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CT scans for pediatric injury in a middle-income country trauma center: Are we repeating past mistakes?

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ABSTRACT

Purpose: Sustained efforts in high-income countries have decreased the rate of unnecessary computed tomography (CT) among children, aiming to minimize radiation exposure. There are little data regarding CT use for pediatric trauma in low- and middle-income countries. We aimed to assess the pattern and utility of CT performed during evaluation of trauma patients presenting to a middle-income country (MIC) trauma center.

Methods: We reviewed pediatric (age<18) trauma admissions at a single tertiary referral center in South Africa. Patient demographics, injury details, surgical intervention(s), and mortality were abstracted from the medical record. CT indications, results, and necessity were determined by review.

Results: Of 1,630 children admitted to the trauma center, 826 (51%) had CT imaging. Children undergoing imaging were younger (median age 11 [IQR: 6, 16] vs 13 [IQR: 7, 17]) and had higher median ISS [9 [IQR: 4, 13] vs 4 [2, 9]) compared to those without imaging (both $p<0.001$). Overall, 1,224 scans were performed with normal findings in 609 (50%). A median of 1 scan was performed per patient (range: 1–5). The most common location was CT head ($n = 695$, 57%). Among patients with positive findings on CT head ($n = 443$), 31 (7%) underwent either intracranial pressure monitoring or surgery. CT of the cervical spine had positive findings in 12 (7%) with no patients undergoing spine surgery. Of 173 patients with abdominal CT imaging, 83 (48%) had abnormal findings and 18 (10%) required operative exploration. Thirteen (16%) patients with abnormal findings on abdominal CT had exploratory laparotomy. Of 111 children undergoing whole body CT, 8 (7%) underwent thoracic and/or abdominal operations.

Conclusion: Use of CT during evaluation of pediatric trauma is common in an MIC center. A high rate of normal findings and low rates of intervention following head, cervical spine, and abdominal CT suggest potential overuse of this resource.

Level of Evidence: Level III

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Introduction

Nearly 1 billion people sustain injuries that require some type of healthcare assessment [1], and trauma is the most common reason to seek medical care during childhood. The costs of injury are staggering and disproportionately affect children living in low- and middle-income countries (LMICs). Among children living in sub-Saharan Africa, the scourge of injury costs as many as 6471 disability adjusted life-years (DALYs) per 100,000 population, where resources for stabilization and care of traumatic injuries are significantly strained [1]. Given this burden, signficant efforts are underway to improve trauma systems, train new trauma teams, and increase available resources in such regions [2]. As LMICs scale up trauma services, it is important to apply lessons learned during high-income countries (HICs) transition to integrated trauma systems.

The use of computed tomography (CT) scanning is one such example. Fast and anatomically-detailed, CT provides signficant diagnostic and screening advantages. The risks to children exposed to its ionizing radition, however, have given clinicians and researchers pause. Children are uniquely vulnerable to ionizing radition given ongoing growth and development and risk over a larger number of life-years [3]. Overutilization of CT has been reported for pedi-

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atric general [4] and trauma [5] surgery conditions, and sustained efforts in HICs have decreased rates of unnecessary CT scans for pediatric trauma [6].

In LMICs, CT technology is becoming more available and reliable [7] and, in tandem, life expectancy is lengthening. It is not clear how often LMIC health centers are overimaging injured children. To explore this question, we assessed the pattern and utility of CT imaging performed during evaluation of trauma patients presenting to a middle-income country (MIC) trauma center in South Africa. We hypothesized that a substantial proportion of injured children are exposed to radiation via CT with many scans being potentially avoidable.

Methods

Patient population and study setting

This study included injured children (age<18) who presented to the Pietermaritzburg Metropolitan Trauma Service (PMTS) in Pietermaritzburg, South Africa from January 2012 to January 2019. Patients who did not undergo evaluation by the trauma team were excluded.

PMTS is a tertiary referral center in the KwaZulu Natal Province for nineteen rural hospitals, serving a catchment population of approximately three million. It aims to provide comprehensive trauma care to injured patients of any age. All trauma patients are managed by the trauma team and pediatric surgical support is obtained if required. The team is staffed by surgical residents, trauma fellows, and consultant surgeons.

