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Prediction of clinical deterioration after admission from the pediatric emergency department

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ABSTRACT

Background: An ongoing threat to hospitalized patients is delayed recognition of clinical deterioration and its association with increased morbidity and mortality.
Objective: This study evaluated the ability of Pediatric Emergency Medicine (PEM) clinicians to predict clinical deterioration of patients admitted from the Pediatric Emergency Department (PED). Clinical deterioration was defined as unanticipated transfer to an Intensive Care Unit (ICU) within 12 h of PED-to-ward admission.
Methods: This prospective study was conducted in the PED of an urban, academic, tertiary-care children's hospital. Nurses, attending physicians, fellows, and residents completed surveys about their predicted risk of clinical deterioration for each patient admitted to the pediatric ward using a visual analog scale (VAS), and their level of certainty in their prediction using a Likert scale. Additional data included clinician years of experience, and continuity of care versus patient hand-off between clinicians.
Results: 4482 surveys were completed by clinicians for 2892 unique admissions over ten months. Twenty-two patients required transfer to an ICU within 12 h of PED-to-ward admission. Nurses' predictions of deterioration risk were higher for patients who went on to require ICU transfer than for patients who did not. Level of certainty correlated with years of clinician experience and with continuity of care, and was higher for patients predicted to have a low risk of deterioration.
Conclusions: Clinicians are more certain of their predictions with increasing experience, continuity of care, and when predicted risk is low.

1. Introduction

Patient safety and quality improvement remain paramount concerns for health care organizations, regulatory agencies, insurance companies, the lay media, and the public [1]. An ongoing threat to hospitalized patients is delayed recognition of clinical deterioration and its association with increased morbidity and mortality [2,3]. Following admission to the hospital from the Pediatric Emergency Department (PED), some patients soon require unanticipated transfer to a higher level of care. Mechanisms to temper this risk include strategic appropriation of critical care beds, timely intervention for patients with worsening clinical status, and systematic identification of these patients using scoring algorithms. Identifying patients at risk of clinical deterioration during their stay in the PED may further decrease morbidity and mortality.

Many hospitals have implemented Rapid Response Teams (RRTs) to recognize signs of patient deterioration and to intervene in accordance with recommendations from the Institute for Healthcare Improvement [4]. Evaluations of RRTs in pediatric centers have shown mixed results, with some studies reporting decreased mortality and other studies demonstrating no difference before and after implementation [5,6,7,8,9]. Some children's hospitals use a Pediatric Early Warning Score (PEWS), which incorporates data from respiratory, cardiovascular, and behavioral status, to identify hospitalized patients at risk of deterioration and to initiate early intervention [10,11,12,13,14,15]. Studies of PEWS in inpatient settings have shown high sensitivity and specificity in identifying children at risk of deterioration, but the use of modified scoring algorithms and different threshold scores confounds comparisons across institutions [10,11,12,13,14,15]. Other centers have explored adapting PEWS for use in the PED to predict patient disposition, but have found that it has poor discriminatory ability in this setting [16,17,18,19].

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Prediction of Clinical Deterioration after Admission from the Emergency Department

Please complete one survey per provider for each patient admitted to the floor.
Exclude patients sent directly to the PICU, NICU, CTICU, or OR.

1. Role: (please circle)

Nurse	Attending	Fellow	Resident
Years as RN: _____	Years as MD: _____	Year: 1 2 3	Year: 1 2 3 4 Type: Peds EM FM

2. Continuity of Care: (please check one)

___ I evaluated the patient at their initial presentation.

___ I assumed care from the patient's previous physician or nurse.

3. Length of Stay: (LOS column on tracking board)

Total time in ED: _____
HH:MM

4. Was a PICU consult requested for this patient?

Yes No Don't Know

5. Likelihood of clinical deterioration:

What is the chance that this patient will require transfer to the PICU within twelve hours?

Draw a vertical dash across the line below

0% 100%

_____

How certain are you of your prediction?

5 completely certain
4 somewhat certain
3 neutral
2 somewhat uncertain
1 completely uncertain

Fig. 1. Study survey instrument.

