management.

Conclusion: This study demonstrates that monitoring renal function and mechanical ventilation is crucial in reducing morbidity and mortality in these patients. The use of these parameters as indicators to predict postoperative risk is recommended to improve prognosis and short- and long-term survival.

Keywords: *Congenital Heart Disease; Creatinine; Mechanical Ventilation; Morbidity and Mortality*

Abbreviations

CPB: Cardiopulmonary Bypass; CNS: Central Nervous System; PICU: Pediatric Intensive Care Unit (PICU); AKI-CS: Acute Kidney Injury Associated with Cardiac Surgery; ICU: Intensive Care Unit; NICU: Neonatal Intensive Care Unit; HNP: Hospital para el Niño Poblano; (GW): Gestational Weeks

Introduction

A congenital heart disease is defined as one or more abnormalities in the structure and function of the heart and great vessels [1], occurring during embryonic development, particularly between the third and tenth weeks of gestation (GW) [4]. These defects are present at birth and, depending on their complexity, can cause profound physiological alterations in blood circulation dynamics [9], even if they are detected later in life [1].

Between 3% and 4% of all newborns present a significant congenital malformation at birth, with congenital heart diseases being the most common in different countries [1]. In Mexico, according to a study conducted by the Cardiology Department of the Hospital Infantil de México, it is estimated that between 4 to 12 per 1,000 live births present congenital heart defects [5].

The prevalence of congenital heart diseases has increased over the years, leading to a higher number of accurate and timely diagnoses. It is important to consider that the more premature the newborn, the greater the likelihood of developing this condition. In 2010, Godfrey., *et al*. reported a prevalence of 43 per 1,000 in very low birth weight preterm infants (≤ 1,500g) [1,2]. If detection occurs during the fetal stage, the prevalence is even higher than in live births [1], as some cardiac defects are so severe that they are incompatible with life.

A study conducted between January 2006 and December 2010 in a secondary-level general hospital and a tertiary-level maternal and perinatal hospital in the State of Mexico analyzed the incidence, survival, and risk factors for mortality in a cohort of newborns. The overall incidence was 7.4 per 1,000 live births. Among preterm newborns, the incidence was 35.6 per 1,000 live births, while in term newborns, it was 3.68 per 1,000 live births [1].

On the other hand, 21.2% to 25% of patients with congenital heart disease, particularly those with complex congenital heart defects, present extracardiac abnormalities, malformative syndromes, or chromosomal disorders, which complicate patient care and increase mortality rates [1,4]. Mortality due to congenital heart disease in children under one year of age accounts for approximately 35% of deaths from congenital anomalies and around 10% of all deaths within this period [4]. Among congenital heart diseases, Tetralogy of Fallot is currently the most common cyanotic heart defect [3]. Likewise, 9% of patients born with heart defects present aortic coarctation as their primary anomaly. Globally, this condition ranks fourth in frequency, while in Mexico, it ranks fifth, often manifesting during infancy [5]. Lastly, transposition of the great arteries accounts for 3% to 5% of all congenital heart defects and 20% of cyanotic congenital heart diseases [6]. Its prevalence varies, but it has been reported to occur in 20.1 to 30.5 per 100,000 births, with a higher incidence in males [7].

In Mexico, 50% of congenital heart defects require surgical procedures, and 30% of these are performed using cardiopulmonary bypass (CPB) [1].

In the treatment of this condition in neonates and pediatric patients, early surgical repair is now a common practice, replacing the initial palliative approach followed by later correction. CPB systems have evolved over time, becoming a safe and highly efficient tool in the treatment of cardiac disorders [8].

The primary goal of CPB is to perfuse vital organs and preserve their function by maintaining adequate oxygen transport. However, complications may arise, including central nervous system (CNS) dysfunction, pulmonary and renal alterations, increased susceptibility to infections, and shock, among others [11].

A 2014 study by Hemant., *et al*. demonstrated that postoperative cardiac and extracardiac complications occurred in 43% of pediatric patients undergoing cardiac surgery. These complications were observed in surgeries performed both with and without CPB support. In procedures using CPB, a longer duration of bypass was significantly associated with a higher incidence of cardiac and extracardiac complications. Postoperative complications were largely related to factors such as prolonged mechanical ventilation, length of stay in the pediatric intensive care unit (PICU), and overall hospital stay duration [14].

This study revealed a higher incidence of extracardiac complications compared to cardiac complications. The observed complication rate was higher than previously reported rates, which ranged from 33% to 39% in pediatric patients and 29% in neonatal patients [14].

A study conducted by the society of thoracic surgeons congenital heart surgery, which analyzed 47,840 neonates, concluded that birth during the early-term period (37 to 38 weeks of gestation) was associated with worse outcomes after cardiac surgery in both the neonatal and pediatric periods. These findings are consistent with recently identified associations between early-term birth and outcomes in neonates without congenital defects [15].

