Risk factors associated with unplanned ICU admissions following paediatric surgery: A systematic review

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Background. Unplanned admissions to the intensive care unit (ICU) have important implications in the general management of patients. Research in this area has been conducted in the adult and non-surgical population. To date, there is no systematic review addressing risk factors in the paediatric surgical population.

Objective. To synthesise the information from studies that explore the risk factors associated with unplanned ICU admissions following surgery in children through a systematic review process.

Method. We conducted a systematic review of published literature (PROSPERO registration CRD42020163766), adhering to the Preferred Reporting of Observational Studies and Meta-Analysis (PRISMA) statement. The Population, Exposure, Comparator, Outcome (PECO) strategy used was based on: population – paediatric population, exposure – risk factors, comparator – other, and outcome – unplanned ICU admission. Data that reported on unplanned ICU admissions following paediatric surgery were extracted and analysed. Quality of the studies was assessed using the Newcastle-Ottawa Scale.

Results. Seven studies were included in the data synthesis. Four studies were of good quality with the Newcastle-Ottawa Scale score ≥7 points. The pooled prevalence (95% confidence interval) estimate of unplanned ICU stay was 2.69% (0.05 - 8.6%) and ranged between 0.06% and 8.3%. Significant risk factors included abnormal sleep studies and the presence of comorbidities in adenotonsillectomy surgery. In the general surgical population, younger age, comorbidities and general anaesthesia were significant. Abdominal surgery and ear, nose and throat (ENT) surgery resulted in a higher risk of unplanned ICU admission. Owing to the heterogeneity of the data, a meta-analysis with risk prediction could not be performed.

Conclusion. Significant patient, surgical and anaesthetic risk factors associated with unplanned ICU admission in children following surgery are described in this systematic review. A combination of these factors may direct planning toward anticipation of the need for a higher level of postoperative care. Further work to develop a predictive score for unplanned ICU stay is desirable.

Keywords. Intensive care, critical care, unplanned, ICU admission, postoperative, paediatric surgery.

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Contribution of the study

Unplanned admissions to the intensive care unit (ICU) have been acknowledged as an overall marker of safety.[1] Awareness of this concept has encouraged research to determine the incidence and risk factors of these occurrences. This research has been interrogated in a systematic review process with beneficial conclusions drawn; however, these studies included adults and non-surgical patients.[2-4] To date, we have not been able to find a systematic review addressing the risk factors associated with unplanned ICU admissions in paediatric surgical patients.

Identifying specific risk factors in the preoperative assessment of paediatric surgical patients will inform improved decision making by surgeons and anaesthetists. Understanding these factors allows for an improved awareness during perioperative decision making and parental counselling and consent. Resources can be efficiently allocated[5] and high-risk patients rather transferred to centres that have an ICU available and sufficient expertise to manage them. This forward planning is especially important in lower-income settings where judicious use of resources is required.[6] We conducted a systematic review of published literature to synthesise the information from studies that explore the risk factors associated with unplanned ICU admissions following surgery in children.

Methods

Registration and reporting

This systematic review was registered with PROSPERO, registration CRD42020163766. A human research ethics committee waiver (W-CP-191108-2) from the University of the Witwatersrand was obtained. The protocol established adheres to the Preferred Reporting of Observational Studies and Meta-Analysis (PRISMA) statement.[7] A PRISMA flow diagram of the study is presented in Fig. 1.

Database search

We conducted a search of the PubMed and Scopus medical databases. The PubMed search strategy is outlined in Table 1. The search was

performed independently by two authors (SE and PNM) on 17 and 19 July 2020 and was repeated on 24 October 2021, and included all papers to that date.

Our search strategy was based on the following PECO framework:

- Population: paediatric surgical patients
- Exposure: risk factors
- Comparator: other
- Outcome: unplanned ICU admission.

The eligibility criteria were publications that reported on risk factors of unplanned ICU admission, cohort and case control studies, and population including paediatric patients only (age ≤18 years). Ineligibility criteria were non-English studies, duplicate studies and studies with insufficient data that could not be obtained after communicating with authors.

Data collection

The search results were exported into Endnote, then transferred to Microsoft Excel for data management. Duplicates were removed from the spreadsheet. SE and PNM independently screened each abstract for eligibility according to the abovementioned inclusion and exclusion criteria. Where there was uncertainty about articles for inclusion, this was resolved with input from other reviewers (YM and PMC). Additionally, we performed a hand-search from the reference lists of eligible manuscripts to identify other relevant papers which might have been missed during the search of the PubMed and Scopus electronic databases.

Quality assessment

A full text review of eligible papers was done to assess study quality. This was assessed with the Newcastle-Ottawa Scale, the results of which are shown in Table 2. A score ≥7 points was used as a threshold to identify studies of good quality. All eligible studies were included in our final systematic review, irrespective of their quality assessment finding.

Data extraction

Data extracted from each study included geographical location, study design, sample size, whether single or multicentre, type of surgery and significant risk factors for unplanned ICU admission.

Data analysis

Descriptive statistical methods, specifically determining frequencies and percentages, and univariate analyses were used to establish the most common risk factors from all the eligible papers. No meta-analysis was performed.

Results

The results of the literature search of PubMed and Scopus are illustrated in Fig. 1. The search produced 760 papers, of which 225 were duplicates. The title and abstracts reviewed independently by SE and PNM yielded 10 full-text articles for review. The reasons for exclusion of 525 abstracts are depicted in the PRISMA flow diagram (Fig. 1). Following screening of the reference lists of all full-text manuscripts, a potential paper was found but was not included after full-text review, as the study included patients aged more than 18. Expert consultation was sought during the data collection process and attention was brought to an additional article of relevance.[8] This systematic review therefore includes seven papers for analysis, with a total of 348 567 patients.