Severity of illness scores serve to summarize and quantify a patient's condition, but cannot encapsulate the overall impression of a trained provider [20,21]. Capturing this assessment remains challenging, especially for patients who are sufficiently ill to require hospitalization, but do not meet criteria for admission to a critical care unit at the time of admission. The prognostic ability of clinicians has been evaluated in estimating mortality risk in the NICU and PICU [22,23,24,25,26]. These studies indicate that physician and nurse prognostication is fairly accurate, improves with experience, and correlates with levels of certainty [22]. To our knowledge, the ability of PED clinicians and trainees to predict subsequent inpatient deterioration has not been evaluated. The primary objective of this study is to evaluate the ability of nurses, attending physicians, fellows, and residents in the PED to predict patient clinical deterioration. Secondary objectives included evaluating correlations between predicted risk and certainty, between certainty and years of experience, and between certainty and continuity of care.

2. Methods

2.1. Study design and population

This prospective study took place from June 2013 through March 2014 in the PED of an urban, academic, tertiary-care children's hospital with over 70,000 visits annually. Data collection took place for 10 months, ending when a new electronic medical records system was implemented in April 2014. This study was approved by the hospital's Institutional Review Board with expedited review and waiver of written informed consent. Participating clinicians included registered nurses,

board-certified or board-eligible PEM attending physicians, PEM fellows, and rotating residents from Pediatric, Emergency Medicine, and Family Medicine programs.

Patient encounters were eligible for inclusion if a patient in the PED was admitted to the pediatric ward. Patient encounters were excluded if the patient was sent directly to the Operating Room (OR) from the PED, as clinicians would not have had an opportunity for reevaluation between the operative intervention and arrival to the pediatric ward. Encounters were also excluded if the patient was directly admitted from the PED to the PICU, NICU, or Cardiothoracic Intensive Care Unit (CTICU). Intensive care admission at this institution is indicated for patients requiring vasopressor agents, continuous albuterol, high-flow nasal cannula, or initiation of non-invasive positive pressure respiratory support or mechanical ventilation. This hospital does not have a step-down unit. Patients may be cared for on the regular pediatric ward if they are otherwise stable even in the presence of a tracheostomy tube, home use of non-invasive positive airway pressure or mechanical ventilation, or need for continuous insulin infusion. Multiple admissions to the hospital for the same patient during the study period were included as separate encounters. Age, gender, and admission PEWS were collected for all patients during the study period.

2.2. Survey content and administration

Survey questions for each patient encounter included clinician role, clinician years of experience, and continuity of care (i.e., whether a clinician evaluated the patient at initial presentation or assumed care later in the PED course upon hand-off). Clinicians' predictions of clinical deterioration were indicated by making a vertical mark along a 100 mm VAS to answer the question, "What is the chance that this patient will require transfer to the ICU within 12 h?" This 100 mm line was anchored at each end to indicate 0% to 100% chance of ICU transfer. After making this prediction, clinicians used a 5-point Likert scale (with anchors that ranged from "completely uncertain" to "neutral" to "complete certain") to answer the question, "How certain are you of your prediction?"

Survey content and response process using the VAS were evaluated with clinicians prior to initiation of the study and again after collection of initial responses as mechanisms of establishing reliability of the instrument [27]. To ensure that the VAS would be used as intended, nurses received training during change-of-shift announcements, attending physicians and fellows were trained during staff meetings, and residents received email instructions and live demonstration upon beginning their rotation. The survey instrument is displayed in Fig. 1.

2.3. Study protocol

At the time of each patient transfer from the PED to the pediatric ward, the nurse, attending physician, fellow, and resident physician caring for that patient had the opportunity to voluntarily complete the survey, which was attached to standard admission paperwork. Voluntary completion of the survey was emphasized in order to minimize disruption to patient care and departmental flow.

All RRT activations during the study period were evaluated to identify events occurring within 12 h of admission from the PED that resulted in transfer to the PICU, NICU, or CTICU, or death on the pediatric ward. The 12-h interval was chosen based on the hospital's historical data and recommendation from the hospital's clinical committee that reviews all RRT activations, all of which are logged for quality improvement purposes. RRT activations not requiring ICU transfer were excluded as these generally reflected transient events (e.g., self-limited seizure, tachycardia relieved by fluid bolus, need for minor respiratory intervention such as suction), rather than significant clinical deterioration requiring ongoing critical care. For patients who required RRT activation, their medical records data were reviewed for medical history, nature of clinical deterioration, and subsequent critical care intervention.

