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A Prospective Study of Patient Safety Incidents Occurring During Retrieval in a Regional Pediatric Transport Service

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Abstract

Introduction: The primary aim of this study was to quantify patient safety incident rates during retrieval in our state emergency pediatric transport service. Secondary aims were to describe the patient cohort and retrieval characteristics, including the interventions performed by the transport teams.

Methods: This was a prospective, descriptive safety audit. Data relevant to patient safety incidents, retrieval and patient cohort characteristics, and team interventions were recorded and analyzed for 365 consecutive retrievals between February 11th and August 11th, 2018.

Results: Half the patients were under two years old, respiratory illnesses dominated (233, 63.8%), and few were mechanically ventilated (44, 12.1%). There were 31.5 safety incidents per 100 retrievals, the most frequent being delayed urgent departures, equipment malfunction, and hypoxia (12.9, 4.4 and 4.1 per 100 retrievals respectively). Of those safety incidents, we considered 44.4% (16/36) preventable. There were 5.5 adverse events and 0.5 major harm incidents per 100 retrievals. Procedures by the team were infrequent, with only three central lines (0.8%) placed and four endotracheal intubations (1.1%) performed.

Conclusion: Safety incidents during retrieval were common and often preventable, though rates of harm were substantially lower. These events occurred in a patient cohort that appeared to have a relatively low level of acuity when compared to other studies. Delayed departures were frequent and often related to team availability. Procedural interventions were uncommon which has implications for staff training. Overall, the study identified several important areas in which we may improve the safety of our service.

Keywords: Patient transportation; Pediatric; Critical care; Patient safety; Data collection; Australia

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Introduction

Background

Pediatric critical care and sub-specialty services are commonly centralized, on the premise that higher volume services produce improved outcomes [1-3]. This model depends on transport services that can retrieve sick children without compromising their safety [1,4]. Consequently, there is increasing emphasis on measuring and comparing transport service performance and safety [5,6].

While safety event reporting is ubiquitous, challenges remain regarding terminology, measurement techniques, event analysis and performance benchmarking [7-11]. Efforts to standardize safety terminology have occurred [10-12]. In pediatric retrieval important performance indicators have been identified by expert consensus to standardize research, enable service comparison, and establish best practice [13,14], though their prospective validation has been limited [5,7,15].

Analyzing transport incidents requires an understanding of the socio-technical system in which they occur [16]. This analysis includes the interaction between patient, disease, interventions, equipment, the transport environment, team dynamics, and systems factors. Recognized risk factors for transport incidents are the severity of illness and team composition [4,17-20], distance, mode of transport, preparation, use of checklists, and pre-departure stabilization [4,21]. However, adjusting for these variables when benchmarking services remains problematic.

Rationale

There has been little published on local pediatric retrieval safety since Henning et al. [22] from our institution in 1991. We sought to address this gap in the literature by prospectively measuring the Patient Safety Incident (PSI) rates in our service. We aimed to identify all PSIs that occurred while the patient was under the care of the retrieval team (both during transport and at the referring hospital after team arrival). We measured patient cohort and retrieval characteristics (including interventions) to help interpret these PSI rates and inform our team training program.

Setting

The study involved the pediatric arm of PIPER (Pediatric, Infant, and Perinatal Emergency Retrieval), a service-based at The Royal Children's Hospital (RCH) in Melbourne. PIPER performs all inter-hospital retrievals except major trauma (as defined by the Victorian State Trauma System) for children above the age of 8 weeks and under the age of 18 (approximately 700 retrievals per year) [23].

Retrieval teams routinely include a doctor and a nurse. The medical staff is primarily registrars on rotation from the Pediatric Intensive Care Unit (PICU). Nursing staff are either full-time retrieval nurses or PICU nurses with additional training in retrieval. There is one primary retrieval team, though staff may be drawn from the PICU if a second team or particular skill set is required. Pediatric critical care specialists coordinate the retrievals, provide clinical oversight and are available for deployment if needed.