Four studies were of good quality, with a Newcastle-Ottawa Scale score ≥7 points (Table 2).[8-11] The characteristics of the studies are shown in Table 3. Six of the seven studies were from high-income countries and all were retrospective in nature.

Table 1. PubMed† search strategy

Query	MeSH term/phrases
Population Paediatric surgical patients	Paediatric* [Title/Abstract], Pediatrics [MeSH], Pediatric* [Title/Abstract], Child* [Title/Abstract], Child [MeSH], Infant* [Title/Abstract], Neonat* [Title/Abstract], Newborn* [Title/Abstract], Adolescen* [Title/Abstract] 'following surgery' [Title/Abstract], Perioperative period [MeSH], Postoperative period [MeSH], Perioperative* [Title/Abstract], Postoperative* [Title/Abstract], 'after surgery' [Title/Abstract], 'after anaesthesia' [Title/Abstract], 'after anesthesia' [Title/Abstract], 'anaesthesia-related' [Title/Abstract], 'anesthesia-related' [Title/Abstract], 'post surgery' [Title/Abstract], surg* [Title/Abstract]
Exposure Risk factors	'Risk factor*' [Title/Abstract], Risk factors [MeSH], Risk* [Title/Abstract], Hazard* [Title/Abstract], Odds [Title/Abstract], Predict* [Title/Abstract], Likel* [Title/Abstract], Associat* [Title/Abstract], High* [Title/Abstract], Increas* [Title/Abstract], Factor* [Title/Abstract]
Outcome Unplanned ICU admission	Unplanned [Title/Abstract], Unscheduled [Title/Abstract], Unintended [Title/Abstract], Unintentional [Title/Abstract], Incidental [Title/Abstract], Unexpected [Title/Abstract], Unbooked [Title/Abstract], Unanticipated [Title/Abstract] ICU [Title/Abstract], Intensive care unit [MeSH], 'Intensive care' [Title/Abstract], 'High dependency' [Title/Abstract], 'Critical care' [Title/Abstract], 'High care' [Title/Abstract], CCU [Title/Abstract], PICU [Title/Abstract], 'Critical illness*' [Title/Abstract], Critical illness [MeSH], 'Acute illness*' [Title/Abstract], 'Acute disease*' [Title/Abstract], Acute disease [MeSH], 'Catastrophic illness*' [Title/Abstract], Catastrophic illness [MeSH], 'critical incident*' [Title/Abstract], 'critical event*' [Title/Abstract]

MeSH = medical subject heading.
†Scopus search was performed using the keywords from the [Title/Abstract] searches of the PubMed strategy.

Table 2. Newcastle-Ottawa Scale quality assessment scores

Author (year)	Selection	Comparability	Outcome	Overall score	Good study quality?
Tweedie et al. (2012)[10]	3	1	3	7	Yes
Da Silva et al. (2013)[13]	3	1	2	6	No
Landry et al. (2017)[14]	2	1	3	6	No
Arambula et al. (2018)[12]	4		1	5	No
McHenry et al. (2019)[8]	4		3	7	Yes
Allen et al. (2020)[9]	4	1	3	8	Yes
Nasr et al. (2020)[11]	4	1	2	7	Yes

The prevalence of unplanned ICU admissions ranged from 0.06 - 8.3% with pooled prevalence (95% CI) estimates of 2.69% (0.05 to 8.6%) (Fig. 2). There was significant heterogeneity in the analysis. Three studies reported a prevalence of below the pooled estimate while three were higher.

Risk factors were extracted from each paper and additional univariate analysis was performed for individual papers where required. Thereafter they were categorised into unplanned ICU admissions following adenotonsillectomy surgery and those following other surgery. Furthermore, these were grouped as patient, anaesthetic and surgical factors.

Adenotonsillectomy surgery

Patient factors associated with unplanned ICU admissions included abnormal sleep studies[9] and the presence of comorbidities including cerebral palsy and mucopolysaccharidosis.[10] Respiratory complications (pulmonary oedema, atelectasis and pneumonia), including the need for postoperative respiratory support in the form of supplemental oxygen or positive pressure, were significant anaesthetic-related reasons for unplanned ICU admission.[9] Patients who spent a longer time in the post-anaesthesia care unit (PACU), and who spent a longer time requiring supplemental oxygen in the PACU,[12] were more likely to undergo an unexpected escalation of care to ICU. Length of hospital stay was higher in the unplanned ICU cohort than among those not admitted to ICU.[12]