2.4. Data analysis

Surveys were collected daily and data were entered and later analyzed in SPSS [IBM Statistical Package for the Social Sciences, Windows version 19, 2010; IBM Corp, Armonk, NY]. Survey summary statistics included frequencies, means, standard deviations, medians, and 95% confidence intervals (CI) of the mean. CIs were selected for interpretation, with non-overlapping CIs indicating significant differences between means [28]. Differences were evaluated between patients for whom surveys were or were not completed, using Chi-square for gender and ICU transfer, and CIs for age and admission PEWS.

Mixed model intraclass correlation with average measures (ICC) assessed consistency of VAS predictions across different clinician roles [29]. Pearson's r tested the correlations between VAS and PEWS, between predicted risk and prediction certainty, and between prediction certainty and clinician years of experience. Conventionally, values of Pearson's r between 0.10 and 0.29 are small effect sizes (i.e., substantial, albeit statistically weak, associations); values between 0.30 and 0.49 are moderate effect sizes (i.e., statistically moderate associations), and values at 0.50 or higher are large effect sizes (i.e., statistically strong associations) [30].

3. Results

During the 10-month study period, 58,570 patient visits took place in the PED and 5807 patients were admitted to the hospital (9.91%). A total of 5045 patients (86.88% of admissions) were admitted to the pediatric ward, 253 patients (4.36% of admissions) were admitted directly to the operating room, and 509 patients (8.77% of admissions) were admitted directly to an intensive care setting.

Participating clinicians included 90 registered nurses, 17 PEM attending physicians, 6 PEM fellows, and 216 rotating residents. As surveys were independently and voluntarily completed by each provider caring for a patient, each admission could be represented by up to four surveys. Of 5045 total ward admissions, 2892 (57%) were represented by at least one survey and were included as study patients for data analysis. A total of 4482 surveys were submitted for these 2892 admissions. Patients for whom surveys were completed were not different than patients for whom surveys were not completed in terms of gender, age, admission PEWS, or subsequent ICU transfer (Table 1).

A total of 22 patients required transfer from the pediatric ward to an ICU within 12 h of admission, 12 of whom were represented by at least one survey in the PED (57%). Twenty-one of these patients were transferred to the PICU and one to the NICU due to age and history of prematurity. These patients are described in Table 2. Nurses had significantly higher VAS scores for patients who subsequently required transfer to the ICU compared to those patients who did not (Table 3). For attending, fellow, and resident physicians, there was no significant difference in VAS scores between patients who did and did not require ICU transfer (Table 3). ICC for VAS scores between attending physicians and nurses was moderate at 0.52 [95%CI0.43–0.60,N = 557].

Table 4 shows the correlations between VAS and PEWS, between

Table 1
Deteriorating patient characteristics.

Patients	Surveys completed	Surveys not completed
Age	Mean = 6.7 years (SD = 6.23, CI: 6.5–7.0)	Mean = 7.1 years (SD = 6.3, CI: 6.8–7.3)
Gender	n = 1278 females (44.2%)	n = 935 females (43.4%)
PEWS Score	Mean = 0.54 (SD = 0.95, CI: 0.51–0.58) (Median = 0)	Mean = 0.52 (SD = 0.92, CI: 0.48–0.56) (Median = 0)
Transfer to PICU	n = 12 (0.41%)	n = 10 (0.46%)

Table 2
Characteristics of patients transferred to the PICU or NICU.

