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ORIGINAL PAPER

Critical incidents in paediatric critical care: who is at risk?

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Abstract We evaluated the characteristics of children for whom critical incidents (CIs) were reported by performing prospective collection of patient data and retrospective review of reported CIs in a multidisciplinary neonatal–paediatric intensive care unit of a tertiary care university children's hospital. A period of 1 year was analysed (January to December 2007; 1,251 admissions). CIs comprised adverse events (actual patient injury), as well as near-misses. The report form of critical incidents was web-based and reporting was voluntary, anonymous and non-punitive. The severity of all CIs was divided into minor, moderate and major. Patients with and without CIs were compared regarding the following characteristics: Paediatric Index of Mortality (PIM2), duration of mechanical ventilation, length of stay in the intensive care, admission mode (surgery, cardiopulmonary bypass, cardiac/non-cardiac unit), age and sex. There were 360 CI reports (83 per 1,000 patient days; 13% major, 26% moderate, 61% minor severity). Of these, 310 CIs could be assigned to 198 specific patients. In the univariate analysis, patient-related risk factors for CIs were higher PIM2 score ($p<0.0001$), increased length of stay ($p<0.0001$), mechanical ventilation ($p<0.0001$), increased ventilator days ($p<0.0001$), male gender ($p=0.022$) and young age ($p<0.0001$). Using a logistic regression model, mechanical ventilation ($p<0.0001$), male gender ($p=0.034$) and length of stay ($p<0.0001$) continued to be associated with the occurrence of CIs. *Conclusion* CIs often occur in paediatric intensive care. Among the patient-related factors, male gender, mechanical ventilation, and length of stay are independently associated with CIs. Already known at admission to intensive care are male gender and, usually, requirement for mechanical ventilation. Improved knowledge of the risk factors for CIs could help to minimize their frequency and thus improve quality of care.

Keywords Intensive care · Paediatric · Gender · Critical incident · Severity of illness · Length of stay · Overtreatment

Introduction

During the last years, enormous advances in critical care medicine have taken place. While these advances are generally regarded as positive, this progress has introduced many invasive procedures that have the potential of causing harm to the patient. Moreover, the involvement of various physicians and nurses in patients' care in an intensive care unit necessitates effective communication between the different specialties [1, 4, 17]. The intensivist has an important coordinating role in this environment [2]. Nevertheless, such complex systems are prone to errors.

Kohn et al. concluded in their report *To Err is Human* that medical errors are a substantial cause of hospital-related morbidity and mortality, resulting in 44,000 to 98,000 patient deaths per year in US hospitals [10]. Under these circumstances, it is especially important to monitor critical incidents (CIs). CIs are defined as adverse events that lead to patient harm, as well as potentially harmful near-misses [8]. On our paediatric intensive care unit (PICU), a non-punitive, anonymous and voluntary CI reporting system is employed, which is considered to be more efficient than medical chart review [23]. There have been previous investigations about characteristics of patients who experienced a CI on neonatal and paediatric intensive

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care units [9, 22]; however, patients in a multidisciplinary neonatal–paediatric intensive care unit have not been examined thus far with respect to the association between CIs and severity of illness.

The objective of our study was to examine if there are patient-dependent predictors that increase the risk of experiencing a CI.

Methods

The study was performed in the 19-bed multidisciplinary neonatal–paediatric intensive care unit of the University Children's Hospital in Zurich, Switzerland. The intensive care unit admits patients under the age of 16 years and is divided into two wards: PICU A (general neonatal–paediatric intensive care) and PICU B [cardiac intensive care with extracorporeal membrane oxygenation (ECMO)]. In some cases we admit adult patients that have been in our PICU before. The unit also takes part in the regional neonatal transport system. There is a 24-h dedicated physician coverage with the medical staff consisting of seven consultants and eleven paediatric residents. The patient to nurse ratio ranges from 1:1 to 2:1; for ECMO patients, it is 1:2. Most of the orders are computer-aided, additions during the day are handwritten. Three times a week, a pharmacist accompanies the doctors on ward rounds and checks prescriptions. For the present study, data on CIs and patient characteristics from January to December 2007 were analysed.

