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Discordance in CT interpretations between pediatric radiology overreads and community and adult radiologists reads following traumatic injury

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ABSTRACT

Introduction: For pediatric trauma patients, imaging interpretations from transferring institutions may differ from those of pediatric radiologists. At our Level I pediatric trauma center, all outside CT scans are reinterpreted by pediatric radiologists. This study evaluates the discordance rate between initial outside CT interpretations and pediatric overreads, examining whether continued secondary review is needed.
Methods: We retrospectively compared CT interpretations of pediatric radiologists and transferring radiologists in pediatric trauma patients transferred to our center from 2021 to 2023. Included patients had a documented injury, an outside interpretation, and a pediatric overread. CT scans reviewed included the head, cervical/thoracic/lumbar spine, chest, and abdomen & pelvis (A&P).
Results: A total of 500 patients with 1,192 CT scans were included. Overall discordance was 16 % (189/1,192). Patients with discordant scans had higher injury severity scores (ISS 14 vs. 10, $p = 0.006$). CT A&P had the highest discordance rate at 25 % (101 scans, $p < 0.001$), and the second highest rate of major treatment changes (38 %, $p < 0.001$). CT C-spine had the highest rate of discordant scans resulting in major treatment change (63 %, $p < 0.001$). Only 13 discordant cases would have changed transfer decisions; eleven involved CT head scans.
Conclusion: Significant discordance exists between outside and pediatric radiologist CT interpretations in pediatric trauma, particularly for CT A&P. Although head CT overreads were the only scans that might have prevented transfer, the overall discordance rate justifies the need for pediatric radiologist review at Level I pediatric trauma centers.

1. Introduction

Traumatic injuries are a leading cause of emergency department (ED) visits and death in pediatric patients [1,2]. However, access to pediatric-specific care is limited, with only 65 % of American children living within 60 min of pediatric trauma centers, resulting in more than 80 % of pediatric emergency care occurring in non-children's hospitals where specialized pediatric radiology expertise may be limited [3,4]. In the United States, only 3 % of radiologists are subspecialized in pediatrics and are predominantly concentrated in academic centers and metropolitan areas [5]. As a result, children with trauma-related injuries are frequently transferred to pediatric trauma centers after undergoing initial imaging interpreted by general or adult radiologists. To address potential variability, it is common practice at many pediatric centers to secondarily review outside imaging by fellowship-trained pediatric radiologists. At our Level I pediatric trauma center, all outside CT scans are reinterpreted by pediatric radiologists. The time spent waiting for this scan can be less than 10 min or longer than an hour. It should be noted that only stable patients will wait for transfer until scans have been overread. Unstable patients are transferred immediately.

Previous studies have assessed the disagreement rate in overreads, but none have looked at predictors of discordant reads. Discordance rates in all overreads vary from 12 to 41 %, while the discordance rate for abdominal CTs ranges from 27 to 54 % [6–8].

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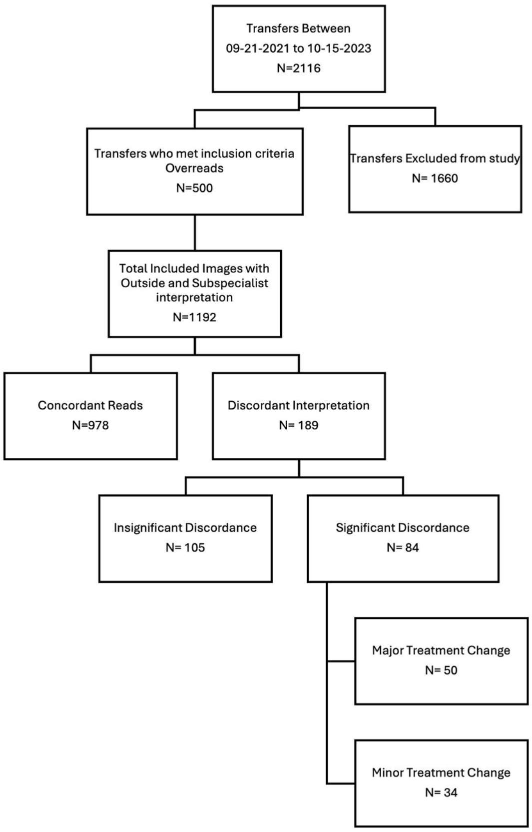

Fig. 1. Consort diagram outlining categorization of scans into discordance, level of significance, and impact on treatment.

