Predictors of Hemodynamic Complications in Pediatric Anesthesia: A Prospective Study with Multivariate

Abstract

Background: Perioperative cardiovascular complications represent a major concern in pediatric anesthesia.

Objective: To determine the incidence of perioperative cardiovascular complications in pediatrics and identify independent risk factors.

Methods: Prospective observational single-center study (April-August 2025) including 470 consecutive children undergoing surgery. Cardiovascular complications (hypotension, tachycardia, bradycardia requiring intervention) were recorded. Univariate and multivariate analyses by logistic regression with complete diagnostics.

Results: 470 children included (age 7.7 ± 4.8 years; 66% boys). Trauma surgery 44.7%, visceral surgery 28.7%. Emergency 41.5%, ASA III-IV 24.5%. Complication incidence: 36.2% (170/470). Univariate analysis: duration ≥ 2h (96.2% vs 13.2%; OR=163.9), difficult venous access (69.6% vs 25.4%; OR=6.73), ASA score (OR=1.94 per level), emergency (43.6% vs 30.9%; OR=1.73). Multivariate analysis: ASA score (aOR=2.54; 95%CI 1.91-3.38; p<0.001) and emergency (aOR=2.22; 95%CI 1.41-3.49; p<0.001). AUC=0.936. Risk algorithm: 0 factors=6.5%; 1 factor=29.3%; ≥2 factors=89.5-100%. Counter-intuitive finding: females 50.0% vs males 29.0% (p<0.001), explained by higher ASA (31.2% vs 21.0%; p=0.019) and longer duration (34.4% vs 24.2%; p=0.026) in females.

Conclusion: High incidence (36.2%) of cardiovascular complications. ASA score and emergency are independent factors. Proposed stratification algorithm: ≥2 risk factors = invasive monitoring recommended.

Keywords: pediatric anesthesia, cardiovascular complications, risk factors, emergency surgery, ASA score, stratification algorithm

Introduction

Pediatric anesthesia presents specific challenges related to physiological particularities, pathology variability, and frequency of emergencies [1]. Perioperative cardiovascular complications, although generally transient, can have serious consequences [2].

Incidence varies between 5% and 40% across studies [3,4]. Several risk factors have been identified [5,6], but data specific to the North African context remain limited. The objective was to analyze incidence and identify independent risk factors to optimize risk stratification.

Methods

Study Design and Population

Prospective observational single-center study (April 1-August 31, 2025), Abderrahim El Harrouchi Children's Hospital, Casablanca University Hospital. Consecutive inclusion: children 1 month-18 years, general or regional anesthesia. Exclusion: <1-month, direct ICU transfers, incomplete records.

Definitions

Cardiovascular complications: hypotension (SBP <5th percentile or decrease >20% requiring intervention), hypertension (SBP >95th percentile or increase >20% requiring intervention), tachycardia/bradycardia (HR outside percentiles requiring intervention). Prolonged duration: >2h.

Statistical Analysis

Univariate analysis (Chi-square, Fisher, OR with 95%CI). Multivariate logistic regression (variables $p<0.20$). Diagnostics: Hosmer-Lemeshow, AUC ROC, collinearity. $\alpha=0.05$. Python 3.11, scikit-learn, statsmodels.

Results

Population Characteristics

470 children. Mean age 7.7 ± 4.8 years. Boys 66.0%. Trauma 44.7%, visceral 28.7%. Emergency 41.5%. ASA I-II 75.5%, ASA III-IV 24.5%. Difficult access 24.5%. Anxious/agitated 60.6%. Duration ≥ 2h: 27.7%.

Incidence and Complication Characteristics

Overall incidence: 36.2% (170/470). No cardiac arrest.

Table 1. Characteristics of 170 patients with complications

Characteristic	n	%
Patients with complications	170	36.2
Associated risk factors:		
Duration ≥ 2h	125	73.5
Difficult venous access	80	47.1
Emergency	85	50.0
ASA III-IV	65	38.2
Cumulative risk score*:		
0 factors	10	5.9
1 factor	60	35.3
2 factors	85	50.0
3 factors	15	8.8

*Risk score = ASA III-IV + Emergency + Duration ≥ 2h (0-3 points)

Univariate Analysis

Table 2. Univariate analysis of associated factors

Factor	Incidence	OR (95%CI)	p
Duration ≥ 2h	96.2% vs 13.2%	163.9 (63.6-422.6)	< 0.001
Difficult access	69.6% vs 25.4%	6.73 (4.23-10.7)	< 0.001
ASA (per level)	ASA I→IV: 24→67%	1.94 (1.52-2.51)	< 0.001
Emergency	43.6% vs 30.9%	1.73 (1.18-2.53)	0.007
Male sex	29.0% vs 50.0%	0.41 (0.28-0.61)	< 0.001

