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RESEARCH ARTICLE

PREDICTORS OF HEMODYNAMIC COMPLICATIONS IN PEDIATRIC ANESTHESIA: A PROSPECTIVE STUDY WITH MULTIVARIATE ANALYSIS

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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 study (April-August 2025) including 470 children undergoing surgery. Cardiovascular complications (hypotension, tachy/bradycardia requiring intervention) were recorded. Uni and multivariate analyses were performed.

Results: 470 children included (age 7.7 ± 4.8 years; 66% boys). Emergency procedures accounted for 41.5% and ASA III-IV status for 24.5%. The incidence of complications was 36.2%, with most events being mild to moderate and no cardiac arrest reported. Univariate analysis: duration ≥ 2 h (OR=163.9), difficult venous access (OR=6.73), ASA score (OR=1.94 per level), and emergency surgery (OR=1.73) were associated with complications. Multivariate analysis: ASA score (aOR=2.54; $p < 0.001$) and emergency surgery (aOR=2.22; $p < 0.001$) were independent predictors. The proposed risk algorithm showed increasing complication rates according to the number of risk factors: 0 factors=6.5%; 1 factor=29.3%; ≥ 2 factors=89.5-100%. A higher incidence was observed in females (50.0% vs 29.0%; $p < 0.001$), likely explained by a higher prevalence of risk factors.

Conclusion: High incidence (36.2%) of cardiovascular complications. ASA score and emergency are independent factors. The proposed stratification algorithm may be clinically useful; however, further validation is required before routine implementation.

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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 was performed using Chi-square or Fisher's exact test, with odds ratios (OR) and 95% confidence intervals (CI). Variables with $p < 0.20$ were entered into a multivariate logistic regression model. To address quasi-complete separation, a penalized logistic regression was performed as a sensitivity analysis. Model performance was assessed using goodness-of-fit and discrimination measures. A p -value < 0.05 was considered statistically significant. Statistical analyses were performed using standard statistical software.

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 ≥ 2 h: 27.7%.

Incidence and Complication Characteristics

Overall incidence: 36.2% (170/470)

Most complications were mild to moderate, and no cardiac arrest was recorded.

Table 1. Characteristics of 170 patients with complications

Characteristic	n	%
Patients with complications	170	36.2
Associated risk factors:		
Duration ≥ 2 h	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 ≥ 2 h (0-3 points)

Univariate Analysis:-**Table 2. Univariate analysis of associated factors**

Factor	Incidence	OR (95%CI)	p
Duration ≥ 2 h	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 \rightarrow IV: 24 \rightarrow 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. However, these findings should be interpreted with caution given the methodological limitations discussed below

Incidence and Comparison with Literature:-

Our incidence of 36.2% is higher than that reported in the APRICOT study (5.2% severe CV events) [1].

The relatively high incidence observed is likely explained by differences in outcome definitions, as our study included all cardiovascular events requiring intervention, including mild and transient abnormalities, whereas APRICOT focused exclusively on severe events [1].

Additionally, our cohort included a higher proportion of high-risk patients, particularly emergency procedures (41.5%) and ASA III-IV status (24.5%), which likely contributed to the increased incidence.

Severe cardiovascular complications such as cardiac arrest remain relatively rare in pediatric anesthesia, as reported in registry-based studies [3,4], supporting the interpretation that our high incidence reflects broader inclusion criteria rather than increased severity.

Independent Risk Factors:-

ASA score (aOR=2.54) and emergency surgery (aOR=2.22) are robust predictors and consistent with previously reported risk factors in pediatric anesthesia [1,2].

These factors likely reflect underlying patient severity and limited opportunity for preoperative optimization in emergency settings.

Duration \geq 2h, although not included in multivariate analysis due to quasi-complete separation, represents a very high-risk marker (96.2% complications).

However, this association should be interpreted cautiously, as statistical instability and potential reverse causality may have influenced this finding.

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 \geq 2h: 34.4% vs 24.2%), explaining this difference.

Sex was therefore not considered a causal factor but rather a proxy for differences in surgical risk profiles, as previously suggested in studies reporting heterogeneous sex-related perioperative outcomes [6]. Counter-intuitively, calm children had more complications (47.2%) than anxious/agitated ones (26–29%).

These findings should be interpreted cautiously, as they may reflect residual confounding rather than a true protective effect of anxiety.

Hypotheses:

- (1) severely ill children sedated preoperatively appearing calm,
- (2) anxious children receiving more stabilizing premedication,
- (3) residual confounding with unmeasured factors.

Clinical Stratification Algorithm:-

The proposed algorithm (0 factors=6.5%, 1 factor=29.3%, \geq 2 factors=89.5-100%) offers a simple clinical decision tool. Such a pragmatic approach may be particularly useful in resource-limited settings for early identification of high-risk patients.

Patients with \geq 2 factors may justify invasive monitoring, optimized preoperative resuscitation, senior team involvement, and anticipation of complications.

Such risk-based approaches are consistent with previous studies emphasizing perioperative risk prediction models in pediatric anesthesia [9].

However, this model has not been externally validated and should therefore be considered exploratory.

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).

The absence of time-resolved intraoperative data prevents establishing a temporal relationship between exposure and outcome. 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 highlights a high incidence of perioperative cardiovascular complications in pediatric anesthesia. ASA score and emergency surgery appear to be key predictors. The proposed risk stratification model may be clinically useful; however, further validation in independent cohorts is required before routine implementation.

Ethics Approval and Consent to Participate :-

This study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Informed consent was obtained from the parents or legal guardians of each patient prior to inclusion. Patient data were anonymized prior to analysis.

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