Additionally, many of these discordant reads have been noted to have a significant influence on the care of these patients. No large studies have assessed the rate of disagreement in pediatric trauma patients, and none have assessed patient factors that may contribute to higher rates of discordant reads.

In this study, our aim was to determine the rates of discordance between initial CT imaging interpretation and reinterpretation by an attending pediatric radiologist at a pediatric level I trauma center for transferred patients. Additionally, we sought to establish the impact that discordance had on clinical care. We stratified the clinical impact of overreads into major and minor categories. Major impacts included findings that necessitated immediate subspecialty referral, a change in admission status, additional urgent imaging, or instances where the overread would have prevented patient transfer. Minor impacts referred to changes such as nonurgent treatment, outpatient referral, or any care modifications that could safely be delayed up to 24 h without adverse consequences. Finally, we stratified discordance rates and clinical impact according to body system scanned. We hypothesized that a significant proportion of the reads would be discordant, but the impact on clinical care of these discordant reads would be relatively low.

2. Methods and materials

The Institutional Review Board approved this study. The study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guidelines.

2.1. Study design and data source

We retrospectively analyzed the trauma registry at an American College of Surgeons (ACS) verified Level I pediatric trauma center. The data set includes all children transferred to the Level I pediatric trauma center from another facility from September 2021 through October 2023 for traumatic injuries. Eligible patients had undergone outside hospital CT imaging with both initial interpretation and corresponding pediatric radiologist overread available in the electronic health record (EHR) (see Fig. 1). The cross-sectional imaging modalities included were CT head, CT cervical spine, CT thoracic spine, CT lumbar spine, CT chest, and CT abdomen/pelvis (A&P). Patients with qualifying studies on multiple dates were included for each unique encounter. We excluded cases that only had imaging performed at the Level I pediatric trauma center, lacked a documented outside interpretation, or involved other imaging modalities (e.g., CT maxillofacial, extremity CTs, MRI, ultrasound, or radiographs). Patient age, race, ethnicity, and ISS were collected from the trauma registry. Age in years was categorized into the age groups of less than 10 years old, 11–17 years old, and older than 17 years old. ISS was categorized into mild if the ISS was less than 9, moderate for ISS between 9 and 15, severe for 15–25, and major for ISS greater than 25.

2.2. Primary outcome

Each outside interpretation was compared to the pediatric radiologist's overread. The pediatric radiologist's interpretation was considered the reference standard. Discordance was defined using the following criteria: 1. A change in interpretation of injury severity; 2. Omission of a finding identified in the overread; 3. Inclusion of a finding not identified in the overread; 4. An explicit disagreement or reinterpretation as stated by the pediatric radiologist. In cases of ambiguous interpretations, patients were initially designated as discordant. Studies not meeting these criteria were classified as concordant. All discordant encounters identified were re-evaluated and verified by one of two board-certified pediatric trauma surgeons (RAS and KWR).

2.3. Secondary outcomes

To determine the clinical significance of discordant reads, we categorized discordance as being clinically insignificant or significant, as adapted from previously published methodologies (see

Table 1
This table demonstrates examples of each discordance category used in this study. Cases are categorized as No Discordance (no difference between outside hospital [OSH] and pediatric over-read), Minor Discordance (findings of limited clinical relevance), Major Discordance (missed or overcalled findings with potential clinical impact), and Transfer-Altering discordance (discordance that would have changed the need for transfer). OSH = outside hospital; ED = emergency department; ICU = intensive care unit.

Type	OSH Diagnosis	Over-read Diagnosis	Key Difference	Clinical Outcome
No discordance	Subdural hematoma	Subdural hematoma	No change	Admitted to the floor
Minor discordance	Skull fracture	Vascular groove	Overcalled skull fracture	Discharged from ED
Major discordance	Normal	Skull fracture and extra-axial hematoma	Missed skull fracture and hemorrhage	Admitted to ICU, repeat imaging
Transfer-Altering	Midline shift	No midline shift	Overcalled the critical finding	Discharged from ED

Table 2
This table demonstrates the demographic and imaging characteristics of the concordant and discordant CT Read groups. Continuous variables are presented as median (interquartile range). Categorical variables are presented as a number (percentage). ISS = Injury Severity Score CT = Computed Tomography.