These data challenge the common belief that delivery at any time during the term period is equally safe and appropriate. They compel us to reconsider the practice of elective delivery in fetuses with complex congenital heart defects during the early-term period [15].

Compared to full-term newborns with congenital heart disease, those born prematurely have an approximately twofold higher risk of in-hospital mortality. Furthermore, prenatal diagnosis of congenital heart disease has been associated with an increased likelihood of preterm birth [15].

Chang., *et al*. demonstrated that female patients were 51% more likely to die than male patients [12]. Additionally, Jenkins., *et al*. studied cases of congenital heart surgery across 37 hospitals and found that the risk of in-hospital death increased when surgery was performed at low volume institutions. However, larger institutions reported higher complication rates but lower mortality rates, which could be explained by their management of more complex heart conditions and their better-equipped facilities to rescue patients from adverse effects [12].

Until a few years ago, the prognosis for patients with congenital heart disease undergoing cardiac surgery with cardiopulmonary bypass (CPB) was poor, as most of these patients were in a nutritionally deficient state. Moreover, they often presented with recurrent respiratory infections, along with other complications. These, combined with the effects of the surgical procedure itself such as prolonged mechanical ventilation, arrhythmias, low cardiac output, and sepsis could significantly increase morbidity and mortality in these patients [9].

Many forms of congenital heart disease are associated with elevated pulmonary vascular resistance, which can persist after CPB and disrupt hemodynamic stability in the immediate postoperative period. Excessive bleeding after CPB occurs in both pediatric and adult patients; however, in pediatric patients, risk factors include preoperative cyanosis, prolonged CPB duration, deep hypothermia, and excessive suctioning of the surgical field [8].

Improvements in perfusion techniques, surgical methods, and perioperative management have substantially reduced postoperative morbidity and mortality over the past two decades [8].

Advances in diagnosis, surgical treatment, and postoperative care for pediatric patients with congenital heart disease have progressively improved survival rates. However, patients requiring more complex cardiac surgeries and those experiencing multiorgan failure after the procedure have a high incidence of cardiac surgery-associated acute kidney injury (CSA-AKI) [17]. In the postoperative period, these patients are at increased risk of renal dysfunction due to reduced cardiac output, CPB-induced alterations, hemolysis related complications, and even sepsis [17].

CSA-AKI is closely linked to adverse outcomes, including prolonged mechanical ventilation, extended stays in the pediatric intensive care unit (PICU) and hospital, and increased mortality [16]. Risk factors for CSA-AKI are classified into renal and extrarenal categories, with the latter including constitutional, hemodynamic, and inflammatory causes [13].

Previous studies have identified prematurity, surgical complexity, preoperative and perioperative comorbidities, markers of inadequate systemic oxygen delivery, prolonged mechanical ventilation, CPB pump failure, sepsis, and hematologic complications as risk factors for postoperative pediatric CSA-AKI [13,16].

The incidence of CSA-AKI requiring continuous renal replacement therapy (CRRT) after cardiac surgery with CPB ranges from 1% to 17%, depending on the complexity of the procedure [17].

There is still limited information on the outcomes of patients requiring renal replacement therapy after cardiac surgery [17]. As a result, preventive or therapeutic measures for CSA-AKI remain scarce, including fluid restriction, maintaining adequate urine output, and avoiding nephrotoxic agents. Given the association between CSA-AKI and postoperative outcomes in pediatric cardiac surgery, efforts aimed at modifying CSA-AKI risk could lead to significant reductions in postoperative mortality, shorter stays in the intensive care unit (ICU) and hospital, and lower institutional costs. While some risk factors are modifiable, research efforts to identify strategies for reducing CSA-AKI rates and improving patient outcomes are ongoing [16].

Materials and Methods

A mixed-methods, observational, analytical, cross-sectional, retrospective, prospective, single center, homodemic, and sequential exploratory study was conducted on neonatal and pediatric patients with complex congenital heart diseases including Tetralogy of Fallot, Aortic Coarctation, and Transposition of the Great Arteries who underwent surgical intervention with CPB at a tertiary level hospital.

Statistical analysis

Descriptive statistics were performed using measures of central tendency and dispersion, considering the significant difference between the mean renal and ventilatory scores in the population. Statistical significance was determined using the odds ratio, and a relationship was analyzed through logistic regression, maintaining the same significance level. Additionally, positive and negative predictive values were calculated using the online logarithmic program SAMIUC.

Results

A total of 130 patients with complex congenital heart diseases from Hospital para el Niño Poblano were included in the study. A higher prevalence was observed in females, with 66 women (50.7%) and 64 men (49.3%). Among the study population, 72 patients (55.7%) were diagnosed with aortic coarctation, 40 (30.7%) with tetralogy of fallot, and 18 (13.6%) with transposition of the great arteries.