Methods

This descriptive, prospective safety audit was granted ethics approval by the RCH Hospital Research and Ethics Committee. Definitions of key terms are found in Table 1.

Data collection

A list of PSIs (found in Table 2) was compiled from previously published studies, including national consensus statements addressing transport safety metrics [13,14,18,24]. 'Logistics related' events considered relevant to patient safety were also included. Data collection forms requested all incidents that occurred, their perceived preventability, relevant peak/nadir vital signs, and cause of delayed departures, PIPER interventions, team member seniority, the presumed diagnosis, and the referring centre. Retrievals were categorized as 'go-now' (defining triggers are listed in Table 3) or urgent (all others that were non-elective). Target deployment times were 15 and 30 min, respectively. Forms were completed for every retrieval for six months (11th February, 2018 to 11th August 2018). Missing data were completed by a discussion with the team or analysis of the retrieval clinical notes.

Data review and analysis

Incidents were grouped based on whether they related to a pathophysiological event, an intervention, an equipment problem, or a logistical issue. This grouping was pragmatic and similar to previous studies [18,25]. Pathophysiology incidents were categorized as treatment or disease-related. These decisions, as well as classification of preventability and severity, were ultimately decided by the investigators after review of the audit forms and retrieval documents, and discussion with the team involved (definitions in Table 1). Alternatively, results of the departmental review were followed if this had occurred (for cases selected by senior staff for local safety and quality audit). The logistics group was excluded from preventability analysis as this characteristic was unable to be adequately determined for the majority of these events. The disease-related group was excluded by definition. Severity was only assessed where harm was identified (stratified as minor or major harm). Disease-related incidents were not considered adverse events.

To contextualize our cohort and PSI rates, we used a recent analysis of the Pediatric Intensive Care Audit Network (PICA Net) transport dataset, published by the UK Pediatric Intensive Care Society Acute Transport Group, as a comparator [6].

Results

Patient cohort and retrieval characteristics

Patient age, diagnosis, and critical care interventions are described in Table 4 and 5. Retrieval mode, distance, urgency, destination, and team composition data are found in Table 6. Departures were spread evenly between day shift (0700 to 1900, 53%) and night shift (1900 to 0700, 47%). Most retrieval was from nearby metropolitan or regional centers, though substantial minorities of transports were from more than 200 kilometers away. A small number of 'nurse only' transports occurred in circumstances of elective transport or increased workload (utilizing clinical nurse consultants).

Patient safety incidents

PSI rates are listed in Table 2 (percentages equate to incidents

Table 1: Terminology.

Term	Definition
Patient safety incident[a]	Event or circumstance during health care which could have, or did, result in harm to a person
Adverse event[a]	Patient safety incident which caused harm (not including disease related incidents)
No harm incident[a]	Patient safety incident which affected the patient but did not cause harm
Disease related[b]	Incident thought to be caused by the disease or its progression and clearly not preventable (by the transport team)
Treatment related[b]	All incidents not considered disease or logistics related, including those associated with the use (or non-use) of a drug, test or medical treatment
Logistics related[b]	Incident related to staffing or departure times
Harm[a]	Includes physiological disturbance, injury, suffering, disability and death
Major harm[b]	Where harm includes death, permanent disability or significant, unexpected medical or surgical intervention
Minor harm[b]	All harm not qualifying as major
Preventable[a]	Potentially avoidable with standard care in the given circumstances
Patient retrieval[b]	All deployments where the team treated a patient at the referring hospital (includes transported and non-transported patients)

[a]Terms based on ACSQHC and WHO definitions [12,13,15]
[b]Terms defined specifically for this study

Table 2: Patient safety incident rates.

