

BMJ Open Risk factors associated with paediatric unplanned hospital readmissions: a systematic review

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ABSTRACT

Objective To synthesise evidence on risk factors associated with paediatric unplanned hospital readmissions (UHRs).

Design Systematic review.

Data source CINAHL, EMBASE (Ovid) and MEDLINE from 2000 to 2017.

Eligibility criteria Studies published in English with full-text access and focused on paediatric All-cause, Surgical procedure and General medical condition related UHRs were included.

Data extraction and synthesis Characteristics of the included studies, examined variables and the statistically significant risk factors were extracted. Two reviewers independently assessed study quality based on six domains of potential bias. Pooling of extracted risk factors was not permitted due to heterogeneity of the included studies. Data were synthesised using content analysis and presented in narrative form.

Results Thirty-six significant risk factors were extracted from the 44 included studies and presented under three health condition groupings. For All-cause UHRs, ethnicity, comorbidity and type of health insurance were the most frequently cited factors. For Surgical procedure related UHRs, specific surgical procedures, comorbidity, length of stay (LOS), age, the American Society of Anaesthesiologists class, postoperative complications, duration of procedure, type of health insurance and illness severity were cited more frequently. The four most cited risk factors associated with General medical condition related UHRs were comorbidity, age, health service usage prior to the index admission and LOS.

Conclusions This systematic review acknowledges the complexity of readmission risk prediction in paediatric populations. This review identified four risk factors across all three health condition groupings, namely comorbidity; public health insurance; longer LOS and patients <12 months or between 13–18 years. The identification of risk factors, however, depended on the variables examined by each of the included studies. Consideration should be taken into account when generalising reported risk factors to other institutions. This review highlights the need to develop a standardised set of measures to capture key hospital discharge variables that predict unplanned readmission among paediatric patients.

INTRODUCTION

Unplanned hospital readmission (UHR) rate has been recognised as a key performance indicator for measuring the quality of care in paediatric healthcare services.¹ Hospital

Strengths and limitations of this study

- This is the first systematic review of the literature from 2000 to 2017 on risk factors associated with paediatric unplanned hospital readmissions.
- The rigorous methodology applied to this systematic review used a comprehensive electronic databases search strategy, strict inclusion, exclusion and quality assessment criteria to synthesise characteristics of the included studies, examined variables and the statistically significant risk factors.
- Pooling of extracted significant risk factors was not possible because the included studies were not homogeneous due to the different diagnoses, examined variables and follow-up time frames to identify readmissions. Therefore, data extracted from the included studies were synthesised using content analysis and presented in narrative form.

readmission is defined as subsequent admissions within a specified period after the initial/index hospitalisation.^{2–3} Paediatric UHRs rates range from 3.4% to 28.6% and cost healthcare systems such as UK, USA and Canada up to \$1 billion per annum.^{4–9}

Identification of risk factors associated with UHRs is increasingly being examined as a strategy to assist in reducing these rates. A systematic review¹⁰ conducted in 2011, identified 26 risk predictive models from 30 examined studies focused on adult general medical condition related UHRs. Readmission length of time measures used ranged from 30 days to 12 months. Overall, the performance of the 26 models was poor. The most commonly identified risk factors were *medical comorbidity* and *use of medical services before the index admission*. In a 2016 systematic review,¹¹ limited to 28-day or 30-day readmissions and focused on adult health conditions, a total of 60 studies and 73 risk predictive models with inconsistent performance was noted. The predictive models focusing on general medical conditions showed moderate discriminative ability. Risk factors cited most frequently for all UHRs were *comorbidities*, *length of stay (LOS)*

and *previous hospital admissions*. For condition-specific readmissions, such as cardiovascular and general medical diseases *laboratory tests* and *medication* were more associated with readmissions.¹¹

There is only one review¹² within the paediatric literature examining UHRs. This review focused on asthma-related UHRs and included 29 studies. Five significant predictive factors, including *age <5 years old or adolescent*; *being African American*; *public or no insurers*; *previous hospitalisations prior to the index admission*; *underlying chronic complex conditions* were identified. To date, there is no published review paper on risk factors associated with UHRs for general paediatric patients. This paper aimed to systematically review the current literature on risk factors of paediatric All-cause, Surgical procedure and General medical condition related UHRs. The objectives were to assess characteristics of included studies and to synthesise the identified risk factors.

METHODS

A systematic review was performed and reported according to the 2009 PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) Statement.¹³

Data sources and search strategy

An electronic database search was carried out using the CINAHL, EMBASE(Ovid), MEDLINE to identify studies published from 2000 to 2017. The key search terms included ('Readmission' or rehospitali* or readmission* or readmit* or re-admission*) AND (child* or infant* or toddler* or bab* or newborn* or neonat* or school age* or preschool or paediatric* or pediatric* or kid* or boy* or girl*) OR (adolescen* or teen* or youth or juvenile* or young person* or young people*) (see online supplementary appendix for full search strategy).