In our unit, selected patient characteristics are collected prospectively (minimal data set of the Swiss Society of Intensive Care): age, sex, length of stay, length of invasive and non-invasive ventilation, principal diagnosis (ANZPIC diagnostic score [20]), type of admission (elective, non-elective), mortality and severity of illness score. Severity of illness is measured by the paediatric index of mortality version 2 (PIM2) [18, 21]. PIM2 is a simple model that is considered accurate enough to describe the risk of mortality in children and suitable for monitoring the quality of paediatric intensive care.

CI monitoring was implemented in 2000 as a voluntary, non-punitive and anonymous electronic reporting process. Both, incidents with patient harm and near-misses are reported. Near-misses that cause no harm are also regarded as an informative source for quality improvement [8]. Reports are completed exclusively by nurses and doctors. Our reporting form consists of a narrative section about the CI, including contributory factors, actual harm to the patient, proposals of measures to prevent similar events in the future, and the exact times of the event and its recognition. Moreover, the patient's birth date is noted. By comparing the birth dates, we were able to match the CIs and the patient characteristics. The CI reports are analysed and categorised into 11 groups: drug administration, drug prescription, patient management, respiration (including accidental extubation), equipment dysfunction, communication, other installations, vessel catheters, documentation, nosocomial infection and other. Thus, our categorisation system includes event types (such as respiration) and contributing factors (such as communication). Our instructions for categorisation are as follows: whenever a drug is involved, the CI has to be categorised as a drug CI (prescription or administration). For the other categories, the root cause (as it appears from the reporter's description) must be taken (documentation, nosocomial infection, communication, patient management, equipment dysfunction); when the root cause is not obvious or when the root cause does not fall into one of the categories, the appropriate event type must be applied (respiration, vessel catheter, other installations). Reporting of accidental extubations is compulsory in order to use this type of incident as a quality indicator (number of accidental extubations per 100 intubation days).

Two paediatricians (ON and BF) reviewed all reports of 2007 and independently rated the severity (actual harm) of the reported CIs according to Frey et al. [8] as follows: major (score 3, death or need for therapeutic interventions specific to the intensive care unit (ICU); e.g. need for intubation and ventilation after tenfold overdose of a sedative drug), moderate (score 2, requiring routine therapy available outside the ICU; e.g. small nasal necrosis after nasal intubation) and minor (score 1, requiring no interventions; e.g. prescription of an antibiotic without the unit milligramme). Inter-rater agreement was analysed and showed a kappa coefficient of 0.88.

The quality management group analysed the CI data every 4 months. It consisted of two physicians (one consultant, one resident), four registered nurses trained in intensive care, the responsible nurse for ICU equipment and a pharmacist. A staff meeting with the nursing and medical team was organised every 4 months in order to discuss the reports and proposed preventive measures. The measures (responsible person, deadlines, evaluation) were controlled by the quality management group.

We calculated rates of categories and severity of CIs, specific rates of CI per 1,000 patient days and accidental extubations per 100 intubation days. We compared the groups with and without CIs according to PIM2 score, length of stay, age, sex, admission to PICU A or B, admission after cardiopulmonary bypass, admission after surgery, whether ventilated or not, and length of mechanical ventilation. We distinguished between invasive and non-invasive ventilation.

Data are given as median (range) or frequency (percentages), as appropriate. PIM2 score is given as mean (SD).

Differences between the groups were analysed using the Chi-squared test and the Wilcoxon test, as appropriate (univariate analyses). Multiple logistic regression analysis was used for multivariate analyses. A p value less than 0.05 was considered statistically significant.

Results

In 2007, 1,251 patients were admitted to our PICU, of which 729 were male with a total of 4,318 patient days. Seventeen female adults and 27 male adults are included in this number. Expected mortality (mean PIM2 score) was 3.99%, observed mortality 2.96% and standardised mortality ratio (observed/expected mortality) 0.74 (95% confidence interval, 0.51–0.97). The median length of stay in the PICU was 1.5 days (range, 0.1–77.8). Of the total, 532 patients were mechanically ventilated (42.5%, invasive and non-invasive ventilation), 506 were intubated (1,348 intubation days) and 56 were on non-invasive ventilation (152 days). Some patients had both ventilation techniques. There were 161 patients admitted after cardiopulmonary bypass and 534 patients admitted after surgery or specific interventions like cardiac catheter procedures; 717 did not undergo surgery.