Characteristic	Concordant Reads, N = 978[a]	Discordant Reads, N = 191[a]	p-value[b]
Age (years)	12.9 (7.3, 15.3)	12.1 (6.7, 15.1)	0.2
Age groups			0.086
<10 years	326 (81 %)	77 (19 %)	
10–16 years	598 (86 %)	99 (14 %)	
17 years	56 (81 %)	13 (19 %)	
ISS	10 (6, 17)	14 (9, 17)	**<0.001**
ISS groups			
Mild (ISS<9)	269 (89 %)	32 (11 %)	
Moderate (9–15)	436 (85 %)	78 (15 %)	
Severe (16–25)	160 (77 %)	49 (23 %)	
Major (>25)	436 (85 %)	78 (15 %)	
Unknown	17	8	
Race			0.6
Asian	7 (88 %)	1 (13 %)	
Black	20 (71 %)	8 (29 %)	
Native American	46 (87 %)	7 (13 %)	
Unavailable	137 (84 %)	26 (16 %)	
Polynesian	10 (83 %)	2 (17 %)	
White	758 (84 %)	147 (16 %)	
Ethnicity			>0.9
Hispanic	106 (84 %)	20 (16 %)	
Non-Hispanic	703 (84 %)	136 (16 %)	
Unavailable	169 (83 %)	35 (17 %)	
Imaging type			**<0.001**
CT abdomen & pelvis	159 (74 %)	56 (26 %)	
CT cervical spine	243 (94 %)	16 (6.2 %)	
CT chest	136 (81 %)	31 (19 %)	
CT head	330 (82 %)	74 (18 %)	
CT lumbar spine	57 (90 %)	6 (9.5 %)	
CT thoracic spine	53 (87 %)	8 (13 %)	

[a] n (%); Median (IQR).
[b] Pearson's Chi-squared test; Wilcoxon rank sum test; Fisher's exact test.

Table 1 for examples) [8,9]. *Clinically insignificant* changes were defined as additional findings with no potential to change management or incidental findings not requiring follow-up. *Clinically significant* reads were defined as differences with the potential to alter clinical management or affect patient outcomes. Clinically significant reads were then sub-categorized into major and minor changes in treatment. Major changes included changes that would require immediate sub-specialty referral, a change in admission status, additional urgent imaging, or cases where the overread would have prevented transfer. Minor changes included nonurgent treatment, outpatient referral, or any change in care that would not be adversely affected by a 24-h delay. All categorizations were independently reviewed by two board-certified pediatric trauma surgeons.

Additionally, we sought to understand the effect of discordant reads on unnecessary transfers of patients. Therefore, in all patients whose read led to a major change in treatment, it was assessed whether the discordant aspect of the read would have resulted in a change in the decision to transfer the child. These cases were categorized as a change in transfer pattern. Additionally, among these patients, we determined whether the discordance resulted in an unnecessary transfer and thus categorized these reads as discordant, resulting in unnecessary transfer.

2.4. Statistical analysis

All statistical analyses were performed using R (Version 4.3.1) [10]. Hypotheses were tested using a two-sided approach, with $p < 0.05$ considered statistically significant. Univariate analyses were performed using Wilcoxon rank sum tests for continuous variables and chi-squared tests for categorical variables. Patients with missing ISS were excluded from ISS univariate analysis. A multivariable regression was performed to measure the odds of discrepant reads. We performed a generalized linear model, which included imaging type, age group, and ISS group. These variables were chosen a priori and based on univariate significance. Patients with missing ISS were excluded from the multivariable model.

3. Results

Out of 2,116 pediatric trauma patients transferred to our facility during the study period, 500 met the inclusion criteria. These patients had 1,192 imaging studies with an outside hospital interpretation and a pediatric subspecialist overread (see Table 2). CT head was the most common imaging study (33.8 %). The majority of our patients were white (77 %), non-Hispanic (72 %), and male (63 %). The median patient age was 11.7 years (IQR 5–15), and the median Injury Severity Score (ISS) was 10 (IQR 5–14).

In total, 189 of 1,192 studies (15.8 %) demonstrated discordance between the outside and pediatric radiologist interpretations. CT A&P had the highest rate of discordant reads (26 %), while CT cervical spines had the lowest rate of discordant reads (6.2 %) (Table 3). The differences in the rate of discordant reads were statistically significant. Additionally, patients with discordant reads had a significantly higher ISS than those with concordant reads (14 vs 10, $p < 0.001$). Neither race nor age was significantly associated with discordant reads. On multivariate analysis, CT A&P had significantly higher odds of discordant reads in comparison to every other imaging type, other than CT chest, which had no significant difference

Table 3
This table compares discordance grade, treatment changes, and transfer outcomes across different CT imaging types among transferred pediatric trauma patients. Values are presented as a number (percentage). CT = Computed Tomography.