1. 12 yo M with chronic lung disease, home oxygen, gastric tube
2. 32 mo M with hemophagocytic lymphohistiocytosis, bone marrow transplant, chronic lung disease
3. 9 yo M with acute lymphoblastic leukemia, endocarditis, central line
4. 15 yo F with hypertriglyceridemia, diabetes, recurrent necrotizing pancreatitis
5. 3 mo F with genetic syndrome, congenital heart disease, gastric tube
6. 3 yo F with chromosomal deletion, seizures, chronic lung disease, home BiPAP
7 yo M with atypical teratoid rhabdoid tumor, central line, VPS
8. 5 yo M with cyclic vomiting syndrome
9 mo M otherwise healthy and admitted for croup
10. 5 yo M 26-week premature infant with TPN-dependence, central line, gastric tube
11. 14 yo F with Dandy Walker syndrome and seizure disorder, VPS, gastric tube
12. 3 wk M ex 34-week premature infant with grade 5 urinary reflux (Transfer to NICU.)
13. 16 yo F with mitochondrial disease, diabetes, TPN-dependence, central line, gastric tube
14. 5 yo M with trisomy 21, chronic lung disease and repaired congenital diaphragmatic hernia
15. 8 mo F with heterotaxy and congenital heart disease with Blalock-Taussig shunt
16. 20 mo M with genetic syndrome, tracheostomy and ventilator dependence, gastric tube
17. 2 mo M with congenital heart disease and Blalock-Taussig shunt
18. 14 mo M with congenital heart disease, tracheostomy, gastric tube
19. 27 mo M ex 25-week premature infant with chronic lung disease, home oxygen
20. 8 yo F with mitochondrial disease, TPN-dependence, central line, gastric tube
21. 7 yo M with astrocytoma, VPS, and hypopituitarism
22. 6 yo F with hydrocephalus and VPS

BiPap: bilevel positive airway pressure; VPS: ventriculo-peritoneal shunt; TPN: total parenteral nutrition.

VAS and prediction certainty, and between prediction certainty and clinician years of experience. VAS and PEWS were correlated positively for each clinician type (Table 4). Prediction certainty was inversely related to predicted risk of deterioration (Table 4 and Figs. 2–5). Prediction certainty correlated positively with years of experience for nurses and residents, but not for attendings and fellows, for whom they were inversely correlated (Table 4). Nurses and attending physicians expressed greater certainty regarding patients for whom they had continuity of care than for patients they received as a hand-off (Table 5).

4. Discussion

Prognostic accuracy of physician and nursing staff has been variably reported in previous studies. Bradman et al., for example, found that triage nurses were more accurate at prospectively predicting admission to the hospital, compared to scoring algorithms [20]. As another example, Stevens et al. found that predictions of NICU mortality by nurses and physicians were similar to one another and to a scoring algorithm, with both clinician groups overestimating mortality [23]. In our study, we found that nurses assigned a higher risk of deterioration for patients who did indeed go on to require ICU transfer. Accuracy of predictions by nurses may be attributed to the nurse-initiated nature of most RRT activations on the ward and to more time spent at the bedside in the PED. While each nurse manages up to four patients concurrently, an attending physician is responsible for up to 30 patients and for overall department flow, resulting in less time at the bedside of each patient.

Table 4
Correlations.

Correlates	Clinician Type	N	Pearson Correlation Coefficient (*r*)
Predicted risk of deterioration (VAS*) and PEWS	Nurse	1216	0.29**
	Attending	1621	0.18**
	Fellow	254	0.35**
	Resident	923	0.20**
Predicted risk of deterioration (VAS) and prediction certainty	Nurse	1328	−0.51**
	Attending	1804	−0.57**
	Fellow	286	−0.53**
	Resident	1030	−0.44**
Prediction certainty and years of experience	Nurse	1326	0.36**
	Attending	1805	−0.01
	Fellow	286	−0.05
	Resident	1029	0.16**

* Visual Analog Scale (VAS); $^{**}p \leq 0.01$

Our study finding of an inverse correlation between predicted risk of deterioration and prediction certainty offers insight into the cognitive challenge of clinical medicine. In a study of dyspneic adult patients in the emergency department, clinical uncertainty was associated with higher rates of morbidity and mortality [31]. In the present study, clinicians expressed less certainty about patients to whom they assigned a higher risk of deterioration. This highlights the clinical dilemma of patients who are not sufficiently ill to warrant admission to an ICU, yet are ill enough to raise prediction uncertainty. Prediction certainty correlated with level of experience for nurses and residents, but not for other types of clinicians. While Sklar et al. demonstrated that uncertainty exists at all levels, Lingard et al. described how areas of uncertainty, as well as the portrayal and management of that uncertainty, shift over the course of medical training [32,33]. They point out that, although novices express more uncertainty regarding their own limited knowledge, experienced teachers also acknowledge and accept both individual uncertainty as well as uncertainty intrinsic to the practice of medicine.

