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Types of diagnostic errors reported by paediatric emergency providers in a global paediatric emergency care research network

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ABSTRACT

Background Diagnostic errors, reframed as missed opportunities for improving diagnosis (MOIDs), are poorly understood in the paediatric emergency department (ED) setting. We investigated the clinical experience, harm and contributing factors related to MOIDs reported by physicians working in paediatric EDs.

Methods We developed a web-based survey in which physicians participating in the international Paediatric Emergency Research Network representing five out of six WHO regions, described examples of MOIDs involving their own or a colleague's patients. Respondents provided case summaries and answered questions regarding harm and factors contributing to the event.

Results Of 1594 physicians surveyed, 412 (25.8%) responded (mean age=43 years (SD=9.2), 42.0% female, mean years in practice=12 (SD=9.0)). Patient presentations involving MOIDs had common undifferentiated symptoms at initial presentation, including abdominal pain (21.1%), fever (17.2%) and vomiting (16.5%). Patients were discharged from the ED with commonly reported diagnoses, including acute gastroenteritis (16.7%), viral syndrome (10.2%) and constipation (7.0%). Most reported MOIDs (65%) were detected on ED return visits (46% within 24 hours and 76% within 72 hours). The most common reported MOID was appendicitis (11.4%), followed by brain tumour (4.4%), meningitis (4.4%) and non-accidental trauma (4.1%). More than half (59.1%) of the reported MOIDs involved the patient/parent–provider encounter (eg, misinterpreted/ignored history or an incomplete/inadequate physical examination). Types of MOIDs and contributing factors did not differ significantly between countries. More than half of patients had either moderate (48.7%) or major (10%) harm due to the MOID.

Conclusions An international cohort of paediatric ED physicians reported several MOIDs, often in children who presented to the ED with common undifferentiated symptoms. Many of these were related to patient/parent–provider interaction factors such as suboptimal history and physical examination. Physicians' personal experiences offer an underexplored source for investigating and mitigating diagnostic errors in the paediatric ED.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Emergency care in paediatrics is challenging because of children's unique physiology and difficulties with communication. Prior studies suggest that there are approximately 1.25 million instances of diagnostic errors in the USA among the 25 million annual paediatric emergency department visits.

WHAT THIS STUDY ADDS

⇒ In this survey study, multitudinous paediatric emergency physicians from a global research network shared cases of diagnostic errors underscoring their global burden, importance and shared contributory factors.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The survey results suggest the need to develop systematic approaches to measuring diagnostic errors, which could then enable both local and wider global learning to reduce error rates.

BACKGROUND

Errors in diagnosis are common in the emergency department (ED) because decisions are made under time constraints, under stress, often with inadequate information, involving illnesses that vary in severity or that have evolved insufficiently to allow for diagnostic certainty.[1] Emergency care in children is particularly challenging because of a child's unique physiology and difficulties with communication. The global burden of diagnostic errors in paediatric emergency care remains largely unknown, but conservative estimates of 5% frequency in ambulatory settings translates to approximately 1.25 million instances of diagnostic errors in the USA among the 25 million annual paediatric ED visits.[2–4] These data underscore the

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urgency to investigate the causes of, and harms from, these diagnostic errors in the paediatric ED.

The causes of diagnostic errors are complex, multifactorial and influenced by patient, provider and system factors. Importantly, the ED provider is almost always at the centre of the diagnostic process; and, by some estimates, approximately 75% of errors have a cognitive component and approximately 80% involve a cognitive error during the patient/parent–provider encounter.[5–8] Despite this, few studies investigating clinician perspectives on the causes of diagnostic errors exist in the literature and to our knowledge, there are no studies focused on the paediatric emergency setting.[9 10]

To facilitate data gathering of diagnostic errors from ED physicians, we pragmatically defined them as missed opportunities for improving diagnosis (MOIDs) regardless of patient harm.[3 11–13] In the context of an ED visit, an MOID would be a case where sufficient data to suggest the final, correct diagnosis was present at the first ED/index visit or in which documented abnormal findings at the index visit should have prompted additional evaluation that would have revealed the correct, ultimate diagnosis. Most paediatric ED studies on MOID have been from the USA. To obtain an international perspective on diagnostic errors, we surveyed providers at 71 EDs across 6 countries participating in a large multicentre Paediatric Emergency Research Network (PERN; https://pern-global.com/) to solicit deidentified instances of diagnostic errors, their contributory factors and resultant patient harm.[14]

METHODS

Patient and public involvement

Patients were not involved in this study.

Study design and survey development

We designed and administered a survey using the Qualtrics (Qualtrics, Provo, Utah, USA) online survey platform to paediatric ED providers to solicit specific examples of MOIDs. Respondents provided a briefcase summary of either their own or a colleague's patient encounter and answered questions regarding resulting harm and factors contributing to the event. The survey (online supplemental file 1) was evaluated for construct and face validity and iteratively refined by 10 paediatric emergency medicine physicians at the University of Michigan. Survey questions were mainly closed-ended, although additional open-ended questions allowed participants to express opinions or to provide clarification of responses. The survey was administered from December 2018 to October 2019.