Characteristic	CT Abdomen & Pelvis N = 56[a]	CT Chest, N = 31[a]	CT Head, N = 74[a]	CT C-Spine, N = 16	CT T-Spine, N = 7	CT L-Spine, N = 5	p-value[b]
Discordance grade							**<0.001**
Insignificant	26 (46 %)	24 (77 %)	45 (61 %)	4 (25 %)	3 (43 %)	3 (60 %)	
Significant	30 (54 %)	7 (23 %)	29 (39 %)	12 (75 %)	4 (57 %)	2 (40 %)	
Treatment change							**0.001**
Major	21 (38 %)	2 (6.5 %)	17 (23 %)	10 (63 %)	0 (0 %)	0 (0 %)	
Minor	9 (16 %)	5 (16 %)	13 (18 %)	2 (13 %)	4 (57 %)	2 (40 %)	
None	26 (46 %)	24 (77 %)	44 (59 %)	4 (25 %)	3 (43 %)	3 (60 %)	
Isolated injury transfer change							**<0.001**
No	46 (82 %)	30 (97 %)	60 (81 %)	7 (44 %)	7 (100 %)	5 (100 %)	
Yes	10 (18 %)	1 (3.2 %)	14 (19 %)	9 (56 %)	0 (0 %)	0 (0 %)	
Actual transfer change	0 (0 %)	0 (0 %)	11 (42 %)	2 (12.5 %)	0 (0 %)	0 (0 %)	**<0.001**

[a] n (%).
[b] Pearson's Chi-squared test; Fisher's exact test.

Table 4
This table displays the results of a multivariable analysis on the odds of having disagreement between pediatric radiologist and transferring hospital radiologist reads. Imaging type, age group, and ISS group were included in the model.

Characteristic	OR	95 % CI	p-value
Imaging type)			
CT abdomen & pelvis	–	–	
CT cervical spine	0.19	0.10, 0.35	<0.001
CT chest	0.66	0.40, 1.09	0.11
CT head	0.63	0.42, 0.96	0.029
CT lumbar spine	0.33	0.12, 0.77	0.017
CT thoracic spine	0.33	0.12, 0.76	0.016
Age groups			0.086
<10 years	–	–	
10–16 years	0.68	0.48, 0.97	0.034
17 years	1.07	0.52, 2.06	0.8
ISS groups			
Mild (ISS<9)	–	–	
Moderate (9–15)	1.45	0.94, 2.29	0.10
Severe (16–25)	2.51	1.53, 4.18	<0.001
Major (>25)	2.04	1.09, 3.76	0.023

(see Table 4). Patients aged 10–16 had lower odds of having in comparison to children younger than 10 years old (OR [CI 95 %]: 0.68 [0.48,0.97]; p = 0034). Also, children with severe and major ISS had higher odds of discordant reads in comparison to children with minor ISS (severe OR [CI 95 %]: 2.51 [1.53, 4.18], p < 0.001; major OR [CI 95 %]: 2.04 [1.09, 3.76], p = 0.023).

Among the discordant reads, discordant CT C-spine reads had the highest rates of significance (75 %), followed by CT A&P (54 %) (p = 0.002). CT C-spine and CT A&P also had higher frequencies of overreads resulting in major treatment changes compared to CT head (p = 0.001). However, no discordant reads for CT A&P or CT Chest would have led to differences in the actual transfer decision. In comparison, 13 discordant scans would have resulted in a change of transfer. Eleven were CT heads, while 2 were CT C-spine (Table 5). Of these discordant CT head reads, 10 were overcalled by the outside radiologist, which led to an unnecessary transfer, while only one overread found injuries that warranted transfer in a patient with a previously normal scan. Of the CT C-spine reads, for patient #12, the outside read had concern for a ligamentous injury, while the overread was normal. However, an MRI confirmed the outside read in this case, and the patient was taken for neurosurgical intervention. For patient #13, the outside read had concern for the atlantooccipital ligamentous injury, and the patient was transferred; however, the overread was read as normal, and the patient was discharged from the ED.