The challenge then becomes to channel this uncertainty to increase patient safety, perhaps by increasing observation time or by garnering additional feedback from the bedside nurse. A report by the Institute of Medicine, entitled “To Err is Human,” highlights the importance of developing meaningful and reproducible measures to improve the safety of healthcare systems [1]. Our study demonstrates the ability of caretakers to express their subjective misgivings objectively. The results may be used to support the design of simulation drills for both novice and experienced providers to preempt patient deterioration [34]. Alternatively, models similar to inpatient situation awareness systems can be built that incorporate “clinician gut feeling” [35]. Brady et al. incorporated “clinician gut feeling” with other risk assessments, such as high PEWS, to develop a mitigation plan for patients, which decreased situation awareness failures defined as unexpected ICU transfer [35].

Another risk factor to consider is the discontinuity of care, particularly with the many shift changes that occur in an emergency department. Attending physicians and nurses expressed less certainty in cases for which they assumed patient care from a previous provider than in cases for which they had continuity of care. The role of handoffs

Table 3
Accuracy of predicted risk of deterioration, visual analog scale (VAS).

Clinician type	VAS scores for patients transferred to PICU					VAS scores for patients not transferred to PICU				
	N	Mean	SD	CI	Median	N	Mean	SD	CI	Median
Nurse	7	48.43	25.05	25.26–71.60	53	1340	18.14	17.12	17.23–19.06	14
Attending	9	19.11	17.62	5.57–32.65	16	1801	11.10	14.54	10.42–11.77	7
Fellow	3	35.67	15.63	0–74.50	38	285	12.77	16.53	10.84–14.70	6
Resident	5	28.60	15.77	9.01–48.19	28	1032	20.55	15.65	19.59–21.51	17

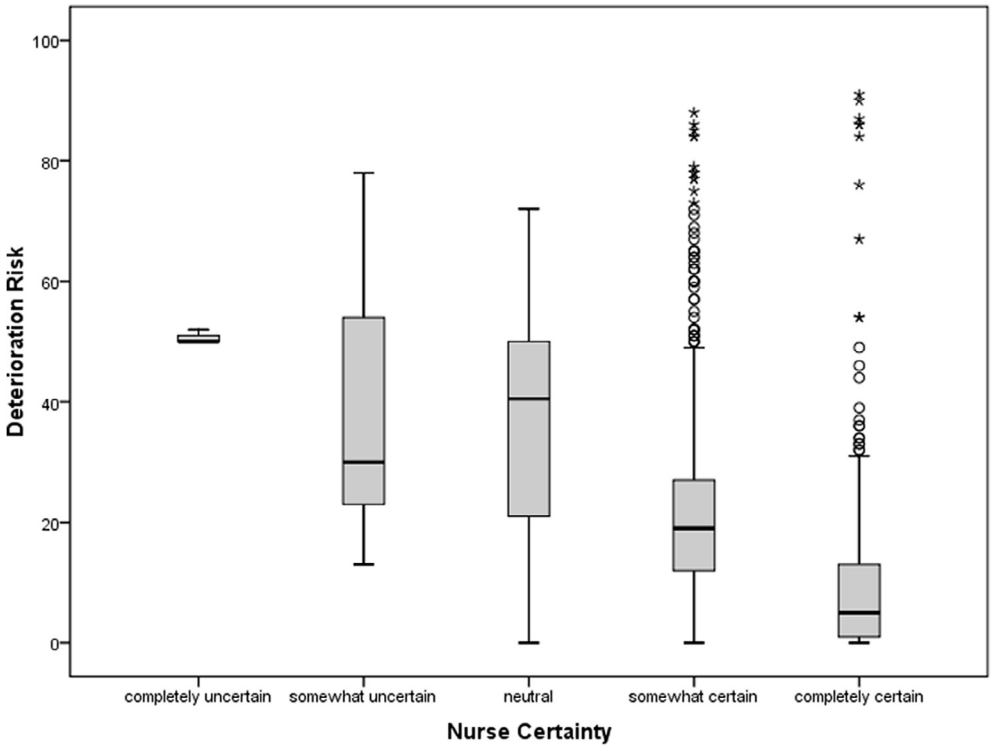

Fig. 2. Nurses' predicted risk of deterioration versus level of certainty. Values above the 90th and 95th percentiles are noted by a circle and asterisk, respectively.