Other surgery
Patient factors

The presence of respiratory and airway abnormalities [13] was seen as significant risk factors in unplanned ICU admissions (Table 4). Age <1 year was also found to be a significant factor.[14] As part of a composite morbidity score validated by Nasr *et al*.[11], other factors associated with unplanned ICU admission included age <5 years, critical illness, chronic condition indicator (CCI) ≥3 or significant CCI ≥2. These factors, along with an ntrinsic surgical risk (ISR) of three or four, demonstrated good discrimination to predict unplanned ICU admission.[11]
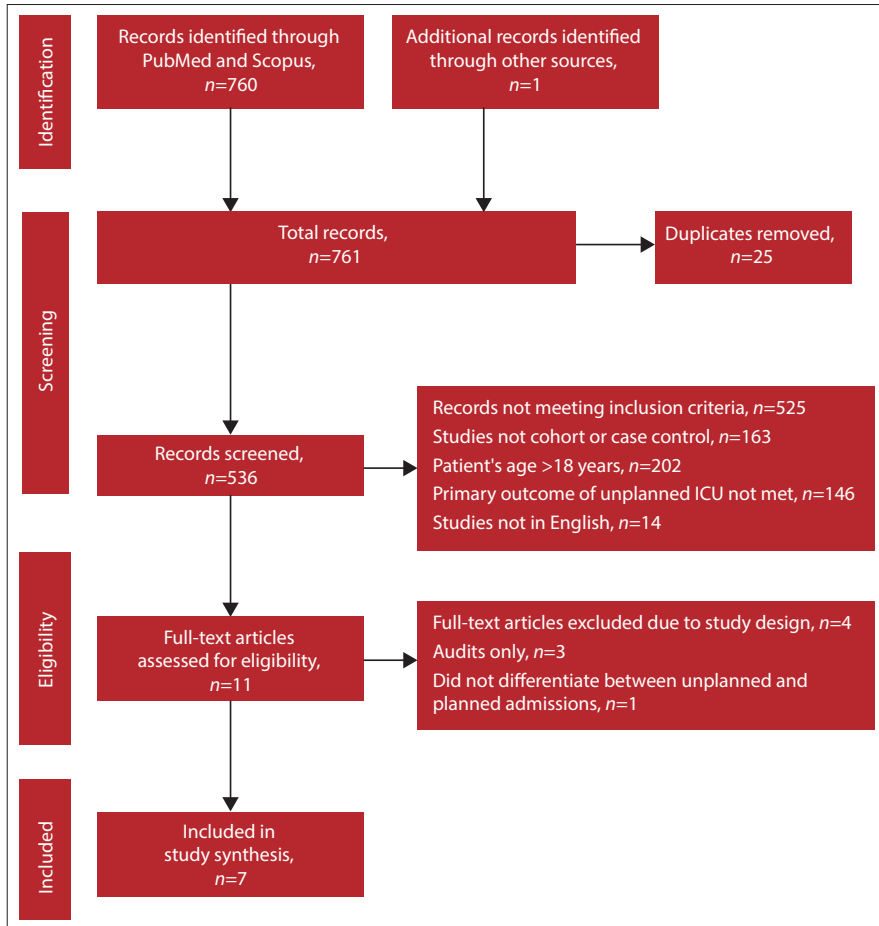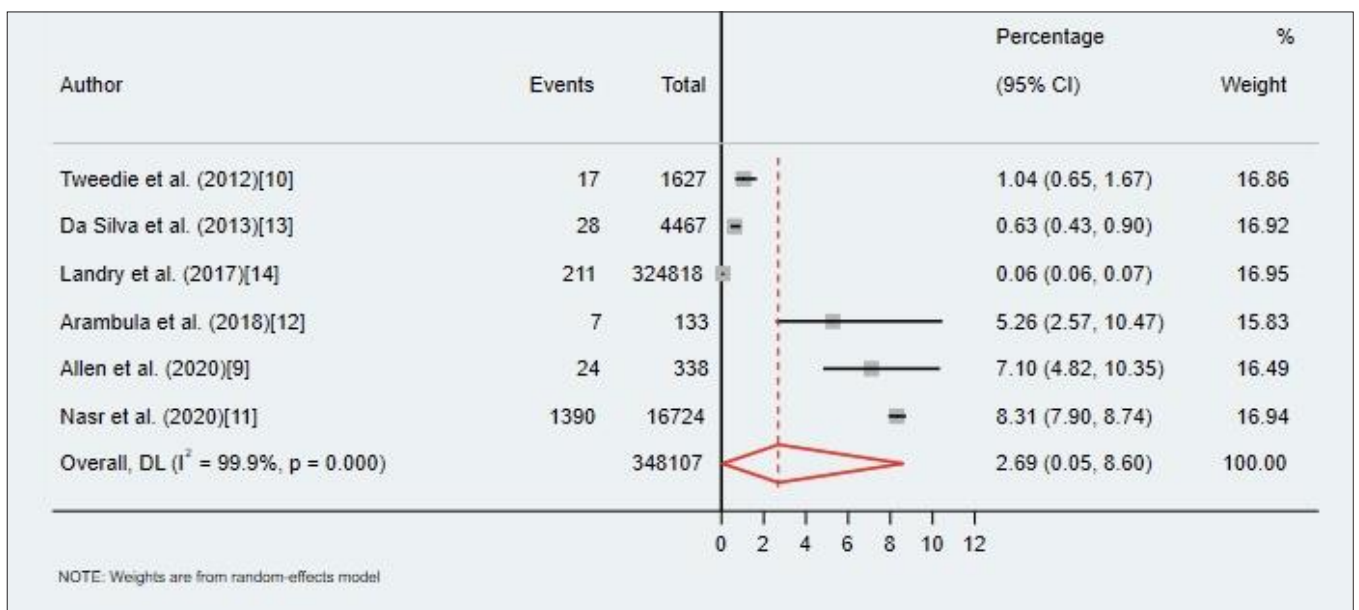

Fig. 1. PRISMA data collection.

Fig. 2. Prevalence of unplanned ICU admissions.