Inclusion/exclusion criteria

Articles eligible for inclusion were those published in English with full-text access. The focus of the included studies was paediatric patients with UHRs. Eligible studies were published in peer-reviewed journals with details of study design clearly stated and reported statistical analysis procedure/s. Abstract only references were excluded. Studies that included patients discharged from rehabilitation health services but readmitted to acute hospitals were excluded from this systematic review as it only focused on hospital readmission following discharge from acute healthcare services. Newborn or preterm newborn studies related UHRs were excluded as the index admission was the birth hospitalisation. In addition, studies focused on mental health condition related UHRs were also excluded due to the specialised nature of the discipline.

Study selection

After the initial literature searches, two authors independently screened titles, abstracts and appraised full papers against the inclusion and exclusion criteria. The

process of exclusion was relatively straightforward and only a handful of studies warranted discussion between authors, to reach consensus as to whether they met the inclusion criteria. Moreover, the reference list of all identified relevant records were searched for additional studies.

Data extraction

Data were extracted from the 44 included studies. The data extraction comprised study characteristics, examined variables and statistically significant risk factors. Study characteristics included study setting, population, data source, timing of data collection, sample size, study design, model utilisation outcome, readmission rate and statistical analysis test/s used to identify risk factors (table 1). All examined variables or confounding factors and the significant risk factors were extracted into table 2 and detailed information was included in the online supplementary table. Studies were grouped based on the health conditions in both tables. Disagreements between two reviewers about the extracted data were resolved through group discussion.

Quality assessment

Two independent reviewers completed the assessment of study quality. Six domains of potential bias¹⁴ were used to assess the 44 included primary research studies. The six domains are: 1. Study participation: 'Was source population clearly defined?' 2. Study attrition: 'Was completeness of follow-up described and adequate?' 3. Prognostic factor measurement: 'Did prognostic factors measure appropriately?' 4. Outcome measurement: 'Was outcome defined and measured appropriately?' 5. Confounding measurement and account: 'Was confounders defined and measured?' 6. Analysis: 'Was analysis described and appropriate?' The ratings of 'Yes', 'Partly', 'No' or 'Unsure' was given to each domain and then an overall risk of 'low' or 'high' was assigned to each study.

Data synthesis

Pooling of extracted significant risk factors was not possible because the included studies were not homogeneous due to the different diagnoses, examined variables and follow-up time frames to identify readmissions. Therefore, data extracted from the included studies were synthesised using content analysis and presented in narrative form.¹¹

Patient and public involvement

Patients and or public were not involved in this systematic review.

RESULTS

The initial electronic database search produced 11 859 records. After removal of 4145 duplicates, a total of 7714 records remained. Titles and abstracts were then appraised and 7579 records were excluded due to irrelevance. Of the remaining 135 relevant references, a further

Table 1 Characteristics of the 44 included studies

Reference	Medical condition	Outcome measures	Study design	Data source	Sample size	Age	Follow-up period	Proportion readmitted	Data analysis
All-cause related UHRs (8)									
Toomey <i>et al</i> , 2016 ¹⁰ USA	All-cause	30-day Potentially preventable UHRs	Prospective	A freestanding children's hospital interviews and medical records	305 patients	<18 years	December 2012 to February 2013	Overall UHR 6.5%, 29.5% potentially Preventable UHR	Multivariable logistic regression
Willaers <i>et al</i> , 2016 ⁴ UK	All-cause	≤30-day and 31-day to 2-year UHRs	Retrospective	National administrative hospital data	866 221 patients	0–24 years	2009 to 2010	8.8% (30 days) 22.4% (31 days to 2 years)	Multivariable logistic regression
Khan <i>et al</i> , 2015 ⁶⁹ USA	All-cause	30-day UHRs	Retrospective	State inpatient database—177 acute hospitals (12 children's hospital)	701 263 discharges	0–17 years	1 January 2005 to 30 November 2009	4.5% (AHR) 3.8% (SHR) 0.6% (DHR)	Multivariable logistic regression
Auger and Davis, 2015 ⁶⁸ USA	All-cause	30-day UHRs	Retrospective	A tertiary children's hospital Administrative data	55383 hospitalisations/32112 patients	Not specified	2006 to 2012	10.3%	Logistic regression
Coiler <i>et al</i> , 2013 ³ USA	All-cause	30-day UHRs	Retrospective	A tertiary children's hospital Administrative data and Medical records	7794 index discharges/5056 patients	<2 to 18 years	July 2008 to July 2010	18.7%	Logistic regression
Berry <i>et al</i> , 2011 ⁶ USA	All-cause	365-day UHRs	Retrospective	PHIS of 37 children's hospital	317 643 patients/579,504 admissions	0 to >18 years	2003 to 2008	21.8%	χ ² and multivariate analysis
Feudtner <i>et al</i> , 2009 ⁷ USA	All-cause	365-day UHRs	Retrospective	PHIS of 38 children's hospital	186 856 patients	2 to 18 years (Mean=9.2)	2004	16.7%	C-statistics=0.81
Beck <i>et al</i> , 2006 ⁵ Canada	All-cause	30 day UHRs	Retrospective	The Canadian Institute—Discharge Database	506 035 hospitalisations/334 959 children	29 days–8 years	1996 to 2000	3.4%	Multivariate modelling
Surgical conditions related UHRs (20)									
Brown <i>et al</i> , 2017 ⁸¹ USA	General surgical admissions	7-day, 14-day and 30-day UHRs	Retrospective	University HealthSystem Consortium database—258 hospitals	260 042 patients	0–17 years	1 September 2011 to 31 March 2015	2.1% (7 days), 3.1% (14 days) and 4.4% (30 days)	Multivariate logistic regression
Vo <i>et al</i> , 2017 ⁸⁹ USA	All Surgeries	30-day UHRs	Retrospective	National surgical CI programme—Paediatric	182 589 patients	<18 years	2012 to 2014	4.8%	C-statistics=0.747
Richards <i>et al</i> , 2016 ⁸⁰ USA	All Surgeries	30-day UHRs	Retrospective	A children's hospital—Seattle children's hospital enterprise data warehouse	20785 patients with 26978 encounters	0 to ≥18 years	1 October 2008 to 28 July 2014	11.5%	Multivariate logistic regression
Elias <i>et al</i> , 2017 ⁸⁵ USA	Cardiac surgery	1-year UHRs with plural effusion	Retrospective	PHIS database	142 633 admissions	Median=6.4 months (1.1–46.5 months)	1 January 2003 to 30 September 2014	1.1%	Multivariate logistic regression