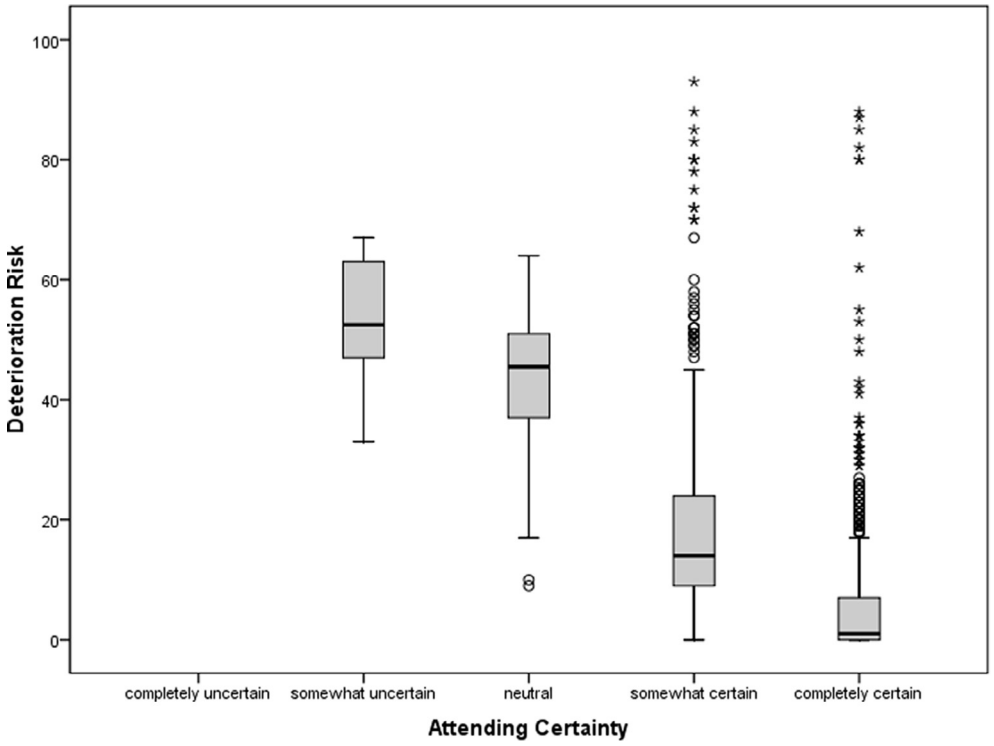

Fig. 3. Attending physicians' predicted risk of deterioration versus level of certainty. Values above the 90th and 95th percentiles are noted by a circle and asterisk, respectively.

in patient safety has been highly scrutinized following limitations on trainee work-hours and is the subject of interventions to implement standardized communication in order to improve patient safety [36,37]. This study illustrates that patient handoffs, even at the attending level, add to the uncertainty in provider predictions. Moreover, both discontinuity of care and clinician gut feeling may be risk factors addressed, at least partly, through increased observation time in the emergency department or with standardized multidisciplinary transfer protocols [38].

Of the 22 patients requiring transfer to the ICU within 12 h, 21 had complex medical conditions including underlying genetic, cardiac, pulmonary, or oncologic disease, many of whom were technology-