Table 3. Characteristics of included studies

Author (year of publication)	Country	Study design	Total number of patients in study	Unplanned ICU group (n)	Number of sites	Selection bias	Surgery type
Tweedie et al. (2012)[10]	UK	Retrospective cohort	1 627	17	Single centre	Y	Adenotonsillectomy
Da Silva et al. (2013)[13]	Brazil	Case-control	4 467	28	Single centre	Y: patients with TBI excluded	No exclusions
Landry et al. (2017)[14]	USA	Retrospective cohort	324 818	211	Multicentre	N	No exclusions
Arambula et al. (2018)[12]	USA	Retrospective cohort	133	7	Single centre	Y: Patients with known OSA or sleep disordered breathing	Adenotonsillectomy
McHenry et al. (2019)[8]	USA	Retrospective cohort	460	158	Single centre	Y: Trauma and weekend admissions not included	Urology, cardiac and orthopaedic procedures excluded
Allen et al. (2020)[9]	USA	Retrospective cohort	338	24	Single centre	Y: Patients with known OSA or sleep disordered breathing	Adenotonsillectomy
Nasr et al. (2020)[11]	Canada	Retrospective cohort	16 724	1 390	Single centre	N	Most non-cardiac surgery (tonsillectomy, strabismus surgery excluded)

ICU = intensive care unit; USA = United States of America; UK = United Kingdom; OSA = obstructive sleep apnoea; TBI = traumatic brain injury; Y = Yes; N = No.

Anaesthetic factors and other outcomes

General anaesthesia,[13,14] and weekday and night-shift cases,[14] were more likely to have unplanned ICU admissions. Cases performed by an attending anaesthesiologist were more likely to be admitted to ICU unplanned.[14] One paper found that most of the unplanned ICU admissions resulting from an anaesthetic cause were inevitable based on the presenting medical condition, but these factors were not reported on specifically.[13]

Surgical factors

Two studies found that general paediatric surgery including abdominal surgery, and ear, nose and throat (ENT) surgery, resulted in a higher risk of unplanned ICU admission.[8,13] Emergency surgery was almost three times more likely to result in unplanned ICU admission.[13] Events which resulted in unplanned ICU admission were found to be predictable and preventable and included issues related to endotracheal tube care and inappropriate intravenous fluid administration.[13] An ISR quartile of three or four was found to be significant and included in a morbidity score validated by Nasr et al.[11]

Two studies demonstrated that patients in the unplanned ICU group required mechanical ventilation and spent a longer time on oxygen compared with the planned ICU group.[12,13] Cases longer than 60 minutes, and those involving the head, upper abdomen and radiological procedures were significant risk factors in this group.[14]

Discussion

In the present study, the prevalence of unplanned ICU admission was 2.69%. Risk factors associated with unplanned ICU stay were found to be patient, surgical and anaesthetic related. Significant patient, surgical and anaesthetic risk factors associated with unplanned ICU admission reflect similar risk factors of perioperative respiratory adverse events and postoperative respiratory complications.[15,16]

During adenotonsillectomy surgery, patient-related risk factors included preoperative sleep studies, which demonstrated the presence of obstructive sleep apnoea (OSA) and sleep-disordered breathing.[9] This would be expected as this is one of the primary reasons why patients present for surgery. Compared with planned ICU admissions, the unplanned ICU group had lower preoperative apnoea-hypopnoea indices (AHIs): again, a reflection that patients with a higher severity will be planned to be transferred to ICU directly postoperatively for monitoring or support. Also specific to adenotonsillectomy surgery was the finding that cerebral palsy and mucopolysaccharidoses increased the risk of ICU admission.[10] What is notable about these diseases is their chronic nature, the involvement of multiple systems and the possibility of airway difficulty, suggesting that in these cases ICU admission could potentially have been predicted.

A longer time in the PACU post tonsillectomy, mostly owing to desaturation and requiring supplemental oxygen, was found to be significant and would indicate the potential need for an escalated level of care.[12] This finding may also direct consideration toward introducing more high-care units which carry less of a resource burden than an ICU bed. At-risk patients who only require closer monitoring and simple therapies rather than invasive organ support could be managed in this setting for a certain period of time and would obviate the need for ICU care.[17]

Patients who required unplanned ICU admission postoperatively were found to need respiratory support in the form of supplemental oxygen or mechanical ventilation.[12,13] This is in keeping with the fact that the reason for ICU admission was commonly respiratory related. Length of stay in hospital and duration of mechanical ventilation or oxygen requirement was longer even when compared with the planned ICU groups.[12,13] Only