4. Discussion

This study found a discordance rate of 15.8 % between outside radiologists and pediatric subspecialists in CT interpretations for transferred pediatric trauma patients. CT abdomen and pelvis had the highest rate of discordant reads, while CT C-spine had the lowest rate of discordant reads. Patients with more severe injuries also had higher rates of discordant reads. Discordant CT C-spine and CT A&P reads had the highest rate of resulting in a major treatment change; however, none of the CT A&P reads would have resulted in a change in the transfer status of the patient. Only

Table 5
This table shows the clinical details of pediatric trauma patients with discordant CT head or cervical spine interpretations. For each patient, the initial OSH diagnosis, subspecialist over-read diagnosis, nature of the discrepancy, hospital stay duration, associated injuries, and clinical outcomes are listed. "Overcalled" indicates an over-diagnosis at the OSH, while "Missed" indicates findings identified only on subspecialist review. CT = Computed Tomography, OSH = Outside Hospital, Dx = Diagnosis, EDH = Epidural Hematoma, SDH = Subdural Hematoma, ED = Emergency Department, MRI = Magnetic Resonance Imaging.

Patient Number	Age	CT Body region	OSH Dx	Over-read Dx	Difference	Hospital Stay (days)	Other Injuries	Outcome
1	5 years	Head	Epidural	Normal	Overcalled EDH	1	Femur fracture	Discharged from ED
2	13 years	Head	Subdural hematoma	Midline shift	Missed Midline Shift	1	None	Admitted to ICU, Follow up imaging
3	6 months	Head	SDH	Artifact	Overcalled SDH	1	None	Discharged from ED
4	8 weeks	Head	Skull Fracture	Vascular Groove	Overcalled Skull Fracture	1	None	Discharged from ED
5	11 months	Head	SDH, Skull Fracture Midline Shift	SDH, Skull Fracture, No midline Shift	Overcalled Midline shift	1	Frontal Scalp Hematoma	Admitted to Floor
6	11 years	Head	Normal	Skull Fracture, Extra-axial hematomas	Missed Skull Fracture and Hematoma	2	None	Admitted to ICU, Repeat imaging
7	8 years	Head	Frontal Lobe contusion	Normal	Overcalled hemorrhagic contusion	1	None	Admitted to floor
8	13 Month	Head	Occipital Lobe Fracture	Normal	Overread skull Fracture	1	None	Discharged From ED
9	3 years	Head	SDH	Normal	Overcalled SDH	1	None	Discharged From ED
10	3 years	Head	Subarachnoid hemorrhage	Streak Artifact hemorrhage	Overcalled SAH	1	None	Admitted to Floor
11	18 months	Head	Skull fracture, Extra axial hemorrhage	Normal	Overcalled Skull Fracture & Extra axial hemorrhage	1	None	Admitted to ICU, X-rays of L spine and C spine
12	13 years	C-Spine	Trace anterolisthesis C5-6, with slight anterior subluxation at facet joints. Reversal of lordosis and widening of interspinous distance	Mild loss of cervical lordosis secondary to cervical collar	Overcalled concern for ligamentous injury	4	None	MRI confirmed ligamentous injury and patient had operative intervention with Neurosurgery
13	21 months	C-Spine	Atlantooccipital ligamentous injury with widening of atlantooccipital intervals	Normal	Overcalled the atlantooccipital ligamentous injury	1	None	Neurosurgery consulted and patient was discharged from the ED

discordant reads for CT head and C-spine would have prevented unnecessary transfers.

Our overall discordance rate findings are supported by a previous study by Miller et al., who found a discordance rate of 14.1 % among a similar population. This agreement suggests that the discordance rate among overreads remains around 15 % and is consistent across regions. However, there were significant differences in the discordance rates by body type imaged, with CT A&P having the highest discordance rate at 26 %. Previous studies by Onwubiko et al. assessing the discordance rate in CT A&P performed in transferred patients found a discordance rate of 19 % [7]. The increased discordance rate in our study may be due to the widened definition of discordance compared to Onwubiko et al. Additionally, we found that CT A&P had the highest rate of significant disagreements, which were more likely to have major impacts on the patient's treatment plans. The rate of major disagreements found in other states has been between 18 and 35 %. In our study, the rate was significantly lower. This result may be due to the fact that we have only looked at traumatic injury, while the other studies have included patients transferred for non-traumatic reasons. The misses on outside reads can have significant consequences, as shown by the rate of major treatment changes caused by the findings on the overreads. However, none of these disagreements would have resulted in a transfer decision change when accounting for the child's other injuries. Therefore, postponing a transfer while awaiting an overread is likely unwarranted.