Participants and survey distribution

Survey participation was voluntary, and respondents did not receive any incentives. The survey was distributed to ED physicians participating in the PERN, a consortium of global paediatric emergency care research networks.[15] PERN is a collaborative network of seven paediatric emergency care research networks including: (A) Research in European Paediatric Emergency Medicine (REPEM), (B) Paediatric Emergency Care Applied Research Network (PECARN), (C) Pediatric Emergency Medicine Collaborative Research Committee of the American Academy of Pediatrics, (D) Paediatric Emergency Research Canada (PERC), (E) Paediatric Research in Emergency Departments International Collaborative, (F) Paediatric Emergency Research in the United Kingdom and Ireland (PERUKI) and (G) Red de Investigación de la Sociedad Española de Urgencias de Pediatría (RISeuP)/Spanish Paediatric Emergency Research Grou. Together, the 7 research networks manage >2 million paediatric emergency presentations per annum, in 71 hospitals, in 5 of the 6 WHO regions.[14] Each participating network within PERN identified a lead investigator who was responsible for providing a list of sites and site champions from their network. Site champions completed a brief survey describing their ED characteristics and provided names and emails of potential participants at their site. These names and email IDs were used to create unique personal survey links that were emailed to each potential participant, which were used for measurement of response rate and to send a follow-up with requests to complete the partial responses. Each potential participant received up to two reminders to start the survey, and those with partial responses received a third reminder to complete the survey, if needed.

Definition of diagnostic error: Investigators from our group have successfully operationalised the measurement of diagnostic errors by viewing them as missed opportunities to make a correct or timely diagnosis regardless of patient harm.[3 11–13] We provided the following example to assist the providers in describing an instance of a missed opportunity they may have experienced.

> Briefcase summary: A 2-month-old male child presented to the ED with non-bilious vomiting for 1 week and failure to thrive. The physical examination revealed a normal appearing infant without obvious dehydration.
> Diagnosis and disposition at first ED visit: Gastro-oesophageal reflux and discharged home.
> Final, correct diagnosis: Patient came back with persistent vomiting 36 hours later, an ultrasound revealed a hypertrophic pyloric stenosis.
> MOID: Although reflux as well as many other aetiologies can cause vomiting, hypertrophic pyloric stenosis should be a differential diagnosis at the initial visit and not obtaining or arranging for an ultrasound abdomen represents an MOID.

Outcomes: The primary outcome was to describe the frequency of conditions that could have been diagnosed at initial or index ED evaluation. The secondary outcomes were descriptions of the contributory factors and patient harm from MOIDs, with stratification and analysed by individual network. We created a categorisation system based on body systems (online supplemental table 1) for index and repeat ED visit complaints and diagnoses. For example, patients presenting with vomiting were categorised as having a gastrointestinal system condition while those presenting with headaches

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were categorised as having central nervous system conditions. If the patients were diagnosed with acute gastroenteritis at the index ED visit, they were categorised as having a gastrointestinal diagnosis. On repeat ED visit, if they were diagnosed with appendicitis, they were then categorised as having a gastrointestinal system final diagnosis. However, if the patient had a diagnosis of intracranial tumour, then they were categorised as having an oncological condition.

Contributory factors to MOIDs were categorised by adapting the diagnostic process dimensions described in the Safer Dx Framework.[16] These dimensions are described in the survey (online supplemental file 1) and include the following categories: (A) patient-related factors (eg, delay in seeking care, language barriers, caregiver factors adversarial or incomplete history, left against medical advice), (B) patient/parent–provider encounter factors (eg, problems with patient history such as incomplete or misinterpreted history, problems with physical examination such as incomplete or misinterpreted examination findings, failure to review prior records, failure to order an indicated diagnostic test), (C) diagnostic tests (ordered but not performed or not interpreted appropriately), (D) follow-up/tracking factors related to tests and referrals, (E) consultations (not ordered, not available, contradictory recommendations, etc) and (F) miscellaneous factors (workload too high, lack of resources, institutional factors, etc).

Statistical analysis

We performed descriptive statistics including absolute and relative frequencies or means with SDs or medians with IQRs, as appropriate, to compare all survey question responses. We present summary statistics for the entire cohort and display differences stratified by individual research network. We used SAS V.9.4 (SAS Institute) for all quantitative analyses and report our results using elements from the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE), The SUrvey Reporting GuidelinE (SURGE) and Checklist for Reporting Results of Internet E-Surveys (CHERRIES) guidelines.[17–20]

RESULTS

The survey was distributed to 1594 physicians across all participating EDs in PERN, of whom 412 (25.8%) responded. Mean age of respondents was 43 years (SD 9.3), and mean years in practice was 12.0 (SD 9.0); 58.0% identified as male. The response rate by participating network is given in figure 1. Providers worked a median 11.0 (IQR 6.0) shifts per month. Distribution by training included 67% PEM, 10.2% paediatrician, 9.2% PEM in training, 3.9% general EM, with the remainder of participants indicating that they received both PEM and general EM training. Six of the seven networks in PERN contributed to MOIDs cases, and the distribution of participants