Table 4. Risk factors associated with unplanned ICU admissions

Author	Parameter	N (%)/median (IQR)/means ± SD		UOR (95% CI)	p-value
		Unplanned ICU	Other		
Adenotonsillectomy surgery					
Tweedie et al.[10]					
	Cerebral palsy	3 (18)	50 (3)	6.6 (1.8- 23.6)	0.02
	MPS	2 (12)	20 (1)	10.4 (2.2 - 48.7)	0.02
Arambula et al.[12]					
	Number of comorbidities	2.1±1.4	0.9±1.1	-	0.01
	Pre-operative AHI	6.1±4.8	19.4±17.5	-	0.06
	Total PACU time on O_2 (min)	176.2±133.5	43.0±57.5	-	<0.00
	Total PACU time on O_2 (%)	76.8±38.6	30.1±29.3	-	0.00
	Total PACU time (min)	225.3±121.3	144.5±119.9	-	0.09
	Length of hospital admission (days)	4.7±2.8	1.3± 1.4	-	<0.00
	Days requiring supplemental O_2	3.5±2.7	1.2±1.9	-	0.01
	% days requiring O_2	63.1±34.7	32.9±29.4	-	0.03
Allen et al.[9]					
	OSA	12 (50)	46 (29)	2.4 (1 - 5.7)	0.05
	Sleep study	12 (50)	46 (29)	2.4 (1 - 5.7)	0.05
	Hypopneas	38 (40)	7 (21)	-	0.01
	RDI	12 (16)	6 (5)	-	0.03
	AHI	7 (18)	2 (3)	-	0.01
	Respiratory support	21 (88)	12 (8)	84 (21.9 - 322.6)	<0.00
	Complications	15 (63)	12 (8)	20 (7.3 - 55.2)	<0.00
Other surgery					
Patient factors					
Da Silva et al.[13]					
	Respiratory tract/airway abnormality	8 (29)	6 (7)	5.5 (1.7 - 17.5)	0.01
Landry et al.[14]					
	Age: under 1 year/13 - 18 years	71 (0.1)	52 (0.1)	2.3 (1.6 - 3.2)	<0.00
	ASA PS class: III/I - II	82 (0.2)	113 (0)	4.4 (3.3 - 5.8)	<0.00
	ASA PS class: IV/I - II	16 (0.2)	113 (0)	4.0 (2.4 - 6.8)	<0.00
McHenry et al.[8]					
	PELOD score	10 (0 - 11)	1 (0 - 10)	-	<0.01
	Presence of disability (VPSDis)	-	-	3.7	0.01
Nasr et al.[11]	RAMPS score*				
Anaesthetic factors					
Da Silva et al.[13]					
	General anaesthetic	27 (96)	64 (73)	10.1 (1.3 - 78.7)	0.02
	SaO_2<90% at any time	10 (36)	8 (9)	5.6 (1.9 - 16.1)	0.00
	VCCAMM 1 - 3	24 (86)	24 (27)	16 (5.0 - 50.9)	<0.00
	VCCAMM 4 - 5	17 (61)	19 (22)	5.6 (2.3 - 14.0)	0.00
	Predictable adverse events	10 (36)	13 (15)	3.2 (1.2 - 8.5)	0.03
	Preventable adverse events	8 (29)	8 (9)	4 (1.3 - 12.0)	0.02
	Mechanical vent + haemodynamic instability	9 (32)	10 (11)	3.7 (1.3 - 10.4)	0.02
	Length of mechanical vent (days)	4.5 (3.8 - 9.5)	2 (0.8 - 5)	-	0.01
Landry et al.[14]					
	Other anaesthetic/general anaesthetic	22 (0)	189 (0.1)	0.5 (0.3 - 0.7)	<0.00
	Attending anaesthetist present/not present	79 (0)	132 (0.1)	0.4 (0.2 - 0.8)	0.01
	Weekend cases/weekday cases	14 (0)	197 (0.1)	0.5 (0.3 -0.9)	0.03
	After hours shift/day shift	106 (0.1)	105 (0.1)	2.4 (1.8 - 3.1)	<0.00
McHenry et al.[8]					
	PIM-2 score	0.4 (0.2 - 1.1)	0.14 (0.1 - 0.2)	-	<0.01
Surgical risk factors					
Da Silva et al.[13]					
	Abdominal procedure	15 (54)	27 (31)	2.6 (1.1 - 6.2)	0.05
	Emergency surgery	12 (43)	18 (20)	2.9 (1.2 - 7.3)	0.03
Landry et al.[14]					
	Case duration: 61 - 180 min/<60 min	73 (0.1)	17 (0)	3.9 (3.3 - 5.8)	<0.00
	Case duration: >180 min/<60 min	30 (0.1)	17 (0)	7.4 (4.1 - 13.4)	<0.00
McHenry et al.[8]					
	ENT	-	-	1.2	<0.00
	General paediatric surgery	-	-	2.2	<0.00

ICU = intensive care unit; OSA = obstructive sleep apnoea; CI = confidence interval; IQR = interquartile range; SD = standard deviation; UOR = unadjusted odds ratio; RDI = respiratory disturbance index; AHI = apnoea-hypopnoea index; MPS = mucopolysaccharidosis; ASA PS = American Society of Anaesthesiologists physical status; PELOD = paediatric logistic organ dysfunction; VPSDis = virtual PICU systems disability score; RAMPS = risk assessment of morbidity in paediatric surgery; min = minutes; PACU = post-anaesthetic care unit; vent = ventilation; VCCAMM = Victorian Consultative Council on Anaesthetic Mortality and Morbidity; PIM-2 = paediatric index of mortality score-2; ENT = ear, nose and throat.
*RAMPS score with area under the curve (AUC = 0.797; 95% CI 0.786 - 0.808).

two studies reported mortality outcomes.[10,13] No deaths occurred in the unplanned ICU groups.

In both the general surgery and adenotonsillectomy-specific studies, risk factors for unplanned ICU admission included the presence of significant comorbidity or disability[8,12,14] and, in the general surgical group, younger age.[11,14] Nasr *et al*.[11] encompassed these factors in a small, single-centre study and validated a composite morbidity score: risk assessment of morbidity in paediatric surgery (RAMPS). This score included the presence of age less than five, critical illness, and high CCI scores. These components, along with an ISR of three or four, demonstrated good discrimination to predict unplanned ICU admission, but it is prudent to note that the CCI was not specifically designed for children[18] and an adapted version was used in this study, resulting in one of its limitations.

In the general surgery studies, an association between risk scores and unplanned ICU admissions was found, with a higher paediatric index of mortality 2 (PIM-2) score, paediatric logistic organ dysfunction (PELOD) score, and American Society of Anaesthesiologists (ASA) status (III - IV) having a strong association.[8,14] Although a higher ASA status by definition suggests organ dysfunction and functional limitation, this tool may be less reliable in paediatrics.[19] The PIM-2 and PELOD scores are used in the ICU setting to indicate disease severity and predict mortality.[20] While an association was found between these scores and unplanned ICU admissions, they would not be suitable in formulating a risk-prediction model for unplanned ICU admissions owing to their retrospective application.