Patient Safety Incidents (*n*=365 retrievals)	All Incidents	Treatment Related	Disease Related	Preventable Incidents	Adverse Events	Major Harm
Pathophysiology, *n* (%)[a]	(0.0%)	0	0	00%)		
Cardiovascular						
Cardiac arrest	1 (0.3)	0	1 (0.3)	0	0	0
Arrhythmia	0	0	0	0	0	0
Hypertension	2 (0.5)	0	2 (0.5)	0	0	0
Hypotension	3 (0.8)	2 (0.5)	1 (0.3)	1 (0.3)	2 (0.5)	0
Myocardial ischemia	0	0.0%)	0.0)	0	0	0
Pulmonary hypertensive crisis	0	0(0.0%	0	0	0	0
Neurological						
Stroke	00.0%)	0(0.0%	0	0	0	0
Seizures	5 (1.4)	0%)	5 (1.4)	0	0	0
Biochemical						
Acidaemia (pH <7.2)	0(0.0%)	0(0.0%)	0(0.0%)	0	0	0
Hypokalaemia (<3.0 mmol/L)	2 (0.5)	2 (0.5)	0(0.0%)	0	2 (0.5)	0
Hyperkalaemia (>6.0 mmol/L)	0	0	00%)	0	0	0
Hypernatraemia(>150mmol/L)	0	0	0	0	0	0
Hyponatraemia (<130mmol/L)	0%)	0	0	0	0	0
Hypoglycaemia (<3 mmol/L)	0	0	0	0	0	0
Hyperglycaemia (>12mmol/L)	0	0	0	0	0	0
Hyperlactaemia (>2 mmol/L)	0	0	0	0	0	0
Haematological						
Anaemia (Hb<70 g/dL)	0	0	0	0	0	0
Bleeding	0	0	0	0	0	0
Respiratory						
Respiratory Arrest	0	0	0	0	0	0
Hypoxia (<90%)	15 (4.1)	2 (0.5)	13 (3.6)	2 (0.5)	2 (0.5)	1 (0.3)
Aspiration	0	0	0	0	0	0
Acute pulmonary oedema	0	0	0	0	0	0
Apnoea requiring intervention	0	0	0	0	0	0
Haemo/pneumothorax	0	0	0	0	0	0
Other air leak	0	0	0	0	0	0
Upper airway obstruction	0	0	0	0	0	0
Other						
Pressure area	0	0	0	0	0	0
Hypothermia	3 (0.8)	2 (0.5)	1 (0.3)	2 (0.5)	2 (0.5)	0
Team member injury	0	0	0	0	0	0
Other	1 (0.3)	1 (0.3)	0	1 (0.3)	1 (0.3)	0
Total	32 (8.8)	9 (2.5)	23 (6.3)	6 (1.6)	9 (2.5)	1 (0.3)
[a] % equates to incidents per 100 retrievals (*n*=365)						
Patient Safety Incidents (*n* = 365 retrievals)	All Incidents	Treatment Related	Disease Related	Preventable Incidents	Adverse Event	Major Harm
Intervention, *n* (%)[a]			N/A			
Intubation attempt >1	2 (0.5)	2 (0.5)		0	2 (0.5)	0
Failed procedure	3 (0.8)	3 (0.8)	)	0	3 (0.8)	0
Malposition of line/tube	1 (0.3)	1 (0.3)		0	1 (0.3)	0
Blocked line/tube	0	0		0	0	0
Unplanned removal of line/tube	2 (0.5)	2 (0.5)		2 (0.5)	2 (0.5)	1 (0.3)

Wrong vessel punctured	0	0		0	0	0
Gas embolism	0	0	0	0	0	0
Limb ischemia	0	0		0	0	0
Vascular thrombosis	0	0		0	0	0
Extravasation	0	0		0	0	0
Perforation of viscera	0	0		0	0	0
Blood product reaction	1 (0.3)	1 (0.3)		0	1 (0.3)	0
Drug reaction	0	0		0	0	0
Medication error	1 (0.3)	1 (0.3)		1 (0.3)	0	0
Total	10 (2.7)	10 (2.7)		3 (0.8)	9 (2.5)	1 (0.3)
Equipment, *n* (%)[a]			N/A			
Equipment malfunction	16 (4.4)	16 (4.4)		6 (4.4)	2 (0.5)	0
Missing equipment	1 (0.3)	1 (0.3)		1 (0.3)	0	0
Total	17 (4.7)	17 (4.7)		7 (1.9)	2 (0.5)	0
Logistics, *n* (%)[a]			N/A	N/A		
Delayed departure Go Now	8 (2.2)	8 (2.2)			0	0
Delayed departure Urgent	47 (12.9)	47 (12.9)			0	0
Skillset/task mismatch	1 (0.3)	1 (0.3)			0	0
Total	56 (15.3)	56 (15.3)			0	0
Grand Total	115 (31.5)	92 (25.2)	23 (6.3)	16 (4.4)	20 (5.5)	2 (0.5)
[a] % equates to incidents per 100 retrievals (*n*=365)						