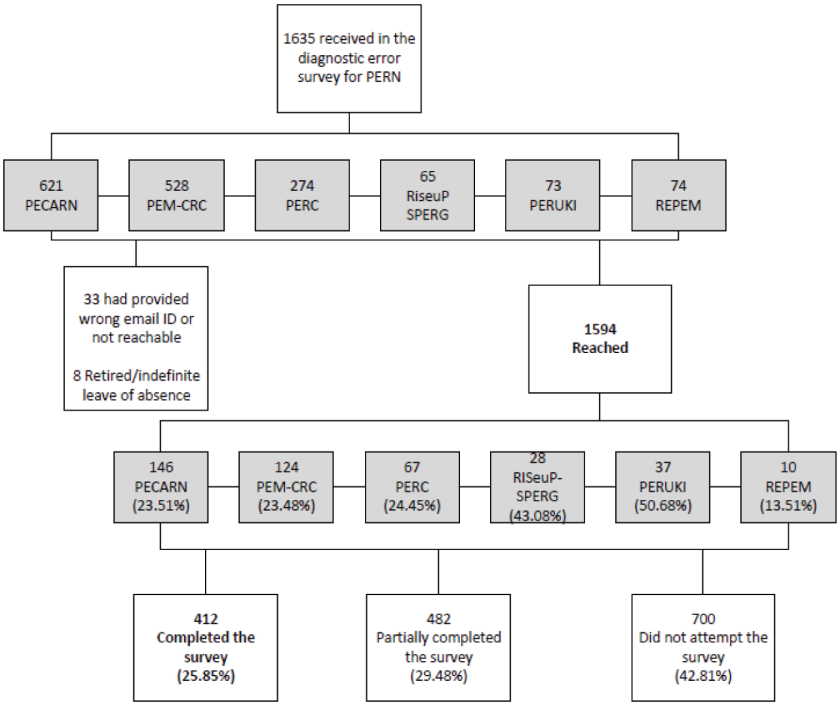

Figure 1 MOIDs study recruitment flow chart. MOIDs, missed opportunities for improving diagnosis; PERN, Paediatric Emergency Research Network; PECARN, Paediatric Emergency Care Applied Research Network; PEM-CRC, Paediatric Emergency Medicine Collaborative Research Committee; PERC, Paediatric Emergency Research Canada; PERUKI, Paediatric Emergency Research in the United Kingdom and Ireland; RISeuP/SPERG, Red de Investigación de la Sociedad Española de Urgencias de Pediatría/Spanish Paediatric Emergency Research Group; REPEM, Research in European Paediatric Emergency Medicine.

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Table 1 Ten most frequently reported presenting symptoms at index ED visit in entire cohort and by network

	All networks n (%)	PECARN (n=146, 35.4%)	PEMCRC (n=124, 30.1%)	PERC (n=67, 16.3%)	PERUKI (n=37, 9.0%)	RISeuP (n=28, 6.8%)	REPEM (n=10, 2.4%)
1. Abdominal pain	87 (21.1%)	33 (22.6%)	31 (25.0%)	12 (17.9%)	5 (13.5%)	6 (21.4%)	0 (0.0%)
2. Fever	71 (17.2%)	19 (13.0%)	20 (16.1%)	17 (25.4%)	6 (16.2%)	7 (25.0%)	2 (20.0%)
3. Vomiting	68 (16.5%)	27 (18.5%)	24 (19.4%)	6 (9.0%)	3 (8.1%)	6 (21.4%)	2 (20.0%)
4. Headache	35 (8.5%)	13 (8.9%)	13 (10.5%)	6 (9.0%)	1 (2.7%)	2 (7.1%)	0 (0.0%)
5. Injury or pain	26 (6.3%)	4 (2.7%)	9 (7.3%)	4 (6.0%)	8 (21.6%)	1 (3.6%)	0 (0.0%)
6. Cough	15 (3.6%)	5 (3.4%)	3 (2.4%)	5 (7.5%)	1 (2.7%)	0 (0.0%)	1 (10.0%)
7. Difficulty breathing	11 (2.7%)	5 (3.4%)	3 (2.4%)	2 (3.0%)	0 (0.0%)	1 (3.6%)	0 (0.0%)
8. Arm pain or injury	8 (1.9%)	3 (2.1%)	2 (1.6%)	0 (0.0%)	1 (2.7%)	1 (3.6%)	1 (10.0%)
9. Fall	8 (1.9%)	2 (1.4%)	3 (2.4%)	2 (3.0%)	1 (2.7%)	0 (0.0%)	0 (0.0%)
10.Chest pain or injury	7 (1.7%)	3 (2.1%)	1 (0.8%)	1 (1.5%)	2 (5.4%)	0 (0.0%)	0 (0.0%)
All others*	69 (16.7%)	30 (20.5%)	13 (10.5%)	11 (16.4%)	7 (18.9%)	4 (14.3%)	4 (40.0%)

*The 'all others' category included symptoms (eg, anxiety; back pain) reported by less than 1.7% of participants.
ED, emergency department; PECARN, Paediatric Emergency Care Applied Research Network; PEMCRC, Paediatric Emergency Medicine Collaborative Research Committee; PERC, Paediatric Emergency Research Canada; PERUKI, Paediatric Emergency Research in the United Kingdom and Ireland; REPEM, Research in European Paediatric Emergency Medicine; RISeuP, Red de Investigación de la Sociedad Española de Urgencias de Pediatría.

by network was PECARN (35.4%), PEM-CRC (30.1%), PERC (16.3%), PERUKI (9.0%), RISeuP (6.8%) and REPEM (2.4%).