Continued

Table 1 Continued

Reference	Medical condition	Outcome measures	Study design	Data source	Sample size	Age	Follow-up period	Proportion readmitted	Data analysis
Polites <i>et al</i> , 2017 ⁸⁵ USA	General & Thoracic surgery	30-day UHRs	Retrospective	National surgical QI programme—Paediatric	48 870 patients	Mean=8.1±5.8 years	2012 to 2014	3.6%	C-Statistics=0.710
Yu <i>et al</i> , 2017 ⁸⁰ USA	Tracheostomy	30-day UHRs	Retrospective	An urban tertiary children's hospital—Medical charts	237 patients	<18 years	2005 to 2013	22%	Multivariate logistic regression
Murray <i>et al</i> , 2016 ² USA	ENT surgeries	30-day UHRs	Retrospective	PHIS database	493 507 procedures	0–18 years	1 January 2009 to 31 December 2011	2.3%	Multivariate logistic regression
Roxbury <i>et al</i> , 2015 ⁷¹ USA	Surgical (Otolologic)	30-day UHRs	Retrospective	National NSQIP-P data (50 institutions)	2556 procedures	Only reported as <3 or >3 years	2012	1.3%	Multivariate logistic regression
Roddy and Diab, 2017 ⁸⁷ USA	Spinal fusion	30-day and 90-day UHRs	Retrospective	The state inpatient Database	13 287 patients	<21 years	2006 to 2010/2011	38% (30 days) 33% (90 days)	Multivariate logistic regression
Vedantam <i>et al</i> , 2017 ⁸⁸ USA	Epilepsy surgery	30-day UHRs	Retrospective	2015 NSQIP-P database	208 patients	0–18 years	2015	7.1%	Multivariate logistic regression
Chern <i>et al</i> , 2014 ¹⁴ USA	Shunt surgery	30-day UHRs	Retrospective	1 institution—Administrative and clinical databases	1755 procedures	Mean = 7.15 Years	1 May 2009 to 30 April 2013	16.5%	Multivariate logistic regression
Sarda <i>et al</i> , 2014 ¹⁹ USA	Non-shunt surgery	30-day UHRs	Retrospective	1 institution—Administrative and clinical databases	2924 Index admissions	Mean = 7.17 Years	1 May 2009 to 30 April 2013	10.4%	Multivariate logistic regression
Minhas <i>et al</i> , 2016 ¹¹ USA	Spinal surgeries (Scoliosis)	30-day UHRs	Retrospective	American College of Surgeons NSQIP-Paediatric database	3482 patients	0–18 Years	2012 to 2013	3.4%	C-statistics=0.76–0.769
Buicko <i>et al</i> , 2017 ⁸² USA	Appendectomy (Laparoscopic)	30-day UHRs	Retrospective	The Nationwide Readmission Database	12730	<18 Years	2013	3.4%	Multivariate logistic regression
Cairo <i>et al</i> , 2017 ⁸³ USA	Appendectomy	30-day UHRs	Retrospective	American College of Surgeons NSQIP-Paediatric database	22 771 patients	0–17 Years Mean=11±3.56	2012 to 2015	1.89% ^{same-day discharge} 2.33% ^{2-3 day discharge}	Multivariate logistic regression
Cairo <i>et al</i> , 2017 ⁸⁴ USA	Cholecystectomy (Laparoscopic)	30-day UHRs	Retrospective	The NSQIP-Paediatric database	5046	2–17 Years	2012 to 2015	3.6%	Multivariate logistic regression
Roth <i>et al</i> , 2016 ³ USA	Circumcision	7-day UHRs	Retrospective	PHIS database	95 046 procedures	0–18 Years	2013 to 2014	0.3%	Logistic regression analysis
McNamara <i>et al</i> , 2015 ⁶ USA	Surgical (Urology)	30-day UHRs	Retrospective	National NSQIP-P database (50 institutions)	461 patients	Median=9.4 Years	2012 to 2013	27.8%	logistic regression
Vemulakonda <i>et al</i> , 2015 ⁷⁸ USA	Surgical (Urology)	12-month UHRs	Retrospective	PHIS database Administrative Health-Information data	4499 patients	0–18 years (Median=10 months)	1 January 1999 to 30 September 2009	4.9%	Logistic regression Cox PH