Postoperative pulmonary complications have been well described and defined in adults, but this is lacking in the paediatric population.[16] Risk scores in adults highlight the strong association between upper abdominal surgery and a higher risk of postoperative pulmonary complications.[21] Abdominal procedures alone can cause fluid and blood loss, electrolyte disturbances which may have been present preoperatively, hypothermia and postoperative respiratory complications.[22] Poorly managed pain, which is not an uncommon occurrence in paediatrics,[23] can also result in splinting and worsen postoperative respiratory function. Da Silva *et al*.[13] found that inappropriate fluid management in the emergency abdominal procedures was one of the reasons for a preventable event. An increased length of surgery of more than 60 minutes was found to be significant, and can relate to technical difficulties of the surgery itself, and the required increased complexity of the anaesthetic.[14]

Another surgical factor increasing risk of unplanned ICU admission was ENT surgery.[8,14] The fact that three of the seven studies included in our review were conducted on children undergoing adenotonsillectomy surgery only, reflects the high-risk nature of this group. In these studies, most patients who required ICU postoperatively were planned.[9,10,12] This is not unsurprising, as patients who present for this type of surgery may already require planned ICU care postoperatively[24] based on the associated issues of existing comorbidities and the pathophysiological effects of chronic upper airway obstruction.[25] One of the most frequent complications post adenotonsillectomy surgery is respiratory compromise[26] and carries the highest incidence of laryngospasm alone. Together with the possibility of recent or current respiratory tract infections, the concerns of a shared airway, the danger of postoperative bleeding, and the chronic effects of their pathology make children presenting for this type of surgery a vulnerable group.[27] These patients may also present with recent respiratory tract infections, thus increasing their risk.[27]

General anaesthesia compared with monitored anaesthesia care, and neuraxial or regional anaesthesia, carried a higher risk of unplanned admissions.[13,14] Perioperative respiratory events are higher under general anaesthesia,[15] and can be due to the effects of airway manipulation, invasive ventilation, atelectasis and the effects of neuromuscular blocking agents and opioids on the respiratory system. Intraoperative hypoxia was also found to be a significant contributor to unplanned ICU admission.[13] This is a reflection of respiratory events ranging from simple atelectasis to more serious issues such as broncho- or laryngospasm, pulmonary oedema and aspiration. Causes of hypoxia were bronchoaspiration, pulmonary oedema, respiratory depression, difficult intubation, accidental extubation and endotracheal tube obstruction.[13]

Radiological procedures were also important risk factors for unplanned ICU admissions, specifically magnetic resonance imaging (MRI) of the brain.[14] Patients presenting for MRI may have significant pathology or systemic disease warranting the need for special investigation (e.g. tumours, cerebral palsy, uncontrolled seizures)[28] and, coupled with the added difficulty of practice in a remote anaesthesia setting, this may lead to unanticipated complications. These patients are often treated on an outpatient basis.

Unanticipated ICU admissions were also higher on weekdays as opposed to weekends.[14] This could be explained by the fact that elective surgery and complicated cases usually occur in the week, when specialist expertise is readily available. It may also be due to the fact that children presenting for emergency cases would be physiologically unwell and ICU would have been pre-empted; the volume of cases over the weekend would also be expected to be much lower than during the week, as noted by Landry *et al*.[14] Unplanned ICU admissions after hours can cause significant strain on systems running on fewer staff, and will result in adverse resource consequences from the increased financial cost. This finding of higher unplanned ICU admissions on weekdays may be vastly different in low- and middle-income countries where the pressure of emergencies is greater due to the burden of injuries [29] and delayed presentation of disease.[30]

Landry *et al*.[14] also examined a range of facility types in all regions of the USA, and were able to make resource comparisons. Cases in the Midwest carried an increased risk of unplanned ICU admissions: the possible explanation was that they are more resource conservative regarding the use of ICU.[14] If this is the case, it can be extrapolated that unplanned ICU admissions may be increased in countries where resources are constrained, as observed in the study by Da Silva *et al*.,[13] and ICU bed availability is limited, thus leading to procedures being performed without a confirmed ICU booking. However, more research is required in this area.

The ICU, as a scarce resource in all countries, requires judicious management.[5] Needless admission and overuse of beds post surgery can result in the unnecessary use of sedation or restraints, invasive procedures, exposure to resistant organisms as well as sleep disruption and parental separation causing added patient anxiety.[31] These consequences need to be weighed against the under-triage of patients who risk substantial morbidity and mortality from a reduced level of care postoperatively. Decision making around ICU bed requirement is a complex interplay of multiple considerations.[32] Some of these include patient factors, bed availability in light of emergency admissions, and the repercussions of surgery postponement where there is substantial pressure of surgical backlogs: this especially in the era of the COVID-19 pandemic.[33] The parties involved around decision making were not

mentioned in the studies included in this review, but it should be a multidisciplinary discussion among anaesthetists, surgeons and intensivists to maximise the strength of the verdict.