Most (62.3%) of the MOIDs involved the reporting clinicians themselves either in isolation or as a part of the clinical care team; while 10.7% were observations of care in which they were not directly involved. The median time in hours to discovery of the MOIDs was 36.0 hours (IQR 52.0); 75.8% were recognised within 72 hours and 87.8% were detected within 7 days. Almost two-thirds reported that the correct diagnosis was made on a repeat ED visit; 6.8% and 2.4% stated the correct diagnosis was made in the in-patient or intensive care unit setting, respectively. Approximately, 1% also mentioned that the correct diagnosis was made at autopsy.

Most patients with MOIDs presented initially with common undifferentiated symptoms, such as abdominal pain (21.1%), fever (17.2%), vomiting (16.5%) and headache (8.5%%) (table 1). Abdominal pain was either the most common or a very common presenting symptom when MOIDs were stratified by individual research network. Acute gastroenteritis (16.7%), viral syndrome (10.2%), constipation (7.0%) and migraine (4.1%) were the top four discharge diagnoses at the index ED visit, and this pattern was largely maintained when stratified by individual research networks (table 2). Participants provided instances of missed appendicitis as the most common MOID overall, in the total dataset and when stratified by network (table 3). Brain tumour, meningitis, non-accidental trauma, pneumonia and intussusception were the other common MOIDs reported by participants.

Difficulties arising from patient/parent–provider interactions were the most frequently cited contributing factor (59.1%) in the total dataset and in all except two networks. Incomplete history-taking or performance of physical examination was identified as a factor within the patient/parent–provider encounter in all but two networks (online supplemental table 2)

More than half of the reported MOIDs led to either moderate (48.7%) or major (10.0%) harm as a result of the MOIDs, while 35% had mild harm and 6.4% reported no harm to the patient (online supplemental figure 1).

DISCUSSION

In this study, a large number of paediatric emergency physicians from a global research network shared cases of diagnostic errors underscoring their global burden, importance and shared contributory factors. Types of errors and contributing factors were common across international regions, suggesting areas for targeted interventions to reduce diagnostic errors globally. Physicians' personal experiences offer an underexplored source for investigating such errors and may provide valuable qualitative information into the cognitive processes and systems factors contributing to MOIDs.

Our study builds on a previous US-based study involving a convenience sample of 310 physicians, including general internists, medical specialists and emergency physicians, who voluntarily reported 583 cases of diagnostic errors.[9] We intentionally focused on obtaining perspectives of paediatric ED providers and leveraged a pre-existing international cohort of research networks to achieve a broader understanding of the challenges faced in this unique practice environment. Contributory factors and level of harm were assessed by questions

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Table 2 Ten most frequent discharge diagnosis at index ED visit in entire cohort and by network

	All networks combined n (%)	PECARN (n=146, 35.4%)	PEMCRC (n=124, 30.1%)	PERC (n=67, 16.3%)	PERUKI (n=37, 9.0%)	RISeuP (n=28, 6.8%)	REPEM (n=10, 2.4%)
1. Acute gastroenteritis	69 (16.7%)	22 (17.1%)	27 (21.8%)	5 (7.5%)	4 (10.8%)	7 (25.0%)	1 (10.0%)
2. Viral upper respiratory infection (URI) or viral infection	42 (10.2%)	13 (8.9%)	8 (6.5%)	10 (14.9%)	4 (10.8%)	5 (17.9%)	2 (20.0%)
3. Constipation	29 (7.0%)	10 (6.8%)	12 (9.7%)	5 (7.5%)	1 (2.7%)	1 (3.6%)	0 (0.0%)
4. Migraine	17 (4.1%)	4 (2.7%)	6 (4.8%)	5 (7.5%)	1 (2.7%)	1 (3.6%)	0 (0.0%)
5. Contusion	15 (3.6%)	5 (3.4%)	4 (3.2%)	1 (1.5%)	2 (5.4%)	1 (3.6%)	2 (20.0%)
6. Gastro-oesophageal reflux disease	14 (3.4%)	5 (3.4%)	4 (3.2%)	3 (4.5%)	1 (2.7%)	1 (3.6%)	0 (0.0%)
7. Musculoskeletal pain	12 (2.9%)	3 (2.1%)	3 (2.4%)	3 (4.5%)	3 (8.1%)	0 (0.0%)	0 (0.0%)
8. Abdominal pain non-specific	10 (2.4%)	7 (4.8%)	2 (1.6%)	1 (1.5%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
9. Urinary tract infection	10 (2.4%)	5 (3.4%)	2 (1.6%)	3 (4.5%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
10. Bronchiolitis	8 (1.9%)	3 (2.1%)	2 (1.6%)	2 (3.0%)	0 (0.0%)	1 (3.6%)	0 (0.0%)
All others*	186 (45.1%)	66 (45.2%)	54 (43.5%)	29 (43.3%)	21 (56.8%)	11 (39.3%)	5 (50.0%)