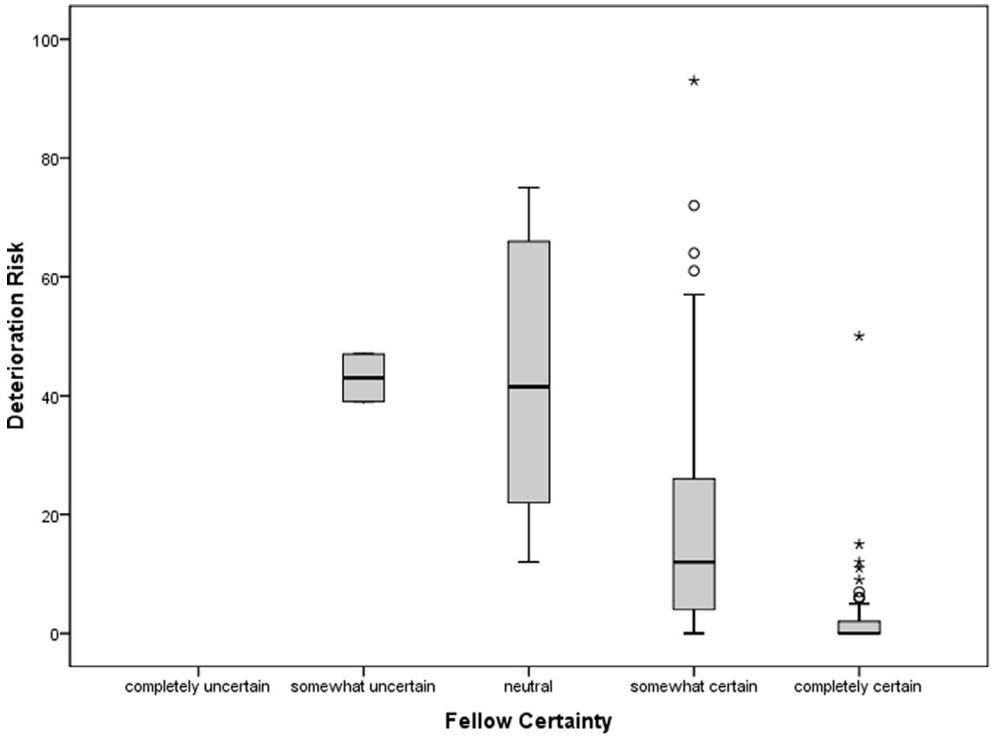

Fig. 4. Fellows' predicted risk of deterioration versus level of certainty. Values above the 90th and 95th percentiles are noted by a circle and asterisk, respectively.

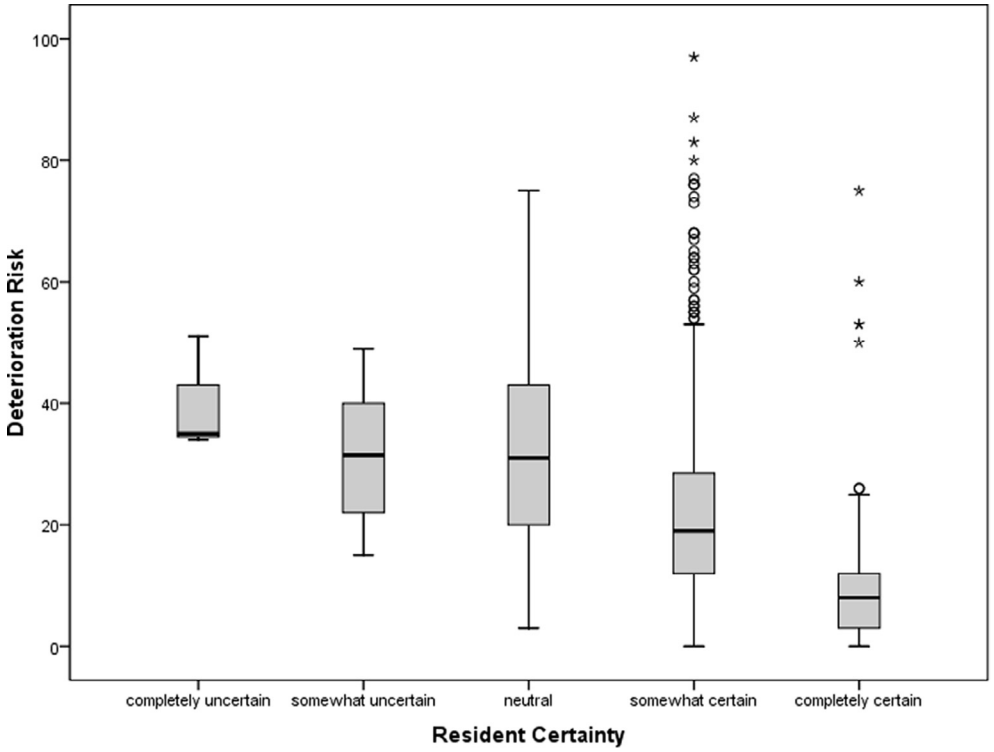

Fig. 5. Residents' predicted risk of deterioration versus level of certainty. Values above the 90th and 95th percentiles are noted by a circle and asterisk, respectively.

dependent. The precarious status of these patients is a perpetual challenge to medical decision-making given their high baseline risk of clinical deterioration. Although this study took place in a tertiary-care children's hospital, 79% of ED visits by medically complex children occur in general EDs [39]. Simon et al. showed that these children are increasingly the disproportionate subjects of inpatient care, with 10% of admissions, 25% of hospital days, 40% of hospital charges, and 43% of inpatient deaths among US children in 2006 [40]. The higher medical risk of these patients was borne out in the current study when medically-complex children were the overwhelming majority of a rare and resource-intensive event. Indeed, Zipkin et al. demonstrated a decrease in the number of RRT activations after implementing a dedicated unit for admitting patients with congenital heart disease, one of the comorbidities identified in our study [41]. Similar to the dedicated

Table 5
Prediction certainty and continuity of care.