Table 1 shows the distribution of categories and severity of all 360 CIs reported in 2007. The incidence of CIs was 83 per 1,000 patient days or 28 per 100 patients. Forty-seven CIs were major (13%), 92 were moderate (26%) and 221 were minor (61%). The respiratory CIs were of the greatest severity. Ten out of the 35 respiratory CIs involved accidental extubation; two of these patients had to be re-intubated. We had a ratio of 0.74 accidental extubations per 100 ventilator days with a reintubation rate of 20%. Drug-related CIs (prescription and administration) accounted for a third of all CIs, but most of them were of minor severity. Tenfold drug-dosing errors scored for 4.8% (six CIs) and programming mistakes of infusion pumps scored for 7.2% (nine CIs) of all medication CIs.

There were 310 CIs that could be linked to specific patients. They occurred in 198 patients, with 60 patients experiencing more than one CI and one patient with 12 CIs. The results of the univariate analyses for the differences between patients with and without CIs are shown in Table 2. The 50 CIs which could not be linked to specific patients fell into the following categories: drug administration (14), patient management (10), drug prescription (six), vessel catheters (five), nosocomial infection (three), other installations (three), communication (two), documentation (two), equipment failure (two), respiration (two) and other (one). Of these, 31 were of minor severity, 15 were rated medium and four major. Patients with increased length of stay had greater chance to be affected by more than one CI (association between length of stay and number of CIs per patient, $r=0.44$, $p=0.01$).

The CI group of 198 patients consisted of 130 boys and 68 girls. Regarding the total of all patients admitted to the PICU in 2007, 18% of the males and 13% of the females had one or more CIs ($p=0.022$). Male patients affected by CIs did not have a significantly higher mean PIM2 score than affected female patients (4.16 vs. 3.79, $p=0.56$). The boys, however, were younger than the girls (median, 1.4 (0–25) and 2.6 years (0–29.2), respectively, $p=0.016$). Gender was not associated with any of the other characteristics.

A multiple logistic regression analysis was performed with CI (yes or no) as the dependent variable and sex, age, mechanical ventilation (yes or no), admission after surgery (yes or no), length of PICU stay and PIM2 score as the independent variables (Table 3). Logistic regression showed that male gender (OR, 1.46; $p=0.034$), mechanical ventilation (OR, 2.99; $p<0.0001$) and length of stay (OR, 1.11; $p<0.0001$) were independently associated with the occurrence of CIs. In the multivariate analysis, admission after

Table 1 Distribution of categories and severity of all critical incidents ($n=360$)

	Minor	Moderate	Major	∑
Drug administration	48	9	8	65
Drug prescription	50	8	2	60
Patient management	28	23	1	52
Respiration	8	6	21	35
Equipment dysfunction	19	6	7	32
Communication	24	4	2	30
Other installations	11	15	3	29
Vessel catheters	3	14	3	20
Documentation	12	5	–	17
Nosocomial infection	11	–	–	11
Other	7	2	–	9
Total	221 (61%)	92 (26%)	47 (13%)	360

Table 2 Characteristics of patients with and without critical incidents

	All patients 1251	Patients with CI 198	Patients without CI 1053	*p* value
Age (years)	1.8 (0–29.1)	0.3 (0–29.1)	2.3 (0–25)	<0.0001
Mechanical ventilation	533 (43%)	144 (73%)	389 (37%)	<0.0001
Duration of invasive mechanical ventilation (hours)	26.1 (0.3–950.7)	62.8 (2.5–950.7)	22.9 (0.3–842.5)	<0.0001
Length of stay in PICU (days)	1.5 (0.1–77.8)	4.9 (0.1–77.8)	1.1 (0.2–71.8)	<0.0001
PIM2 score (%)	4.0 (1.0)	5.9 (9.9)	3.7 (1.0)	<0.0001
Male gender	729 (58%)	130 (66%)	599 (57%)	0.022
Admission after surgery	534 (43%)	71 (36%)	463 (44%)	0.034
PICU				
B (predominantly cardiac)	478 (38%)	66 (33%)	412 (39%)	0.124
A (predominantly non-cardiac)	773 (62%)	132 (67%)	641 (61%)	
Duration of non-invasive mechanical ventilation (hours)	24.3 (1.2–497)	36.4 (1.2–497)	19.7 (3–118)	0.188
Admission after cardiopulmonary bypass	161 (13%)	26 (13%)	135 (13%)	0.75