*The 'all others' category included discharge diagnoses (eg, ear infection; seizure) in less than 1.9% of participants.
ED, emergency department; PECARN, Paediatric Emergency Care Applied Research Network; PEMCRC, Paediatric Emergency Medicine Collaborative Research Committee; PERC, Paediatric Emergency Research Canada; PERUKI, Paediatric Emergency Research in the United Kingdom and Ireland; REPEM, Research in European Paediatric Emergency Medicine; RISeuP, Red de Investigación de la Sociedad Española de Urgencias de Pediatría.

based on newer frameworks (National Academies of Science, Engineering, and Medicine and Safer Dx framework),[2 16] but we found similar proportions of harm to patients compared with that study. Although the cases were self-reported in both studies and direct comparison between the two studies is not possible, only 10.0% of the

Table 3 Ten most frequently reported MOIDs in the entire cohort and by network

	All networks combined n (%)	PECARN (n=146, 35.4%)	PEMCRC (n=124, 30.1%)	PERC (n=67, 16.3%)	PERUKI (n=37, 9.0%)	RISeuP (n=28, 6.8%)	REPEM (n=10, 2.4%)
1. Appendicitis	47 (11.4%)	17 (11.6%)	15 (12.1%)	8 (11.9%)	3 (8.1%)	4 (14.3%)	0 (0.0%)
2. Brain tumour	18 (4.4%)	6 (4.1%)	7 (5.6%)	2 (3.0%)	1 (2.7%)	1 (3.6%)	1 (10.0%)
3. Meningitis	18 (4.4%)	6 (4.1%)	2 (1.6%)	7 (10.4%)	1 (2.7%)	2 (7.1%)	0 (0.0%)
4. Non-accidental trauma	17 (4.1%)	12 (8.2%)	4 (3.2%)	0 (0.0%)	1 (2.7%)	0 (0.0%)	0 (0.0%)
5. Pneumonia	16 (3.9%)	4 (2.7%)	6 (4.8%)	4 (6.0%)	0 (0.0%)	1 (3.6%)	1 (10.0%)
6. Intussusception	16 (3.9%)	6 (4.1%)	5 (4.0%)	2 (3.0%)	2 (5.4%)	1 (3.6%)	0 (0.0%)
7. Diabetic ketoacidosis	11 (2.7%)	6 (4.1%)	2 (1.6%)	0 (0.0%)	0 (0.0%)	2 (7.1%)	1 (10.0%)
8. Sepsis	8 (1.9%)	3 (2.1%)	3 (2.4%)	0 (0.0%)	2 (5.4%)	0 (0.0%)	0 (0.0%)
9. Ovarian torsion	6 (1.5%)	0 (0.0%)	5 (4.0%)	0 (0.0%)	1 (2.7%)	0 (0.0%)	0 (0.0%)
10. Urinary tract infection	5 (1.2%)	1 (0.7%)	1 (0.8%)	1 (1.5%)	0 (0.0%)	2 (7.1%)	0 (0.0%)
All others*	250 (60.7%)	85 (58.2%)	74 (59.7%)	43 (64.2%)	26 (70.3%)	15 (53.6%)	7 (70.0%)

*The 'all others' category included MOIDs (eg, abscess; measles) reported by less than 1.2% of participants.
MOIDs, missed opportunities for improving diagnosis; PECARN, Paediatric Emergency Care Applied Research Network ; PEMCRC, Paediatric Emergency Medicine Collaborative Research Committee; PERC, Paediatric Emergency Research Canada; PERUKI, Paediatric Emergency Research in the United Kingdom and Ireland; REPEM, Research in European Paediatric Emergency Medicine; RISeuP, Red de Investigación de la Sociedad Española de Urgencias de Pediatría.

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reported cases had major harm, compared with 28% in the prior study.

Nearly two-thirds (62.3%) of respondents in this study reported MOIDs in which they were personally involved, and ~93% of reported cases involved some degree of patient harm with 58.7% classified as major/moderate. This proportion is lower than that reported (82.3%) in a previous multicentre study of US-based academic paediatric providers but higher than an Irish study of paediatricians and paediatric residents (44.1%). This likely represents the fact that we did not limit respondents to describing only cases in which they were involved. Nonetheless, these figures underscore that MOIDs contribute significantly to patient harm.[21–23]

Diagnostic safety experts cite the need for feedback and calibration as prerequisites to improve diagnostic expertise.[24] The characteristics of ED care assures that paediatric ED providers are unlikely to learn of their MOIDs unless there is significant associated harm. A potential solution to this problem could include better feedback processes for patients with high-risk conditions (eg, abdominal pain and headache), such as follow-up telephone calls to patients after ED discharge or critical review of cases with return visits to the ED. Among the cases described by respondents, the subsequent final correct diagnoses included many life-threatening conditions that paediatric ED providers are well trained to detect, and know must not be missed (myocarditis, bacterial meningitis, appendicitis and child abuse). However, these were not detected despite the presence of clinical information suggesting evidence existing that should have led to a correct diagnosis. This mirrors a study by Okafor *et al* examining cases of diagnostic errors reported by general emergency providers in which the most common missed cases included must-not-miss diagnoses typical of that practice setting: sepsis, myocardial infarction, fractures, vascular injuries and stroke.[8] These cases are likely to come to the clinician's attention through departmental or institutional safety surveillance mechanisms. However, clinicians often do not report diagnostic errors or may not report errors with minor harm,[25] which suggests the need for alternative mechanisms to supplement error reporting. About 75% of MOIDs became apparent within 72 hours and almost 65% were discovered during a subsequent ED encounter, suggesting that automated return visit evaluation could be potential quality improvement tools for identifying diagnostic errors and alerting clinicians for the need to review their decision-making at a prior encounter.[26 27]