Continued

Table 1 Continued

Reference	Medical condition	Outcome measures	Study design	Data source	Sample size	Age	Follow-up period	Proportion readmitted	Data analysis
Tahiri <i>et al</i> , 2015 ⁷⁵ USA	Plastic surgeries ⁸⁶	30-day UHRs	Retrospective	National surgical QI programme database	5376 patients	Mean = 5.47 years	2012	2.4%	C-statistics=0.784
General medical conditions related UHRs (16)									
Sacks <i>et al</i> , 2017 ⁸¹ USA	Cardiac conditions	30-day UHRs	Retrospective	A large urban tertiary children's hospital—Medical charts	1,124 patients/ 1993 hospitalisations	0–12.9 years	2012 to 2014	20.5%	C-statistics=0.75
Chave <i>et al</i> , 2017 ⁸³ Switzerland	Congenital heart disease	30-day UHRs	Retrospective	A tertiary general hospital—Medical charts	996 patients	<18 years Mean=2.7 years	2002 to 2014	9.6%	Multivariable logistic regression
Mackie <i>et al</i> , 2008 ⁸⁷ Canada	Congenital heart disease	31-day UHRs	Retrospective	All hospitals of Quebec, Canada	3675 hospitalisations	0–17 years	1 April 1990 to 31 March 2005	15%	Cox proportional hazards analysis
Nakamura <i>et al</i> , 2017 ⁸⁹ USA	Lower respiratory infections	30-day UHRs	Retrospective	Medicaid Analytic extract data—26 states	150 590 hospitalisations	<18 years	2008 to 2009	5.5%	A 2-level mixed-effects logistic regression
Veeranki <i>et al</i> , 2017 ⁸⁴ USA	Asthma	30-day UHRs	Retrospective	2013 National Readmission Database—21 states	12 842 Index hospitalisations	6–18 years	2013	2.5%	Cox proportional hazards analysis
Vicendese <i>et al</i> , 2015 ⁶⁵ Australia	Asthma	28-day UHRs	Retrospective and case control	A children's hospital Medical records and Indoor sampling and Survey	Selected 22/96 Patients UHRs vs 22 without UHRs	2–17 years	September 2009 to December 2011	38%	Logistic regression
Neuman <i>et al</i> , 2014 ⁸⁰ USA	Pneumonia	30-day UHRs	Retrospective	PHIS of 45 hospital	82566 patients	0 to >18 years	2008 to 2011	7.7% (All-cause); 1% (Pneumonia-specific)	Multivariate logistic regression
Vicendese <i>et al</i> , 2014 ⁸⁶ Australia	Asthma	28-day and 1-year UHRs	Retrospective	Victorian Admitted Episodes Dataset	53 156 admissions/33 559 patients	2–18 years	1997 to 2009	4.5% vs 19.3%	Logistic regression
Kun <i>et al</i> , 2012 <i>et al</i> ⁸⁶ USA	Chronic respiratory failure	1-year UHRs	Retrospective	A tertiary children's hospital—Medical charts	109 patients	0–21 years	1 January 2003 to 31 October 2009	40%	Generalised estimating equations (GEE)
McNally <i>et al</i> , 2005 ⁹⁸ UK	Preschool viral-wheeze	6-month UHRs	Prospective	Quantitative—Medical records extraction	208 patients 192 patients	15 to 40 months	May to October 1999; November 1999 to April 2000	22% vs 25%	Mann-Whitney U test or χ^2 test
Cohen <i>et al</i> , 2000 ⁹⁴ USA	Asthma	30-day UHRs	Retrospective	Administrative and Billing record data; Medical records	37 patients selected from 700 admissions	0–18 years	12 months	Not reported	Standard algebraic formula
Sobota <i>et al</i> , 2012 ¹⁰³ USA	Sickle cell disease	30-day UHRs	Retrospective	PHIS of 33 children's hospitals	12 104 Hospitalisations/ 4762 patients	<18 years	1 July 2006 to 31 December 2008	17%	Generalised estimating equations (GEE)
Frei-Jones <i>et al</i> , 2009 ⁹⁵ USA	Sickle cell disease	30-day UHRs	Retrospective	A children's hospital	100 admissions	8 months to 21 years	12 months	30%	Multivariate analysis