Table 3: Go-now criteria.

Criteria
Lactate > 6 mmol/L or pH <7.0
Upper airway obstruction persistent despite >2 doses of adrenaline or hypoxemic (SpO_2 < 90%)
Pneumonia with hypoxaemia (SpO_2 <90%) despite locally available non-invasive respiratory support
Sepsis or shock requiring intubation
Sepsis or shock despite >40 ml/kg fluid
Ongoing seizures despite 2 doses of midazolam and loading with long acting agent
Signs of raised intracranial pressure
Unconsciousness with worse than abnormal flexion motor response
Any arrhythmia with haemodynamic compromise
Any child with suspected systemic to pulmonary shunt who is about to be intubated or needing inotropes
Any child with suspected cardiomyopathy/myocarditis who is about to be intubated or needing inotropes
Cardiac or respiratory arrest

per 100 retrievals). There were 31.8 incidents and 5.5 adverse events per 100 retrievals. The most frequent incident was delayed urgent departure, followed by equipment malfunction, hypoxia, delayed go-now departure, and seizure.

Delayed departure

The proportion of delayed go-now and urgent retrievals were 26.7% (8/30) and 14.3% (47/328), respectively. PIPER team availability was the most common problem (46.8% of urgent, 62.5% of go-now), with driver availability the next most common. A minority of delays were due to weather and aircraft availability.

Equipment malfunction

Incidents related to equipment malfunction included the following: Ventilator (circuit leak, expiratory valve dysfunction, problematic auto-triggering), oxygen supply (bottle emptied, 'supply failure'), syringe pump (failure, fall from bracket), monitoring (cable dysfunction) and others (incorrect patient harness fit, vacuum mattress dysfunction, failure of the iStat blood gas analyzer [Abbott Point of Care, Inc. Princeton, NJ, USA]). Two of these events resulted in minor harm. Hypoxia occurred during the transport when the oxygen bottle emptied (backup oxygen was immediately available and hypoxia very brief). Hypercarbia occurred following an expiratory valve failure (identified and corrected). Missing equipment was reported once (video laryngoscope).

Hypoxia and seizures

Most hypoxia incidents were categorized as disease-related (transient fluctuations expected for that diagnosis, e.g., bronchiolitis). Oxygen saturation of less than 80% occurred in a minority of cases. All seizures received appropriate treatment and were categorized as disease-related.

Table 4: Diagnosis and age.

Diagnosis (team assessment) *n*, (%)	**Patients *n*=365**	
Respiratory	233	(63.8)
Bronchiolitis	76	(20.8)
Asthma	49	(13.4)
Pneumonia or pneumonitis	28	(7.7)
Pleural effusion or empyema	3	(0.8)
Croup	49	(13.4)
Upper airway	9	(2.5)
Other respiratory	19	(5.2)
Cardiovascular	13	(3.6)
Pericardial effusion or tamponade	3	(0.8)
Congenital heart disease	5	(1.4)
Dysrhythmia	4	(1.1)
Other cardiovascular	1	(0.3)
Neurological	48	(13.2)
Seizures	36	(9.9)
Meningitis or encephalitis	3	(0.8)
Other neurological	9	(2.5)
Gastrointestinal	6	(1.6)
Gastrointestinal bleeding	2	(0.5)
Acute liver failure	1	(0.3)
Other gastrointestinal	3	(0.8)
Environmental	19	(5.2)
Trauma	6	(1.6)
Burns	2	(0.5)
Ingestion	7	(1.9)
Other environmental	4	(1.1)
Miscellaneous	46	(12.6)
Diabetic Ketoacidosis	13	(3.6)
Sepsis	14	(3.8)
Respiratory Arrest	2	(0.5)
Cardiac Arrest	4	(1.1)
Other miscellaneous	13	(3.6)
Age (yrs) *n*, (%)	**Patients *n*=365**	
0-2 (>8 wks)	182	(49.9)
2-5	89	(24.4)
5-10	52	(14.2)
10-17	42	(11.5)