All analyzed patients (100%) were born at term (> 37 weeks of gestation), with a mean gestational age of 40.4 weeks. Among them, 90% had an adequate birth weight (> 2,500g), 6.9% weighed exactly 2,500g, and only 3% were classified as low birth weight (< 2,500g).

Sixty percent of the patients underwent surgical intervention before the age of five. During surgery, 80% had an aortic cross-clamping time of less than 90 minutes, and 50% were on cardiopulmonary bypass (CPB) for less than 120 minutes.

Of the 130 patients, 52 (40%) remained in phase III of ventilation for less than 72 hours, while the rest developed complications and required prolonged mechanical ventilation.

Among the total patients analyzed, only 83 (63.8%) had a creatinine level of ≤0.5 mg/dL upon hospital admission. Additionally, 65 patients (50%) experienced a twofold increase in baseline serum creatinine levels within 24 hours post-surgery, all of whom passed away.

Discussion

The prevalence of congenital heart diseases has increased over the years in our institution, aligning with national and international reports. This trend reflects an improvement in the number of diagnoses and greater accuracy in identifying cardiac defects.

According to the cited studies, prevalence varies depending on the population and neonatal conditions. Additionally, these studies suggest that prematurity significantly increases the risk of congenital heart diseases. Our findings are consistent with these reports, highlighting the need for early detection and prompt surgical treatment in such cases.

Patients with congenital heart diseases undergoing cardiopulmonary bypass (CPB) surgery have a higher risk of developing severe complications that may lead to mortality. Among these complications, cardiac surgery-associated acute kidney injury (CSA-AKI) and prolonged mechanical ventilation were found to be significantly more frequent in our institution compared to previously published studies.

In recent years, it has been demonstrated that a twofold increase in serum creatinine levels in the immediate postoperative period is considered acute kidney injury and is associated with a poor prognosis. The incidence of CSA-AKI in other studies has been reported to range from 1% to 17%. In contrast, our analysis revealed a much higher incidence of 50%.

Mechanical ventilation times in our patients remain prolonged. According to the reviewed literature, early extubation either in the operating room or within the first six hours post-surgery is associated with shorter hospital stays, a reduced incidence of ventilator-associated infections, and, consequently, a significant decrease in morbidity and mortality. However, none of the patients in our study were extubated within the first six hours, and only 40% were extubated within 72 hours.

Mortality associated with these conditions remains a major concern. Available data indicate that approximately 35% of deaths from congenital anomalies in children under one year of age are attributable to congenital heart defects. Regarding the mortality rate of patients with congenital heart diseases who underwent CPB surgery and developed CSA-AKI, previous studies have reported a mortality rate of 43%. In contrast, our institution reported a significantly higher rate of 50%, which is alarming.

Based on these findings, we can deduce that renal function is the most critical factor in the postoperative care of patients undergoing cardiac surgery with CPB. Both national and international literature agree on the high mortality rate in these patients when acute kidney injury develops, a trend that is consistent with our study population. Additionally, other complications such as those associated with prolonged mechanical ventilation further reduce the likelihood of short- and long-term survival.

Conclusion

Renal injury and prolonged mechanical ventilation in the PICU following surgery are closely linked to immediate complications and decreased short-term survival.

The findings of this study indicate that patients who, 24 hours after CPB surgery, present with serum creatinine levels twice as high as their baseline upon admission are those who develop the highest number of complications and have the highest mortality rates.

Furthermore, it was observed that patients with aortic coarctation are the most frequently affected by CSA-AKI. Therefore, we conclude that meticulous postoperative medical management is essential for all patients undergoing CPB surgery, with particular attention to renal function. This includes avoiding nephrotoxic drugs, ensuring appropriate fluid management without overload, and initiating early dialysis when necessary.

The duration of aortic cross-clamping and CPB are critical factors, as longer durations are associated with increased morbidity and mortality. Consequently, the therapeutic approaches implemented at the Hospital para el Niño Poblano align with the current global trend of minimizing aortic cross-clamping and CPB times, while ensuring precise intraoperative and postoperative management. These strate-

gies aim to reduce the incidence of CSA-AKI and the duration of mechanical ventilation, ultimately lowering complications and mortality rates, an ongoing challenge in current medical practice.

We emphasize the importance of continuously evaluating surgical outcomes in patients with congenital heart diseases using various risk stratification systems. This approach allows for individualized medical management and more accurate estimations of morbidity, mortality, and prognosis. The ultimate goal is to provide high-quality medical care, optimize resources, and reduce hospital stays, thereby minimizing complications and improving survival rates.

Conflict of Interest

No conflicts of interest were reported.

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