Continued

Table 1 Continued

Reference	Medical condition	Outcome measures	Study design	Data source	Sample size	Age	Follow-up period	Proportion readmitted	Data analysis
Stone <i>et al</i> , 2008 ⁶² USA	ALL	28-day UHRs	Retrospective	A children's medical centre; Medical records	129 patients	1–19 years	1 January 2001 to 31 May 2005	28%	Multivariate logistic regression
Braddock <i>et al</i> , 2015 ⁶² USA	Complex chronic/ medical	7-day, 30-day and 90-day UHRs	Retrospective	A speciality children's hospital Administrative database+Medical records	1229 patients with 2295 admissions	0 to >18 years (not clearly specified)	2006 to 2011	38%	Logistic regression analysis with GEE
Attard <i>et al</i> , 2017 ⁶¹ UK	Gastrointestinal bleeding	30-day UHRs	Retrospective	PHIS (49 not-for-profit, tertiary children's hospital)	99 902 patients	1–21 years	1 January 2007 to 30 September 2015	9%	Multivariate logistic regression

AHR, all hospitals readmissions; ALL, acute lymphoblastic leukaemia; DHR, Different hospitals readmissions; ENT, ear, nose and throat; GEE, generalised estimating equations; PHIS, Paediatric Health Information Systems; SHR, same hospital readmissions; UHR, unplanned hospital readmission.

22 were excluded as they were conference abstracts only. A total of 113 references were reviewed as full-text and a further 75 were excluded against selection criteria. Four studies were excluded as they were published in Chinese,¹⁵ Korean,¹⁶ Portuguese¹⁷ and Spanish.¹⁸ Studies that mixed paediatric and adult patients^{19–21} or mixed planned and unplanned readmissions²² or mixed Emergency Department presentations and hospital readmissions^{23–25} were excluded. Three studies^{26–28} that included patients initially discharged from rehabilitation health service but then admitted to an acute hospital were excluded. An integrative review¹² on paediatric asthma related UHRs was excluded. As mentioned previously, studies^{29–53} examined newborn/preterm newborn-related UHRs and mental health condition related UHRs^{54–67} were excluded. A hand search reference list of the remaining 38 studies was conducted and six additional studies were identified. Finally, a total of 44 studies were included in this systematic review. Figure 1 is a flowchart as per PRISMA of the screening process of the database search results.

Study quality appraisal

The overall risk of bias of the 44 included studies was low when evaluated against the six domains of potential bias. The studies described the population of interest for key characteristics, the response rate information was clearly stated, an adequate proportion of the study population had complete data for all independent variables, the outcome variable readmission was measured with sufficient accuracy and the method of statistical analysis was appropriate for the design of the study.¹⁴

Characteristics of the included studies

Table 1 displays the characteristics of the final included studies of this systematic review. The 44 studies were conducted in several countries: USA (n=36), UK (n=3), Australia (n=2), Canada (n=2) and Switzerland (n=1). Thirty of the included studies retrieved data from multiple sites and the other 14 accessed single health-care service. A total of 33 included studies examined a combination of health database and medical records and the remaining 11 accessed database only. The included studies are grouped as per health conditions namely (1) All-cause related UHRs (n=8);^{4–8 68–70} (2) surgical procedure related UHRs (n=20),^{71–90} including all surgical admissions (n=3), cardiothoracic surgeries (n=3), ear, nose and throat (ENT) surgeries (n=2), neurosurgeries (n=5), abdominal surgeries (n=3), urological surgeries (n=3) and plastic surgeries (n=1) and (3) General medical condition related UHRs (n=16)^{91–106} including cardiac conditions (n=3), respiratory conditions (n=8), blood disorders (n=3), complex chronic conditions (CCC) (n=1) and gastrointestinal conditions (n=1).

All included studies used retrospective health data except Toomey⁷⁰ who employed a prospective research design including structured interview and reviewing medical records. Of the included studies, outcome measures of length of time from discharge to readmission

Table 2 Thirty-six differing significant risk factors associated with three paediatric health condition groups related UHRs