Preventability and severity

Only 36 events were assessed for preventability due to the exclusion of logistics and disease-related events (as described in the methods section). The 44.4% (16/36) of these were deemed preventable, equating to an overall rate of 4.4 preventable incidents per 100 retrievals. Two incidents (0.5 per 100 retrievals) were associated with major harm, as they required a medical procedure (re-intubation) in response. Both were related to the same patient event (hypoxia due to accidental extubation).

Specific cases

Two cases were particularly informative. The first involved a patient with a difficult airway. The patient was unable to be intubated at the referring hospital, despite multiple attempts, but was successfully oxygenated and retrieved. The second involved a dislodged endotracheal tube where transient hypoxia was rapidly reversed with re-intubation. These cases are explored further in the discussion.

Table 5: Interventions.

Interventions *n*, (%)	**Retrievals (*n*=365)**	
Invasive ventilation	44	(12.1%)
Intubation	4	(1.10%)
Non-invasive ventilation	1	(0.3%)
High flow nasal prongs	112	(30.7%)
Inter costal catheter	0	(0.0%)
Inotropes	12	(3.3%)
Central line	3	(0.8%)
Drug administration	179	(49.0%)
Cardiac massage	4	(1.1%)
ECMO	0	(0.0%)

Table 6: Retrieval characteristics.

Characteristic	**Retrievals (*n*=365)**	
Team (*n*, %)		
Nurse, Registrar	351	(96.1)
Nurse, Fellow	1	(0.3)
Nurse, Specialist	2	(0.6)
Nurse only	11	(3)
Urgency (*n*, %)		
Go-now	30	(8.2)
Urgent	328	(89.9)
Elective	7	(1.9)
Destination (*n*, %)		
PICU	181	(49.6)
Emergency	155	(42.5)
Ward	18	(4.9)
Left at referring hospital	9	(2.5)
Died at referring hospital	2	(0.5)
Characteristic	Transports (*n*=354)	
Mode (*n*, %)		
Ambulance	287	(81.1)
Fixed wing	50	(14.1)
Helicopter	16	(4.5)
Lear jet	1	(0.3)
Distance (*n*, %)		
0-49 km	186	(51)
50-99 km	69	(18.9)
100-199 km	39	(10.7)
>200 km	60	(16.4)

Interventions

Interventions and procedures done by the PIPER team are summarized in Table 5.

Discussion

Patient cohort and retrieval service characteristics

Compared to the PICA Net transport dataset our proportion of respiratory diagnoses was higher (63.8% *vs.* 44.3%), including bronchiolitis (20.8% *vs.* 15.0%), croup (13.4% *vs.* 1.7%) and asthma (13.4% *vs.* 3.6%) [6]. Other differences in diagnosis rates included seizures (9.9% *vs.* 5.1%) and DKA (3.6% *vs.* 0.8%). This is a substantial case-mix difference in low risk diagnoses [26]. While we did not include an illness severity score in our study, there was a large difference in rates of invasive ventilation (12.1% *vs.* 82.9%). These comparative data would suggest that our case acuity was lower. This difference may reflect variance in the retrieval threshold. Retrieval threshold depends on the diagnosis, patient condition, likely retrieval time, and the capacity of referring health service to manage the illness trajectory. These factors apply particularly to rural and remote locations [27]. Air retrieval was far more common in our study (19% *vs.* 2%), which is understandable given our higher rates of long-distance retrieval (>200 km in 16.2% *vs.* 1.5%) and geographical differences [6]. This higher proportion of distant transports may have contributed to a difference in retrieval threshold.