Our study has several limitations. Despite soliciting broad, international participation, the overall survey response rate was low and suffers from possible reporting bias, recall bias (providers may remember only those cases which had significant outcomes) and availability bias. We mitigated some of these limitations by soliciting only deidentified instances of diagnostic errors and framing cases as learning opportunities. Additionally, we provided an example of an MOID, which allowed the providers to model their own cases accordingly. We comprehensively tested the survey for face, construct and content validity before soliciting participation to mitigate survey design issues. Our response rate was in range of other surveys of paediatricians regarding diagnostic errors.[10 22] Another limitation was our inability to verify the accuracy of the contributory factors or level of harm. It is likely that retrospective recall of diagnostic errors results in inaccurate assignment of contributory causes in some cases. However, it was reassuring to note that most cases submitted included those experienced by the reporting clinician themselves, which allowed them to introspect about the MOIDs and reflects what likely happened in the ED. Finally, the participation of respondents varied across the research networks ranging from 35.4% to 2.4% with a higher participation by paediatric ED providers in North America.

Although our multinational survey was not designed to measure the epidemiology or frequency of diagnostic errors, it nevertheless reveals that diagnostic errors lead to substantial patient harm in paediatric EDs globally. Use of an MOIDS approach was relatively easy for conveying the concept of diagnostic errors. Our findings also reveal the commonality of issues across EDs such as breakdown in patient/parent–provider interactions especially issues with history-taking and physical examination. Thus, interventions aimed at improving information gathering and synthesis during paediatric ED encounters may have substantial potential to reduce patient harm globally. The survey suggests the need to develop systematic approaches to measuring diagnostic errors, which could then enable both local and wider global learning to reduce error rates.

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Correction notice This article has been corrected since it was first published. Author name Richard M Rudy is changed to Richard M Ruddy.

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Contributors PM conceived and designed the study including developing the survey instrument, analysing the results, drafting the manuscript. PM is also the guarantor of this article. PM, JAG, JC, MB, JMC, TC, ML, RO, DR, RMR, KNS, RVZ, AB, NK and HS helped review the survey instrument, discussed the results and assisted in editing the manuscript. PM, JC and AB had full access to all of the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

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Supplement Table 1: Categorization of body systems and distribution of **symptoms at** index ED visit and **reported** MOIDs.

Body System	Symptoms	Diagnoses/Conditions (MOIDS & Final)
Allergy/Immunology	Hives	Anaphylaxis
Behavioral/Psychiatric	Anxiety	Conversion Disorder
Cardiology	Chest Pain Syncope	Anomalous left coronary artery from the pulmonary artery Arrhythmia Bacterial Endocarditis Cardiac tamponade Coarctation of aorta Hypoplastic heart Myocarditis Pericardial effusion Pulmonary artery stenosis Viral Myocarditis
Central Nervous System (CNS)	Headache Seizure Loss of sensation Altered mental status	Abscess, Intracranial Acute flaccid myelitis AV Malformation Botulism Chorea Meningitis Multiple Sclerosis Oculogyric crisis Pseudo tumor cerebri Seizure Shunt Malfunction Stroke Thrombosis of Basilar artery Venous sinus thrombosis
Dermatology	Rash	Impetigo Non-Specific rash
Gastrointestinal (GI)	Abdominal Pain Vomiting Constipation Diarrhea Blood in stool Dark Stool Difficulty swallowing	Acute Gastroenteritis Appendicitis Bowel Obstruction Crohn's Disease Cystic Mass Foreign Body GERD Hirschsprung's Disease Intestinal Invagination Intussusception Liver Failure

		Malrotation Meckel Diverticulum Malfunction of G-tube Necrotizing enterocolitis Pancreatitis Periappendicial abscess Pyloric Stenosis Volvulus
Genitourinary (GU)	Dysuria Flank pain Hematuria Infrequent menses Proteinuria Testicular pain Vaginal discharge	Abscess pelvic Acute renal failure Chlamydia Hematocolpos Hemolytic uremic syndrome Hyperkalemia Imperforate hymen Nephrotic syndrome Ovarian torsion Pregnancy, intrauterine Single kidney renal failure Testicular torsion Urachal cyst Urinary Tract Infection (UTI)
Hematology/Oncology	Anemia Nosebleed	Acute lymphoblastic leukemia Acute Myeloid Leukemia Aplastic anemia crisis Hemophagocytic lymphohistiocytosis Burkitt's lymphoma Cancer of the ovaries Ewing Sarcoma Immune thrombocytopenia Neutropenia Henoch-Schonlein purpura Splenic sequestration Tumor Abdomen Tumor anterior mediastinum Tumor Brain Tumor spinal cord
Infection	Fever Congestion Cough Runny nose Sore throat	Abscess Abdominal Abscess Cerebral Abscess Neck Abscess Retropharyngeal Abscess Thigh Bacterial meningitis Clostridium Perfringens