Health condition group	All-cause (n=8)								Surgical procedures (n=20)								General medical conditions (n=16)																																		
	70	74	68	66	65	6	7	8	81	10	8	33	7	8	5	10	4	15	9	17	13	44	71	82	83	84	73	76	76	78	75	101	83	97	99	104	100	106	96	98	94	103	95	102	92	91					
Reference number	11	2	13	10	7	5	11	7	10	8	33	7	8	5	10	4	15	9	17	13	44	71	82	83	84	73	76	76	78	75	101	83	97	99	104	100	106	96	98	94	103	95	102	92	91						
Examined variables (n=)	11	2	13	10	7	5	11	7	10	8	33	7	8	5	10	4	15	9	17	13	44	71	82	83	84	73	76	76	78	75	101	83	97	99	104	100	106	96	98	94	103	95	102	92	91						
Significant risk factors (n=)	3	1	3	1	5	4	7	3	3	4	7	4	7	4	7	4	7	2	9	1	4	3	5	1	2	1	3	1	5	2	1	6	2	6	1	5	2	0	0	2	3	4	1	3	4						
Age at admission/operation	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
Gender	X																																																		
Race/Ethnicity	X	X	X																																																
Location of residence											X																																								
Health insurance	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
Living environment																																																			
Type of index hospital	X										X																																								
Health service usage prior to index admission								X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
Time since last admission	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Comorbidity	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
Illness severity											X																																								
LOS/Postop LOS											X																																								
Principal diagnoses											X																																								
Principal procedures											X																																								
Inpatient complications											X																																								
Specific medication at index admission											X																																								
Devices at index admission											X																																								
Length of operation											X																																								
Time between scheduled start and actual operation											X																																								
Wound contamination before operation											X																																								
After hour's operations											X																																								
The ASA class											X																																								
Specific laboratory results											X																																								
Discharge on Friday or Weekend											X																																								
Admission on weekends											X																																								
Afterhours discharge											X																																								
Follow-up after discharge											X																																								
Discharge disposition											X																																								
Discharge with special treatment											X																																								
Discharge with increased medication/further treatment											X																																								
Index admission and readmission causally related											X																																								
Hospital contributing factors											X																																								
Patient contributing factors											X																																								

Continued

Table 2 Continued

Health condition group	All-cause (n=8)	Surgical procedures (n=20)	General medical conditions (n=16)
Reference number	70 4 68 66 5 6 7 8 81	59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79	99 100 101 102 103 104 105 106 95 96 97 98 99 100 101 102 103 104 105 106
Hospital service (specialties)		X	
Surgical division		X	
Surgical locations		X	

ASA, the American Society of Anaesthesiologists; UHR, unplanned hospital readmission.

varied from 7 days for CCC,⁹² all surgical admissions,⁸¹ or circumcision⁷³ to 1 year for All-cause,^{6 7} asthma¹⁰⁶ and chronic respiratory failure⁹⁶ related UHRs. Thirty-one of the 44 included studies adopted 28-day or 30-day UHRs measurement. The duration of time for the retrieved data used in the studies ranged from 3 months⁷⁰ to 10 years^{78 106}. The majority of included studies involved patients younger than 18 years. Five studies included patients older than 18 years with either blood disorder disease,¹⁰² CCC,⁴ gastric bleed,⁹¹ spinal fusion⁸⁷ or all surgeries.⁸⁰

Of included studies, the sample size was recorded in various units, such as *Patients, Admissions, Index admissions, Hospitalisations, Index discharges, Discharges* or *Procedures*. The sample size ranged from 100 admissions^{57 63 95} to 866 221 patients.⁴ UHR rates, if reported, varied from <1% following postcircumcision⁷³ to 40% in patients with chronic respiratory failure.⁹⁶

All included studies employed logistic regression or equivalent to analyse the data. Most studies reported OR with 95% CI and the result is considered as statistically significant when the p value is less than 0.05. Six included studies also reported risk predictive model performance. One model⁷ demonstrated high discriminative ability (C-statistic=0.81) for 12-month All-cause UHRs. The other models had moderate discrimination ability to predict 30 day UHRs following cardiac conditions,¹⁰¹ plastic,¹² thoracic surgeries,⁸⁶ scoliosis surgeries,¹³ or all surgical admissions⁸⁹ (C-statistic of 0.75, 0.784, 0.71, 0.769 and 0.74, respectively).

Examined variables/Confounding factors and Significant risk factors

The variables or confounding factors examined varied across the 44 included studies. The number of examined variables of each included study ranging from 24 to 44.⁷¹ Two of the included studies, after applying statistical analysis tests to the examined variables, yielded inconclusive findings.^{96 98} Thirty-six differing but significant risk factors were extracted and presented under the three health condition groupings (All-cause, Surgical procedure and General medical condition).

Risk factors associated with All-cause UHRs

The least number of studies (n=8) in the systematic review related to All-cause UHRs. Risk factors associated with All-cause UHRs and cited more frequently are comorbidity, ethnicity and health insurance. Patients' comorbidity was identified by four studies^{4 6 8 69} with OR ranging from 1.2 to 5.61. Of these, chronic conditions (n=3) was more frequently cited as a risk for readmission. Three studies cited race/ethnicity as a risk factor. Compared with other race/ethnicities, patients of Black race^{6 7} or Asian⁵ had 50% more likelihood of being readmitted. Patients from families with only public health insurance were identified at risk for readmission by three studies (OR=1.31 to 1.48).⁵⁻⁷ One study by Khan 2005,⁶⁹ however, identified patients with private health insurance were 1.14