Our registrars varied in critical care experience. All were provided with retrieval training, and coordinating specialists considered skill mix for all cases before deployment. Senior staff was infrequently required. In comparison, teams in the PICA Net study frequently included consultants (37.5%), again suggestive of a higher acuity cohort. How this variation in our team's experience level may have affected PSI rates is unclear. Previous studies exploring the effect of specialist retrieval teams on outcomes did not explicitly look at service models with this built-in flexibility [1,20].

Patient safety incidents

The high rate of PSIs was not unexpected, as similar studies have found safety incidents to be common and we aimed to maximize information capture [25,28]. The high rate was driven by delayed departures, for which we used a low event threshold. In contrast, the overall degree of attributable harm was lower, as demonstrated by our AE and major harm rates. While this is reassuring, there is potential for improvement, and the question of how to use such data to benchmark our performance remains.

Unfortunately, variation in event definitions makes it difficult to compare our summary data to other studies [29]. Fan et al. [30] raised this issue in a systematic review of adult retrieval studies. They were unable to draw a meaningful conclusion about AE rates for this reason. Nevertheless, examining the data in detail remains informative.

Delayed departures

Our departure targets were considered logistically achievable with an on-site team, so identifying team availability as a common cause of delay was useful. Our surge capacity depends on redundancy in the PICU roster. We use this capacity particularly for go-now and urgent high-risk cases, and the decision to utilize this resource is made by the coordinating retrieval consultant. Lower acuity cases may be considered safe to delay, and this is likely a major contributor to our delayed urgent departure rates. Nevertheless, our response times could improve with increased staffing.

Equipment malfunction

Our malfunction rates were comparable to other studies [6,25]. Problems with therapeutic devices may adversely affect patient care. Failure to adequately secure equipment, the patient, and personnel during transport may result in injury. Our two minor harm events were reviewed. One was an incident involving medical gas supply continuity, which is a critical indicator of transport safety [6,14]. This occurred during an interstate flight (uncommon in our service) so has informed our safety procedures for these long-distance retrievals.

Retrieval equipment needs to be robust, compact, and light, have good battery life, and be artifact resistant [31]. Our equipment was quite reliable during the study period, with only one IV pump failure, one cable dysfunction event and no problems with battery depletion. Surprisingly, our iStat blood gas analyzer failed on a rare occasion when its use was required, despite device testing being part of the team's daily checks. Unfortunately, we were unable to establish if the event was due to incorrect use rather than equipment failure. Nevertheless, it illustrated the importance of both rigorous equipment testing and competence in equipment use and troubleshooting, particularly for such infrequently used devices [32,33]. The near absence of missing equipment events suggests that our pre-departure checklist was effective.

Hypoxia and seizures

Being relatively frequent pathophysiological events, these were highlighted as important scenarios to regularly include in our simulation program, where they can ensure familiarity with the local management guidelines that are available.

Preventability and severity

Just under half of the assessed events were considered preventable, indicating a substantial potential to reduce our PSI rates. Few pediatric retrieval studies have measured preventability. One neonatal study found that 67% of AEs were due to perceived avoidable human error, though how this was assessed was not discussed [25]. In the ICU, preventability rates vary markedly but are often in the range of 50% [34]. Here again, the comparison is problematic, as defining and quantifying preventability can be challenging. While it is best done prospectively, inter-rater reliability may be limited however; it is measured [9]. A more useful approach might involve documenting contributing factors, as is usually done in critical incident analysis. These contributing factors have been included in previous studies [25,32].

Major harm was rare. While our rate approximates that from the neonatal study mentioned above, there are differences in how severity was measured, including the use of a severity *vs.* recurrence likelihood matrix [25]. Unfortunately, there are few other recent studies with comparable data in this regard.