Numerous scoring systems have been created and adapted over the years,[34,35] with the aim of assisting practice through perioperative risk stratification. While risk scores have been developed to predict paediatric mortality[36] and increased perioperative risk,[37] no formal model exists to anticipate the specific need of critical care services in the postoperative period. Nasr *et al.*[11] have started addressing this need by validating a score to predict postoperative morbidity of which part of the outcomes include unplanned ICU admission. While there is not enough evidence from this systematic review to establish a scoring system for escalated care in paediatric surgical patients, knowledge of the identified risk factors can nevertheless guide decision making in the perioperative period. Rather than using the risk factors of unplanned ICU admissions individually, a combination of these factors may direct planning toward anticipation of the need for a higher level of postoperative care. Future research into this topic will also be assisted through efficient data collection based on these factors.

Study limitations

Our systematic review had some limitations. Owing to the paucity of papers found and the heterogeneity of the data, we could not proceed to a meta-analysis. The final articles included for review were all retrospective and had vastly varying methodologies. The studies had diverse selection criteria of cohorts and comparisons, differing definitions of an unplanned ICU admission, and different data extracted as considered relevant. This made it difficult to make suitable comparisons and broad conclusions for this research question. While some studies were large[14] and of good-quality data and analysis,[8-11] it was difficult to fully extrapolate the findings to a global context, given that influences of varying healthcare settings may affect findings very differently.

Conclusion

Identifying the risk factors associated with unplanned ICU admissions has given us more insight into which patients will require more attention, preparation and advanced care. While at-risk patients should not be overlooked, unnecessary admission to an ICU can also be harmful[31] and is a poor use of a scarce resource, and the two ends of the spectrum need to be balanced. In countries where patient load is high and where resources do not meet this demand, theatre efficiency is always optimised by better planning. While the present review has outlined significant patient, surgical and anaesthetic risk factors associated with unplanned ICU admission in children, further studies will be required to afford development of a risk stratification tool in the future.