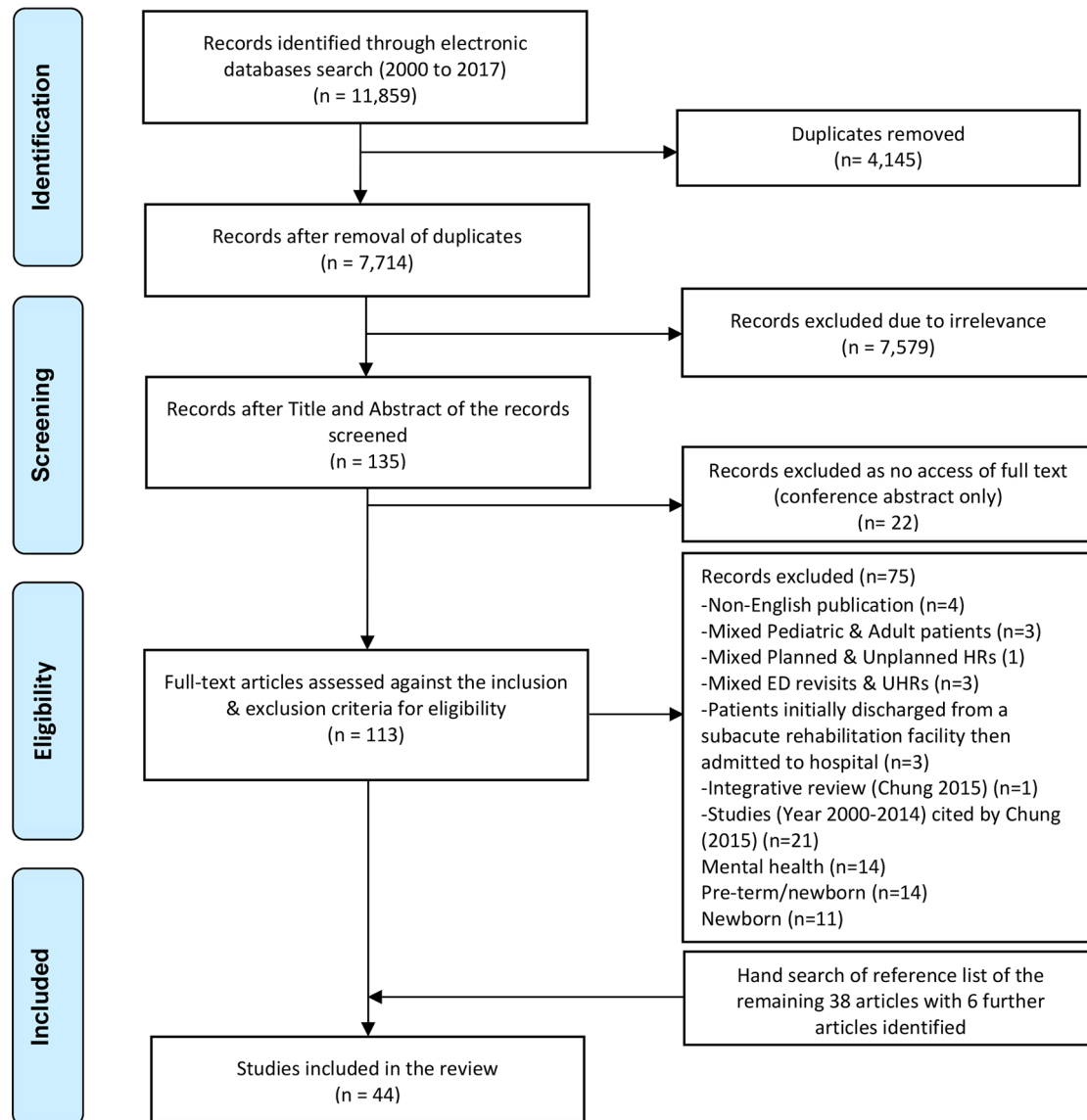


Figure 1 Flowchart for the search and study selection process (PRISMA).

times more likely to be readmitted to a different hospital. Other significant risk factors related to All-cause UHRs are displayed in [table 2](#).

Risk factors associated with surgical procedure related UHRs

The greatest number of risk factors contributing to UHRs were found in the grouping of studies Surgical Procedure. Within the 20 included studies, the most frequently cited risk factors are comorbidity, specific surgeries, LOS, age, the American Society of Anaesthesiologists (ASA) class, development of complications during index admission, duration of surgery, type of health insurance and illness severity. Patients' comorbidity^{71 72 76 82 84-87 89} and specific surgical procedures^{71 72 77 79 81 85-88} were each cited in nine differing studies. The type of comorbidities were not consistent among the studies (OR=1.12 to 10.08).

In general, patients with longer LOS at index admission were found in seven studies to be at greater risk of readmission following surgical procedures (OR=1.01 to 13.96)^{72 79 81 82 86 90} although one study⁸⁷ found shorter

than 3 days of hospitalisation at the index admission was a risk factor for patients who underwent spinal fusion (OR=1.89).

Age at index admission or surgery^{72 77 78 82 85 90} and the ASA class^{71 75 80 83 84 89} were cited in six differing studies. Age, however, was inconsistent across the studies. For example, patients either younger than 1 year⁷⁸ with urological surgeries or older than 13 years⁷² with ENT surgeries were more likely to be readmitted. The ASA class of 3 and above was associated with higher risk of UHRs (OR=1.78 to 7.62). In four studies, patients who developed medical or postoperative complications at the index admission were at risk of readmission with OR ranging from 1.34 to 11.92.^{75 86 87 89}

Public insurance,^{72 73 87} longer operating time,^{75 76 86} and severe health conditions prior to surgeries^{72 79 86} were all cited three times in different studies as increasing the risk of patients UHRs. Other significant risk factors related to surgical procedure related UHRs are displayed in [table 2](#).