Specific cases

In the first case, while the video laryngoscope was on the pre-departure checklist to be carried to every retrieval, it was not carried by the team as intubation was occurring at the time of deployment and airway difficulty only became apparent after departure. The child was eventually intubated at the destination hospital by two experienced pediatric anesthetists utilizing advanced techniques. The case prompted a review of the service's airway equipment and training and demonstrated the importance of meticulous use of pre-departure checklists.

The second case highlighted the risks of moving an intubated child when working in unfamiliar environments. A review of this

event found that a non-PIPER staff member had moved in an unsafe manner, despite the team being present. A protocolized approach to moving children during transport with explicit role allocation may reduce the chance of this occurring.

'Unplanned dislodgement of therapeutic devices' was considered the most important safety metric in the AAP consensus statement [13]. The rate of unplanned extubation in our study was 0.3% of all retrievals, not dissimilar to the 0.2% found in the PICA Net dataset [6]. However, the denominator is the number of transports, whereas a more meaningful denominator would be the number of intubated patients, a number that differs substantially between the two groups. This observation demonstrates how comparative performance metrics can be confounded by service and cohort characteristics.

Interventions

Procedures, such as intubation and central line insertion, were infrequent when compared to the PICA Net dataset (1.1% *vs.* 6.9% and 0.8% *vs.* 10.2%, respectively). Again, this likely reflects the difference in case-mix and acuity. In both studies, the majority of intubations were performed by the referring hospital (approximately 90% in each). This finding demonstrates that the inter-hospital retrieval doctor must remain skilled in critical procedures while having a relatively low procedure volume in practice. We have addressed this need in our service through access to anesthetics lists where procedural skills can be maintained as well as regular simulation of infrequent event scenarios.

Strengths and limitations

The strengths of this study include its prospective design and the use of pre-defined incidents, which included some important service performance metrics (e.g. rates of unplanned dislodgement of therapeutic devices, medical equipment failure, medication errors) [13]. It was a comprehensive dataset addressing preventability, severity and causality. This dataset allowed us to distinguish preventable treatment-related events from inevitable disease-related physiological changes. Interpreting our results in light of service and patient cohort characteristics gave us more comparative information than if we had described incident rates in isolation.

Our study was limited by its small size and descriptive nature, so we could only quantify crude event rates and identify possible trends for future exploration. Without illness severity score data, our ability to quantify cohort disease severity was limited, making it difficult to compare our incident rates to other services, though general themes remain broadly relevant. Potential sources of bias included the lack of investigator blinding in regard to the team members involved in patient care and the fact that preventability and severity was judged primarily by the investigators.

We could certainly improve our PSI list for future data collection. Definitions of physiologic deterioration would ideally include new or increased critical care supports rather than being limited to vital signs, which are often normalized by this supports [28]. Some performance indicators from the referenced studies were not included (e.g., 'use of a standardized patient care handoff' and 'verification of TT placement') [13]. While these are measures of process, they have safety implications. While we asked explicitly for resourcing causes for departure delay, we did not include important factors such as communication, team preparedness, equipment availability and clinical judgment of safety [15]. Similarly, we did not ask whether vehicle-related events contributed to the recorded PSIs. All of these would be worthwhile including in future safety studies.

Conclusion

In summary, we found that safety incidents were common and often preventable (in the minority that was assessable for this characteristic). However, adverse events (incidents with clearly associated harm) were much less frequent and major harm very uncommon. Within the limitations of our data as described above, our cohort may be of lower illness acuity than those reported elsewhere, which, if true, could partly reflect a difference in retrieval threshold. We identified specific areas for service improvement, including departure times, which may be improved through increased staffing. Equipment events illustrated the importance of training. Low procedure rates highlighted the need for skill maintenance to occur *via* other means. Improvements to local data collection were identified relating to the incident choice, event characterization and the inclusion of illness severity data. Future work is needed to validate performance metrics in our regional context to ensure that they remain robust measures of quality in the face of service and cohort variation.

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