We found that cervical spine CT discordances, while less frequent overall, were highly clinically significant. Our study found that 75 % of discordant cervical spine interpretations resulted in major treatment changes. Additionally, discordances in C-spine imaging were associated with the highest proportion of potential changes in transfer status (56 %) and actual changes (12.5 %). These findings are significant given the vulnerability of the pediatric cervical spine [11,12]. Pediatric cervical spine injuries are rare but carry a disproportionately high risk of morbidity and mortality, particularly at the craniocervical junction (occiput–C2), where injuries such as atlantooccipital dissociation and atlantoaxial subluxation are more common in children due to anatomical and biomechanical differences [13]. Timely pediatric radiology review is therefore critical, as failure to identify injuries such as atlantooccipital interval widening, C1–C2 subluxation, or facet fractures can result in inappropriate collar removal, missed surgical indications, and preventable neurologic decline [14]. In our cohort, multiple discordant reads involved instability patterns, including atlantooccipital interval widening, ligamentous injury with MRI recommendation, and subtle anterolisthesis. Most of these children with disagreeing reads were rapidly discharged, indicating an unnecessary transfer; however, one patient with a CT scan read as normal required operative treatment for atlantooccipital interval widening, indicating that the overread was incorrect, while the initial outside read was correct. These findings suggest that pediatric radiology review of cervical spine imaging is extremely valuable for guiding management. Still, when the original and overread disagree, given the significant consequences, it would be recommended to treat the patient conservatively by giving fidelity to the abnormal scan.

We found that despite CT heads having a lower rate of discordant reads than CT A&P, CT head discordant reads represented most of the overreads that could have prevented an unnecessary transfer. Our study found a rate of discordant reads of 18 %. This rate is within the previously reported ranges of 14–34 % for CT head studies [6,8]. Additionally, in our study, disagreeing reads led to major treatment changes in only 4 % of overread scans in comparison to the 16 % found by Eakins et al. [6] Once again, this difference may relate to our study only including trauma patients in comparison to all comers, which may indicate that there are a lower number of major finding differences in patients with traumatic injuries. However, to our knowledge, no study has assessed the impact of overreads on transfer decision-making. In this study, 10 patients were unnecessarily transferred, while one patient was under-transferred based on changes in the read made by the pediatric radiologist. Most unnecessarily transferred patients were discharged from the ED, and none had a hospital stay longer than 1 day. This finding indicates that in children with isolated head injuries, an overread by a pediatric radiologist may be warranted to ensure that the patient is not unnecessarily transferred.

Additionally, we found that more severely injured patients were significantly more likely to have discordant reads. This finding is consistent with previous findings in the adult literature assessing the accuracy of CT in adult trauma patients. Banaste et al. found that a higher clinical severity class and the presence of more than two injured body parts were independent predictors of missed injuries on whole-body CT in trauma patients [15]. Similarly, Eurin et al. and Kok et al. found that higher ISS was significantly associated with missed injuries [16,17]. These findings indicated that in more severely injured patients, it is likely that injuries are missed and these scans deserve to be overread; however, waiting for an overread to guide transfer decision-making in these patients is not necessary, as these patients' stability is tenuous and their known injuries already necessitate transfer.

We must address a significant number of limitations to this study. First, pediatric radiologist interpretations were considered the reference standard, but no third-party arbitration was used, so the accuracy of either interpretation cannot be definitively established. However, we did not comment on the validity of either read and instead only noted instances in which the reads disagreed, but previous studies have indicated that fellowship-trained pediatric radiologists are more accurate than those without pediatric-specific training [18,19]. Additionally, other radiologic factors were not evaluated, including the experience level of outside radiologists and whether discordance rates varied based on the imaging facility. Without this data, we are unable to ensure that outside reads are not read by radiologists with pediatric-specific training. Finally, this is a retrospective study at a single institution, which limits the generalizability of this study, but given that the rate of discordance found in this study is in alignment with other previous studies, it is unlikely that the rate found in this study differs significantly at other institutions [7,8].

5. Conclusion

Among injured children, we found a significant rate of discordance between initial CT imaging interpretation and reinterpretation by an attending pediatric radiologist at a Pediatric Level I trauma center. CT A&P had the highest rate of discordant reads and led to the most major changes in the treatment plan. However, cervical spine and head CT discordances, while less frequent, were more likely to result in major management changes and could have prevented unnecessary transfers or altered transfer decisions. These data support the need for injured children to receive overreads of CT scans of the head, cervical spine, and abdomen and pelvis upon arrival at a Level I pediatric trauma center. Overreading prior to transfer might have prevented transfer in a small number of patients.

Conflict of interest

The authors declare no competing financial interests or personal relationships that could have influenced the work reported in this manuscript.

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