		Disseminated HSV sepsis Lemierre's disease Lyme disease Malaria Mastoditis Measles Osteomyelitis Peripheral neuropathy Pertussis Sepsis Septic arthritis Septic Hip Syphilis Toxic shock syndrome Wound Infection
Inflammation	Knee pain Limp Shoulder pain	Kawasaki disease Transient synovitis of the hip
Musculoskeletal	Arm pain Back pain Elbow Swelling Leg pain Limp Swelling of chest	Pectus carinatum Perthes disease Slipped Capital Femoral Epiphysis (SCFE)
Ophthalmology	Eye swelling Red eye	Conjunctivitis Keratitis
Respiratory	Respiratory distress Cough Difficulty breathing Difficulty swallowing Noisy breathing Stridor Wheezing	Pneumonia Airway Foreign body Pulmonary embolism Bacterial tracheitis Pneumothorax Aspiration Pneumonia Empyema Bronchiolitis Abscess Retropharyngeal
Trauma	Arm pain Back pain Bruise Chest injury Contusion Fall Head injury Knee pain Laceration Limp Motor vehicle injury	Fracture Clavicular Fracture Elbow including supracondylar fracture Fracture Femur Fracture Hip Fracture Radius Fracture Radius Ulna Fracture Skull Fracture Tibia Fracture Wrist Fracture Humerus

	Neck pain Pain Shoulder Pain	Laceration Liver Laceration Non accidental trauma (NAT) Retained Foreign body Supracondylar fracture
Other	Abnormal blood test Choking Fussiness Irritability Persistent crying	Rickets Hypernatremic dehydration

Supplement Table 2: Distribution of Contributory factors for the entire study and stratified by participating networks

	All networks combined *n* (%)	**PECARN (*n*=143, 35.2%)**	**PEMCRC (*n*=122, 30.1%)**	**PERC (*n*=67, 16.7%)**	**PERUKI (*n*=37, 9.1%)**	**RISeuP (*n*=28, 6.9%)**	**REPEM (*n*=9, 2.2%)**
Patient-Provider Encounter	240 (59.1%)	97 (67.8%)	61 (50.0%)	45 (67.2%)	24 (64.9%)	10 (35.7%)	3 (33.3%)
a. Problems with history	166 (69.1%)	66 (68.0%)	48 (94.1%)	33 (73.3%)	14 (58.3%)	4 (40.0%)	1 (33.3%)
• Incomplete or inadequate history	84 (35.0%)	36 (37.1%)	21 (34.4%)	15 (33.3%)	8 (33.3%)	3 (30.0%)	1 (33.3%)
• Misinterpreted or ignored physical historical findings	82 (34.1%)	30 (30.9%)	27 (44.2%)	18 (40.0%)	6 (25.0%)	1 (10.0%)	0 (0.0%)
b. Problems with physical examination	188 (78.3%)	70 (72.2%)	47 (77.0%)	40 (88.8%)	20 (83.3%)	10 (100.0%)	1 (33.3%)
• Incomplete or inadequate physical exam	77 (32.1%)	33 (34.0%)	16 (26.2%)	16 (35.5%)	9 (37.5%)	2 (20.0%)	1 (33.3%)
• Historical findings misinterpreted or ignored	111 (46.3%)	37 (38.1%)	31 (50.8%)	24 (53.3%)	11 (45.8%)	8 (80.0%)	0 (0.0%)
c. Failure to review previous documentation	14 (5.8%)	3 (3.1%)	6 (9.8%)	2 (4.4%)	1 (4.1%)	1 (10.0%)	1 (33.3%)
d. Failed to order an indicated diagnostic test	94 (39.2%)	32 (32.9%)	25 (40.9%)	20 (44.4%)	12 (50.0%)	4 (40.0%)	1 (33.3%)
e. Other (such as unnecessary procedure/tests performed)	41 (17.1%)	18 (18.5%)	10 (16.3%)	6 (13.3%)	6 (25.0%)	1 (10.0%)	0 (0.0%)
Diagnostic Tests	155 (38.2%)	48 (33.6%)	58 (47.5%)	30 (44.8%)	9 (24.3%)	5 (17.9%)	5 (55.6%)
a. not performed at all	41 (26.4%)	12 (25.0%)	11 (18.9%)	9 (30.0%)	3 (33.3%)	4 (80.0%)	2 (40.0%)
b. not performed correctly	5 (3.2%)	1 (2.0%)	2 (3.4%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (40.0%)
c. not interpreted correctly	35 (22.5%)	9 (18.7%)	12 (20.6%)	12 (40.0%)	1 (11.1%)	1 (20.0%)	0 (0.0%)
d. Misidentification of sample	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
e. Misinterpretation of test results	26 (16.7%)	14 (29.1%)	6 (10.3%)	3 (10.0%)	1 (11.1%)	0 (0.0%)	2 (40.0%)
f. Other	51 (32.9%)	15 (31.2%)	24 (41.3%)	8 (26.6%)	3 (33.3%)	1 (20.0%)	0 (0.0%)
Patient-Related Factors	104 (25.6%)	39 (27.3%)	27 (22.1%)	19 (28.4%)	11 (29.7%)	4 (14.3%)	4 (44.4%)
a. Delay in seeking care	2 (1.9%)	0 (0.0%)	1 (3.7%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (25.0%)
b. Language barriers	12 (11.5%)	2 (5.1%)	5 (18.5%)	2 (10.5%)	3 (27.2%)	0 (0.0%)	0 (0.0%)
c. Caregiver factors (absent, adversarial, or incomplete history)	47 (45.1%)	17 (43.5%)	13 (48.1%)	11 (57.8%)	2 (18.1%)	1 (25.0%)	3 (75.0%)
d. Left against medical advice	1 (0.9%)	1 (2.5%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
e. Other	53 (50.9%)	19 (48.7%)	12 (44.4%)	9 (47.3%)	9 (81.8%)	3 (75.0%)	1 (25.0%)
Follow-Up Tracking	48 (11.8%)	13 (9.1%)	13 (10.7%)	8 (11.9%)	2 (5.4%)	10 (35.7%)	2 (22.2%)
a. Problems with follow-up of abnormal diagnostic test results	14 (29.1%)	3 (23.0%)	3 (23.0%)	4 (50.0%)	1 (50.0%)	2 (20.0%	1 (50.0%)