Data are given as numbers (percentages) or median (range). PIM2 score is given as mean (SD). In the group of the patients without CI, there is an unknown number of patients with CI included (maximal 50 patients) who could not be linked to a CI

surgery, PIM2 score and age were no longer associated with CIs. PIM2 score and age remained statistically insignificant when replacing PIM2 score by PIM2 >5% (yes or no) and age by infancy (yes or no) (OR, 1.45, 0.97–2.29 and 1.26, 0.89–1.79, respectively).

Discussion

Our study shows that male gender, mechanical ventilation and length of stay in the ICU were independently associated with the occurrence of one or more CIs in a patient. In the univariate analysis, admission after surgery, duration of invasive mechanical ventilation, age and PIM2 score were also predictive factors.

Like Kanter et al. [9], we found that males are at higher risk of CIs, which is in contrast to other studies [12, 19]. We do not know whether CIs really occur more often in males or whether they are more often detected and reported in our CI monitoring system. Nevertheless, logistic regression confirmed that male gender itself is a significant risk factor for CIs (OR, 1.46, 95% confidence interval, 1.03–2.06, p=0.034). Other authors described an association between male gender and greater severity of illness and mortality rate, at least in premature neonates [3, 15, 16, 24]. In neonatal intensive care, Warrier et al. [27] showed that Caucasian race, male gender, gestational age under 28 weeks and birth weight under 1,000 g were risk factors for higher drug exposure. This might be a reason for a higher rate of CIs for male patients in our study, as medication CIs were the most frequently reported category. Thus, if males do not have higher severity of illness leading to increased need for medication, overtreatment may play a role in incidence of CIs in boys [27]. This assumption can be supported by the study of Valentin et al. [25], in which it was found that adult male ICU patients had more invasive procedures than females, although women had higher severity of illness scores; however, outcome in men and women was not different. According to Kanter et al. [9], higher severity of illness might lead to more interventions and thus increase the risk of CIs; however, in our study, PIM2 score, a reflection of illness severity, did not differ significantly between boys and girls (whole patient sample). Other authors found a higher mortality rate of boys in

Table 3 Logistic regression analysis of probable explanatory factors for whether a patient is affected by critical incident(s) or not

	p value	OR	95% confidence interval
Mechanical ventilation (yes)	<0.0001	2.998	2.032–4.423
Length of stay (days)	<0.0001	1.114	1.078–1.150
Sex (male)	0.034	1.456	1.028–2.062
Admission after surgery (yes)	0.108	0.744	0.518–1.067
Age (weeks)	0.455	1.0	0.999–1.000
PIM2 score	0.836	0.998	0.984–1.013

a non-premature paediatric cardiac ICU population treated with ECMO [14]. On the contrary, Lopez et al. did not find differences in standardized mortality ratio related to gender in their multicenter PICU study [13].

It is not clear whether the longer length of stay we found in the CI group is caused by CIs or whether the risk to experience a CI is higher due to the patients' longer stay in circumstances where invasive procedures, bustle and a high turnover of patients are very common [12]. The association between the number of reported incidents per patient and length of stay is in favour of the latter explanation.

Mechanical ventilation is a risk factor for CIs. Ten percent of all CI reports deal with respiration. The most severe incidents were respiratory in nature, which might be due to the fact that accidental extubations were included in this group and were all considered of major severity. We had 0.74 unplanned extubations per 100 ventilator days, less than other authors have described [13, 14, 22] and similar to rates reported by Ligi and co-workers [12]; however, the case mix should be considered when comparing rates of accidental extubations. Similar to the study of Veldman et al. [26], only two of the ten patients had to be re-intubated.