Clinician Type	Clinician certainty for patients with continuity of care					Clinician certainty for patients without continuity of care				
	N	Mean	SD	CI	Median	N	Mean	SD	CI	Median
Nurse	634	4.36	0.63	4.31–4.41	4	686	4.26	0.74	4.20–4.31	4
Attending	873	4.65	0.54	4.61–4.69	5	920	4.56	0.57	4.52–4.59	5
Fellow	228	4.32	0.56	4.25–4.40	4	55	4.22	0.50	4.08–4.35	4
Resident	651	4.11	0.64	4.06–4.16	4	362	4.02	0.73	3.95–4.10	4

cardiac unit described by Zipkin et al., a system of non-ICU units may be designed specifically for patients with technological dependence, patients with recurrent seizures, and patients on high-flow nasal cannula therapy [41,42].

Our study demonstrates the value of a team approach to patient care, of considering clinicians' subjective evaluation of patient status, and of having extra precaution with patient handoffs and when caring for medically complex children. As nurses performed most accurately in predicting subsequent clinical deterioration, their input is a valuable contribution to disposition decisions. Rather than relying on scoring algorithms that do not provide a full clinical impression, intentional consideration and quantification of clinicians' subjective predictions may be incorporated into patient safety initiatives. As Marcin et al. demonstrated, combined severity scores and provider predictions performed better together [26]. These initiatives should also dedicate additional resources to meeting the needs of medically complex patients in the PED and to examining different inpatient health systems in managing medically complex patients. Additional research is needed on how to best teach clinicians the value of addressing their uncertainty so that they may better recognize deteriorating patients and pragmatically intervene.

5. Limitations

This study was subject to the inherent methodological challenge of examining an event as rare as pediatric in-hospital deterioration. Previous definitions of deterioration have included code-blue events, RRT activations, or initiation of critical care interventions such as intubation or vasopressor infusion [43]. This study evaluated all RRT events, but defined clinical deterioration as requiring transfer to the ICU in order to maintain the highest possible degree of objectivity with the understanding that even initiation of pulmonary and cardiovascular support is dependent upon clinical judgment. The small number of RRT events limited further statistical analysis of the effects of years of experience and continuity of care on accuracy of predictions.

Despite the small number of RRT events, the overwhelming majority of them involved patients with comorbidities. The study being conducted in a tertiary care children's hospital, where there is greater volume of medically complex patients likely contributing to this finding and probably to greater ICU admission rates, making it less generalizable to other settings. Even though patients with comorbidities may be evaluated in general community emergency departments, they are often transferred to tertiary children's hospitals, not contributing to inpatient hospital events in community settings [44].

Our response rate of 57% and lack of qualitative feedback reflect the challenges of a data collection strategy that depends on clinicians' time, especially at the moment of transfer from the PED when priorities of department flow and individual patient care intersect. However, patients for whom surveys were completed did not differ from patients for whom surveys were not completed. The study may be limited in generalizability to other institutions due to variability in acuity of PED patients and criteria for admission to critical care units.

6. Conclusions

For patients who do not meet criteria for critical care at the time of admission, there is greater uncertainty in clinician predictions. Clinicians are more certain of their predictions with increasing experience, continuity of care, and when predicted risk is low. It may be prudent to increase emergency department observation time and to reevaluate patients when clinicians sense possible deterioration or are uncertain of future status, when there is discontinuity of care, and when caring for patient with comorbidities increase the risk of deterioration.

7. Conflict of interest

None.

8. Ethical statement

We take responsibility for the reported research. We have participated in the concept and design, analysis and interpretation of data, and revising of the manuscript. We approve the manuscript as submitted. An Institutional Review Board reviewed approved the research.

9. Funding

None

10. Other disclosures

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