b. Problems with scheduling of appropriate and/or timely follow-up visits/referral	17 (35.4%)	1 (7.6%)	5 (38.4%)	3 (37.5%)	0 (0.0%)	6 (60.0%)	2 (100.0%)
c. Other	19 (39.5%)	8 (61.5%)	5 (38.4%)	1 (12.5%)	1 (50.0%)	4 (40.0%)	0 (0.0%)
Consultations	45 (11.1%)	10 (7.0%)	16 (13.1%)	5 (7.5%)	10 (27.0%)	3 (10.7%)	1 (11.1%)
a. Problems (lack of access or delays) in obtaining consultation	10 (22.2%)	4 (40.0%)	2 (12.5%)	1 (20.0%)	0 (0.0%)	2 (66.6%)	1 (100.0%)
b. Consultant or an "experienced expert" did not lay hands on patient	16 (35.5%)	3 (30.0%)	6 (37.5%)	0 (0.0%)	6 (60.0%)	1 (33.3%)	0 (0.0%)
c. Communication breakdown/Lack of appropriate response from consultants in the ED	14 (31.1%)	3 (30.0%)	3 (18.7%)	2 (40.0%)	6 (60.0%)	0 (0.0%)	0 (0.0%)
d. Contradictory recommendations from several members of same service	2 (4.4%)	0 (0.0%)	2 (12.5%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
e. Contradictory recommendations from different consulting services	6 (13.3%)	0 (0.0%)	3 (18.7%)	0 (0.0%)	1 (10.0%)	2 (66.6%)	0 (0.0%)
Miscellaneous Factors	133 (32.8%)	45 (31.5%)	42 (34.4%)	20 (29.9%)	11 (29.7%)	12 (42.9%)	3 (33.3%)
a. Workload	47 (35.3%)	14 (31.1%)	10 (23.8%)	12 (60.0%)	4 (36.3%)	8 (66.6%)	0 (0.0%)
• Workload was too high	47 (35.3%)	14 (31.1%)	10 (23.8%)	12 (60.0%)	4 (36.3%)	7 (58.3%)	0 (0.0%)
• Workload was too low	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (8.3%)	0 (0.0%)
b. Lack of resources – such as less nursing, respiratory therapists, etc.	12 (9.0%)	1 (2.2%)	5 (11.9%)	3 (15.0%)	3 (27.2%)	0 (0.0%)	0 (0.0%)
c. Workload was complex (high case severity mix in the ED)	33 (24.8%)	7 (15.5%)	14 (33.3%)	6 (30.0%)	2 (18.1%)	3 (25.0%)	1 (33.3%)
d. Patients who arrive with a "known" diagnosis or have been worked up for a diagnosis prior to the index ED visit, i.e. have been assigned a diagnostic label	59 (44.3%)	20 (44.4%)	18 (42.8%)	8 (40.0%)	6 (54.5%)	6 (50.0%)	1 (33.3%)
e. Distractions – too many phone calls/interruptions, etc.	22 (16.5%)	7 (15.5%)	6 (14.2%)	3 (15.0%)	3 (27.2%)	3 (25.0%)	0 (0.0%)
f. Institutional practices and policies	14 (10.5%)	4 (8.8%)	2 (4.7%)	3 (15.0%)	1 (9.0%)	2 (16.6%)	2 (66.6%)
g. Legal factors	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

The gray highlighted rows are the sum of participants who have selected the primary contributing factors for the MOID. For each primary contributing factor, the respondent had the option of specifying multiple sub-categories.

Within each column, percentages do not sum to 100% because participants could select more than one response.

Supplement Figure 1: Impact (harm) of MOID on the patient