1. Haller G, Myles PS, Langley M, Stoelwinder J, McNeil J. Assessment of an unplanned admission to the intensive care unit as a global safety indicator in surgical patients. Anaesth Intensive Care 2008;36(2):190-200. https://doi.org/10.1177/0310057x0803600209
2. Onwochei DN, Fabes J, Walker D, Kumar G, Moonesinghe SR. Critical care after major surgery: A systematic review of risk factors for unplanned admission. Anaesthesia 2020;75 Suppl 1:e62-e74. https://doi.org/10.1111/anae.14793
3. Malycha J, Bonnici T, Clifton DA, Ludbrook G, Young JD, Watkinson PJ. Patient centred variables with univariate associations with unplanned ICU admission: A systematic review. BMC Med Inform Decis Mak 2019;19(1):98. https://doi.org/10.1186/s12911-019-0820-1
4. Vlayen A, Verelst S, Bekkering GE, Schrooten W, Hellings J, Claes N. Exploring unplanned ICU admissions: A systematic review. JBI Libr Syst Rev 2011;9(25):925-959. https://doi.org/10.11124/jbisrir-2011-147
5. Abu Al-Saad N, Skedgel C, Nortje J. Principles of resource allocation in critical care. BJA Educ 2017;17(12):390-395. https://doi.org/10.1093/bjaed/mkx029
6. Murthy S, Leligdowicz A, Adhikari NKJ. Intensive care unit capacity in low-income countries: A systematic review. PLOS ONE 2015;10(1):e0116949-e. https://doi.org/10.1371/journal.pone.0116949
7. Moher D, Liberati A, Tetzlaff J, Altman DG, Group P. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. Int J Surg 2010;8(5):336-341. https://doi.org/10.1016/j.ijsu.2010.02.007
8. McHenry A, Forbes M, Brown M. Patient characteristics and prevalence of unplanned postoperative pediatric intensive care unit admissions. J Pediatr Surg Nurs 2017;6(3):58-67. https://doi.org/10.1097/jps.0000000000000141
9. Allen DZ, Worobetz N, Lukens J, et al. Outcomes intensive care unit placement following pediatric adenotonsillectomy. Int J Pediatr Otorhinolaryngol 2020;129:109736. https://doi.org/10.1016/j.ijporl.2019.109736
10. Tweedie DJ, Bajaj Y, Ifeacho SN, et al. Peri-operative complications after adenotonsillectomy in a UK pediatric tertiary referral centre. Int J Pediatr Otorhinolaryngol 2012;76(6):809-815. https://doi.org/10.1016/j.ijporl.2012.02.048
11. Nasr VG, Valencia E, Staffa SJ, et al. Comprehensive risk assessment of morbidity in pediatric patients undergoing noncardiac surgery: An institutional experience. Anesth Analg 2020;131(5):1607-1615. https://doi.org/10.1213/ane.0000000000005157
12. Arambula AM, Xie DX, Whigham AS. Respiratory events after adenotonsillectomy requiring escalated admission status in children with obstructive sleep apnea. Int J Pediatr Otorhinolaryngol 2018;107:31-36. https://doi.org/10.1016/j.ijporl.2018.01.009
13. Da Silva PS, de Aguiar VE, Fonseca MC. Risk factors and outcomes of unplanned PICU postoperative admissions: A nested case-control study. Pediatr Crit Care Med 2013;14(4):420-428. https://doi.org/10.1097/pcc.0b013e3182720fab
14. Landry EK, Gabriel RA, Beutler S, Dutton RP, Urman RD. Analysis of unplanned intensive care unit admissions in postoperative pediatric patients. J Intensive Care Med 2017;32(3):204-211. https://doi.org/10.1177/0885066616661152
15. Habre W, Disma N, Virag K, et al. Incidence of severe critical events in paediatric anaesthesia (APRICOT): A prospective multicentre observational study in 261 hospitals in Europe. Lancet Respir Med 2017;5(5):412-425. https://doi.org/10.1016/s2213-2600(17)30116-9
16. Egbuta C, Mason KP. Recognizing risks and optimizing perioperative care to reduce respiratory complications in the pediatric patient. J Clin Med 2020;9(6):1942. https://doi.org/10.3390/jcm9061942
17. Lavin JM, Sawardekar A, Sohn L, et al. Efficient postoperative disposition selection in pediatric otolaryngology patients: A novel approach. Laryngoscope 2021;131(S1):S1-S10. https://doi.org/10.1002/lary.28760
18. Berry JG, Ash AS, Cohen E, Hasan F, Feudtner C, Hall M. Contributions of children with multiple chronic conditions to pediatric hospitalisations in the United States: A retrospective cohort analysis. Hosp Pediatr 2017;7(7):365-372. https://doi.org/10.1542/hpeds.2016-0179
19. Mayhew D, Mendonca V, Murthy BVS. A review of ASA physical status - historical perspectives and modern developments. Anaesthesia 2019;74(3):373-379. https://doi.org/10.1111/anae.14569
20. Leteurtre S, Duhamel A, Salleron J, Grandbastien B, Lacroix J, Leclerc F. PELOD-2: An update of the pediatric logistic organ dysfunction score. Crit Care Med 2013;41(7):1761-1773. https://doi.org/10.1097/ccm.0b013e31828a2bbd
21. Miskovic A, Lumb AB. Postoperative pulmonary complications. Br J Anaesth 2017;118(3):317-334. https://doi.org/10.1093/bja/aex002
22. Sun LS, Saraiya NR, Houck PJ. Anesthesia for abdominal surgery. In: Gregory GA, Andropoulos DB, editors. Gregory's Pediatric Anesthesia. 5th ed. Hoboken: Wiley-Blackwell; 2012. ch28. 720-739. https://doi.org/10.1002/9781444345186
23. Taylor EM, Boyer K, Campbell FA. Pain in hospitalised children: a prospective cross-sectional survey of pain prevalence, intensity, assessment and management in a Canadian pediatric teaching hospital. Pain Res Manag 2008;13(1):25-32. https://doi.org/10.1155/2008/478102
24. Walker P, Whitehead B, Rowley M. Criteria for elective admission to the paediatric intensive care unit following adenotonsillectomy for severe obstructive sleep apnoea. 2004;32(1):43-46. https://doi.org/10.1177/0310057x0403200107
25. Tatlipinar A, Duman D, Uslu C, Egeli E. The effects of obstructive sleep apnea syndrome due to adenotonsillar hypertrophy on the cardiovascular system in children. Turk J Pediatr 2011;53(4):359-363. PMID: 21980836
26. De Luca Canto G, Pachêco-Pereira C, Aydinoz S, et al. Adenotonsillectomy complications: A meta-analysis. J Pediatr 2015;136(4):702-718. https://doi.org/10.1542/peds.2015-1283
27. Bangera A. Anaesthesia for adenotonsillectomy: An update. Indian J Anaesth 2017;61(2):103-109. https://doi.org/10.4103/0019-5049.199855
28. Miller MGA. Anaesthesia for MRI:….child's play? S Afr J Anaesth Analg 2005;11(1):28-31. https://doi.org/10.1080/22201173.2005.10872390
29. Nantulya VM, Reich MR. Equity dimensions of road traffic injuries in low- and middle-income countries. Inj Control Saf Promot 2003;10(1-2):13-20. https://doi.org/10.1076/icsp.10.1.13.14116
30. Patel N, Naidoo P, Candy G, Kruger C. Surgical infections at a regional hospital in Gauteng: Reasons for delay to care and profile of pathology. S Afr J Surg 2019;57:30-36. https://doi.org/10.17159/2078-5151/2018/v56n4a2681
31. Rennick JE, Dougherty G, Chambers C, et al. Children's psychological and behavioral responses following pediatric intensive care unit hospitalisation: The caring intensively study. BMC Pediatr 2014;14(1):276. https://doi.org/10.1186/1471-2431-14-276
32. Gopalan PD, Pershad S. Decision-making in ICU – a systematic review of factors considered important by ICU clinician decision makers with regard to ICU triage decisions. J Crit Care 2019;50:99-110. https://doi.org/10.1016/j.jcrc.2018.11.027
33. Chu KM, Marco J, Bougard H, et al. Estimating the surgical backlog from the COVID-19 lockdown in South Africa: A retrospective analysis of six government hospitals. S Afr Med J 2021;111(7):685-688. http://doi.org/10.7196/SAMJ.2021.v111i7.15686
34. Stones J, Yates D. Clinical risk assessment tools in anaesthesia. BJA Educ 2019;19(2):47-53. https://doi.org/10.1016/j.bjae.2018.09.009
35. Ji D, Goudy SL, Raval MV, Raol N. Pediatric surgical risk assessment tools: Systematic Review. J Surg Res 2019;234:277-282. https://doi.org/10.1016/j.jss.2018.09.051
36. Nasr VG, DiNardo JA, Faraoni D. Development of a pediatric risk assessment score to predict perioperative mortality in children undergoing noncardiac surgery. Anesth Analg 2017;124(5):1514-1519. https://doi.org/10.1213/ane.0000000000001541
37. Malviya S, Voepel-Lewis T, Chiravuri SD, et al. Does an objective system-based approach improve assessment of perioperative risk in children? A preliminary evaluation of the 'NARCO'. Br J Anaesth 2011;106(3):352-358. https://doi.org/10.1093/bja/aeq398