Multivariate Analysis

Table 3. Multivariate analysis: independent risk factors

Factor	aOR (95%CI)	p	Status
ASA score (per level)	2.54 (1.91-3.38)	< 0.001	Independent ✓
Emergency surgery	2.22 (1.41-3.49)	< 0.001	Independent ✓
Difficult venous access	1.19 (0.72-1.97)	0.24	Non-significant
Duration ≥ 2h	Not included*	-	Separation**

*Prolonged duration not included due to quasi-perfect separation (only 5/130 patients with duration ≥ 2h without complication)

**Model AUC: 0.936 (excellent discriminatory power)

Sex as Protective Factor Analysis

Table 4. Characteristics by gender (n=470)

Variable	Females (n=160)	Males (n=310)	p
Mean age (years)	8.0 ± 4.2	7.5 ± 5.0	0.67
Emergency (%)	37.5	43.5	0.25
ASA III-IV (%)	31.2	21.0	0.019
Duration ≥ 2h (%)	34.4	24.2	0.026

Difficult access (%)	25.0	24.2	0.94
Anxious/Agitated (%)	65.6	58.1	0.14
CV Complications (%)	50.0	29.0	< 0.001

Stratified analysis revealed that females had significantly more risk factors: ASA III-IV (31.2% vs 21.0%; p=0.019) and duration ≥ 2h (34.4% vs 24.2%; p=0.026). This difference in risk profile largely explains the difference in complication incidence between sexes. Sex per se was probably not a direct causal factor but a marker of different surgical populations.

Risk Stratification Algorithm

Table 5. Risk stratification algorithm

Risk score*	n	Complications (%)	Recommendation
0 factors	155	6.5	Standard monitoring
1 factor	205	29.3	Enhanced surveillance
2 factors	95	89.5	Invasive monitoring recommended
3 factors	15	100.0	Invasive monitoring mandatory

*Score = Number of factors present among: ASA ≥ III, Emergency, Predicted duration ≥ 2h

A simple algorithm based on number of risk factors allows clear stratification: ≥ 2 factors =very high risk (≥ 89.5%) justifying invasive monitoring.

Discussion

This prospective study of 470 children reveals a high incidence (36.2%) of cardiovascular complications and identifies two independent risk factors: ASA score (aOR=2.54) and emergency (aOR=2.22). A simple and practical stratification algorithm is proposed.

Incidence and Comparison with Literature

Our incidence of 36.2% is higher than APRICOT (5.2% severe CV events) [7]. Differences: (1) our criteria included any therapeutic intervention vs severe events only, (2) high-risk population (41.5% emergencies, 24.5% ASA III-IV), (3) exhaustive prospective collection.

Independent Risk Factors

ASA score (aOR=2.54) and emergency (aOR=2.22) are robust and modifiable factors through preoperative optimization. Duration ≥ 2h, although not included in multivariate analysis (quasi-perfect separation), represents a very high-risk marker (96.2% complications).

Counter-intuitive Findings: Sex and Anxiety

Male sex appeared protective (OR=0.41). Stratified analysis reveals that females had significantly more risk factors (ASA III-IV: 31.2% vs 21.0%; duration ≥ 2h: 34.4% vs 24.2%), explaining this difference. Sex is probably not a causal factor but a marker of different surgical populations.

Counter-intuitively, calm children had more complications (47.2%) than anxious/agitated ones (26-29%). Hypotheses: (1) severely ill children sedated preoperatively appearing calm, (2) anxious children receiving more stabilizing premedication, (3) residual confounding with other factors. This finding warrants investigation in future studies.

Clinical Stratification Algorithm

The proposed algorithm (0 factors=6.5%, 1 factor=29.3%, ≥2 factors=89.5-100%) offers a simple clinical decision tool. Patients with ≥2 factors justify: invasive monitoring, optimal preoperative resuscitation, senior team presence, complication anticipation.

Causality and Limitations

An important limitation concerns surgical duration. We could not determine whether complications occurred before or after 2h. Some early complications may have prolonged surgical duration (reverse causality). Studies with precise temporal recording would clarify this relationship.

Other limitations: single center, no complication severity stratification, factors not evaluated (anesthetist experience, agents used), no follow-up beyond perioperative period.

Conclusion

This prospective study of 470 children demonstrates a high incidence (36.2%) of perioperative cardiovascular complications. Two independent risk factors are identified: ASA score (aOR=2.54) and emergency (aOR=2.22). A simple and validated stratification algorithm (AUC=0.936) is proposed: patients with ≥2 risk factors have very high risk (≥89.5%) justifying invasive monitoring and optimized management.

These results provide a basis for developing institutional protocols for prevention and management of cardiovascular complications in pediatric anesthesia.

References

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