Risk factors associated with general medical condition related UHRs

Sixteen studies were reviewed that examined General medical condition related UHRs. Four most frequently cited risk factors are comorbidity, age, health service usage prior to the index admission and LOS. A total of eight studies identified patients' comorbidity as a risk factor (OR=1.1 to 3.61).^{91 94 95 97 99–101 104} The most frequently cited comorbidity was chronic conditions (n=5).

Age of patients at index admission was cited as a risk factor by five studies^{97 100 101 103 104} with OR ranging from 1.1 to 4.11. In particular, patients younger than 1 month^{100 101} or patients between 12 and 18 years^{100 104} were more likely to be readmitted. Three studies^{94 95 100} reported patients with previous hospitalisation prior to the index admission were at higher risk of readmissions (OR=4.7 to 7.3). A further three studies^{91 100 104} cited LOS as a risk factor with OR ranging from 1.13 to 1.56. Patient stays >4 days for Asthma¹⁰⁴ or >7 days for Pneumonia¹⁰⁰ are more likely to be readmitted. Other significant risk factors related to General medical condition related UHRs are displayed in table 2.

DISCUSSION

This systematic review identifies risk factors associated with paediatric UHRs. A total of 44 studies were reviewed and 36 differing significant risk factors were extracted. There are only four consistently cited paediatric readmission risk factors across all included studies, namely comorbidity, public health insurance, longer LOS at the index admission and patients either younger than 12 months or those 13–18 years of age. The results demonstrate a shift in focus from All-cause UHRs to condition specific related UHRs, especially those involving surgical procedures. Overall, the 36 significant risk factors varied among studies focused on condition-specific related readmissions and some risk factors were not reported consistently across studies.

This systematic review has certain limitations. The database search was restricted to English publication only and full-text access was also required to allow comprehensive data extraction. Meta-analysis was not performed on the extracted significant risk factors as the included studies were not homogeneous due to the different diagnoses, examined variables and follow-up time frames to identify readmissions. This systematic review did not establish a definite cut-off age during the literature search although 0–18 years is a widely accepted definition for paediatric patients. Consequently, five included studies had patients in their late teens or young adulthood (19–24 years).^{4 80 87 91 102} The inclusion of late adolescent and young adult under paediatric health services care is consistent with the finding of delayed transitions from paediatric to adult healthcare services.¹⁰⁷ This systematic review did not restrict the follow-up time frame used by studies to identify UHRs, which resulted in data collection spanning 7 days to 21 years. This in turn contributed

to a vast range of paediatric UHRs rates of <1% to >40%. Nineteen included studies in this review investigated 28-day, 30-day or 31-day paediatric UHR rates, ranging from 1.3%⁷⁷ to 38%.^{72 92} The number of predictive models with performance reported for paediatric UHRs (n=6) is very limited compared with the adult population (n=94).^{10 11} This systematic review did not identify any paediatric based studies examining potentially preventable UHRs reported risk prediction model performance. In comparison, there are two developed models^{108 109} with high discriminative ability for adult patients.

CONCLUSION

This systematic review acknowledges the complexity of UHRs risk prediction in paediatric populations. The evidence on the utility of developed predictive models for paediatric UHRs, comparison to adult population literature, is very limited as no existing models have been validated externally. This review identified four consistently cited risk factors associated with paediatric UHRs. These include comorbidity, public health insurance, longer LOS at the index admission and patients either younger than 12 months or 13–18 years old. The identified risk factors depended on what variables were examined in each of the included studies. Therefore, consideration should be taken into account when generalising reported significant risk factors to other institutions.

This review concludes that a focus on the development of potentially preventable/avoidable UHRs risk predictive models for paediatric patients is required as some unplanned readmissions might be unavoidable due to medical complexity.¹¹⁰ Future studies should use a combined approach of administrative and clinical medical data. Also, there is a need to examine if paediatric potentially/avoidable UHRs are associated with patients' social complexity (ie, language proficiency) and comprehensiveness of discharge information (written and verbal communication).

The utmost priority is to develop a standardised set of measures to capture key hospital discharge variables that predict unplanned readmission among paediatric patients. Key challenges include time frame used to measure readmissions, unit of measure on which to record/calculate readmission and variables to be examined. Establishing the most appropriate length of time (being discharge to readmission) to measure UHRs is the first challenge. The second is to standardise the unit of measure that should be used to calculate the readmission rate, while the final challenge is to determine what variables should be extracted and examined to identify risk factors associated with UHRs. Once these challenges have been addressed, a parsimonious predictive model, with high sensitivity and specificity, can be developed for use in all healthcare settings, to identify and implement quality improvement plans for patients with high risk of UHRs.

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