To our surprise, complex patients after cardiopulmonary bypass heart surgery on ward B were not at higher risk for a CI. This might be due to the fact that most of these patients were admitted electively. On the other hand, significantly more children were ventilated on the cardiac ward than on the general PICU (54.4% vs. 35.3%). Therefore, post-operative ventilation does not seem to be a risk factor for CIs.

Severity of illness (PIM2) was associated with CIs in the univariate analysis; patients with a CI had a significantly higher PIM2 score than patients without CIs. As patients with high PIM2 scores suffer from more serious diseases, they might require more invasive procedures that may cause harm to the patient (central lines, hemofiltration, etc.) and thus contribute to CIs. However, in the multivariate analysis, PIM2 score was not independently associated with CIs. Ligi et al. found an association between CIs and Clinical Risk Index for Babies (CRIB) score [12]. CRIB score is applied to newborns of less than 1,500 g of weight and/or less than 32 weeks of gestation.

Children who underwent surgery were at lower risk for CIs ($p=0.034$, univariate analysis), which might reflect the fact that many clinical guidelines are in place for this group of patients. Moreover, these patients often need intensive monitoring but not many interventions on the PICU, most are admitted electively. Significantly, more children in the post-operative group were ventilated (50% vs. 37.2%, $p<0.0001$). The ventilated children in the post-operative group had shorter ventilation times (median, 16.9 vs. 48 h, $p<0.0001$). This may contribute to the lower CI rate in this group.

Because our CI monitoring process is voluntary, the capture rate of CI occurrence is likely not comprehensive; however, we are confident that a substantial part of the true number of CIs has been detected, as reflected in our high reporting rate; we have more CI reports (83 per 1,000 patient days) than reported in other studies. Sharek et al. found a mean CI rate of 32.4 per 1,000 patient days in their study by using the trigger tool approach [19]. Our high reporting rate might partly be explained by the fact that one consultant is very dedicated to the CI monitoring system that the reporting system has been in place now for almost 10 years and that there is a good 'safety culture' in the unit. Furthermore, similar to the study of Frey and colleagues, our approach focuses on incidents rather than on complications [8]. Major complications are rare and are usually made known to all staff, whereas unspectacular incidents might go unrecognized or unreported. Other studies revealed that the non-punitive, anonymous and voluntary character of a CI reporting system encourages and improves reporting [8, 11]. These factors may also explain why the majority of reported CIs were of minor severity; however, it remains unclear whether a high number of reports is proof of wide acceptance of the CI reporting system and good 'safety culture', or if it is a sign of suboptimal quality of care [6].

As mechanical ventilation and length of stay are associated with CI reporting, the question arises whether overtreatment may play a role. Overtreatment is the application of unnecessary, excessive or ineffective medical procedures or drugs, such as unnecessary invasive ventilation or unnecessary prolongation of PICU length of stay. If not indicated, these measures do not improve the outcome for the patient. On the contrary, the patient is exposed to the inherent risks of these processes and may be harmed [5]. Clinicians working in the ICU may be pressured to use the available invasive diagnostic and therapeutic procedures and drugs inappropriately, and may thus cause harm, reflected in CIs. Moreover, increased complexity of care alone may be responsible for increased number of CIs, as physicians are more likely to miss important issues and the system becomes more liable to error [7]. It was not the scope of our study to analyse whether CIs had an impact on the outcome of the affected patients; however, it is likely that some outcome parameters, such as length of stay in PICU, are influenced by CIs and that resources may be channelled away from other clinically important areas [5].

In conclusion, CIs are frequent in paediatric critical care. Though the majority of these incidents do not cause harm to the patient, reporting is important to detect system problems. This may allow the implementation of system changes and thereby increase patient safety. We are convinced that every modern medical unit should use a CI monitoring system in order to guarantee quality of care. In

our centre, male gender, mechanical ventilation and longer stay in the PICU increase the risk of involvement in a CI report. Assuming that CI reporting mirrors the real picture of critical events, these patient groups are liable to increased CI risk. As sex, length of stay in ICU and the need for mechanical ventilation can hardly be changed by CI-preventive strategies, it is important to reduce invasive ventilation time whenever possible, as univariate analysis showed that duration of invasive mechanical ventilation was associated with the occurrence of CIs.

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Conflict of interest The authors declare that they have no conflict of interest.

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