Ethical approvals

This study was reviewed by the Mayo Clinic Institutional Review Board and deemed exempt. The Biomedical Research Committee of the University (BREC) of KwaZulu-Natal granted permission for use of data from the HEMR (BCA221/13).

Data

Data from patients was obtained by review of a prospectively maintained trauma registry. PMTS has a hybrid electronic medical record (HEMR) that serves as a data repository for its registry. Staff receive training to enter information into the HEMR, and the system undergoes continual efforts to maintain data quality and validity.

Patient demographics, injury details, surgical intervention(s), and mortality were abstracted from the HEMR, including injury mechanism, injury severity score (ISS), number and location of CT scans performed, injuries noted on imaging, operations, need for intensive care unit (ICU) admission, hospital length of stay (LOS) and mortality. CT scans were divided by anatomical regions: head, maxillofacial, cervical spine, chest, and abdomen/pelvis. We defined whole body CT as having CT imaging of the head, cervical spine, chest, and abdomen/pelvis. CT angiograms were also reported and reviewed. The indications and radiologic interpretation were obtained from the HEMR. Necessity was determined by duplicate review with the senior author (DLC) adjudicating discrepancies.

Analysis

The primary outcome of interest was the number of potentially avoidable scans. Using existing evidence and expert consensus, the authors (MDT, DBK, MBI, and CRM) developed an algorithm to determine which scans were potentially avoidable. Fig. 1 represents the algorithm chosen to determine whether children had potentially avoidable CT imaging. First, children receiving scans were divided by injury mechanism. We assumed that any scan undertaken for thermal or asphyxia/drowning was necessary given the unique nature of such injuries. For penetrating injuries, we assumed that scans which resulted in successful non-operative management of penetrating injuries were unavoidable [8]. For blunt injury, all children who had scans with negative findings were classified as having had a potentially avoidable scan similar to previous analyses in the pediatric population [5]. For children with blunt injuries and positive findings on CT, their scans were considered potentially avoidable if they did not undergo interventions in any of the regions imaged and their hospital LOS was $\leq$ 2 days. The cutoff of $\leq$ 2 days was chosen based on recent findings of shorter observation periods [9], overnight to 2 days, among children with blunt solid organ injury. If a patient was referred to a higher level of care, we considered this CT scan unavoidable, since such scans are often necessary to make such determinations. Additionally, CT angiograms were considered to be indicated (and therefore unavoidable) in all cases, as these scans provide critical positive and negative results.

Continuous variables were summarized with medians and interquartile ranges (IQRs) and, where appropriate, ranges. Categorical variables were summarized with frequency counts and percentages. We compared demographics, injury details, and interventions between patients with and without CT imaging. Continuous variables were compared using Wilcoxon signed rank sum test while categorical variables were compared using chi-squared and Fisher's exact test where appropriate. Statistical significance was set at $p<0.05$. All analyses were performed using STATA 15.1 (College Station, Texas).

Results

Demographics and admission details for children with and without CT imaging

In total, 1630 children were evaluated at the trauma center over the study period. Over half (n = 826, 51%) had CT imaging. Children who received imaging other than CT scans included 154 with ultrasounds (9%) performed and 936 (57%) with radiographs performed. The demographics of children who underwent CT imaging versus no CT imaging are shown in Table 1. Children receiving scans were significantly younger, more likely to have sustained blunt injuries, and presented with greater injury severity. Statistical analysis demonstrated significantly increased hospital length of stay, need for ICU admission, and referral to quaternary levels of care for patients who had CT imaging compared to those without. Patients who underwent CT were significantly less likely to undergo surgery and experience in-hospital death compared to those who did not have CT imaging.

CT scan locations and results

Overall, 1224 scans were performed with normal findings in 609 (50%). A median of 1 scan was performed per patient (range: 1–5). The most common location was CT head (n = 695, 57%), Fig. 2.The rates of normal scans by location are shown in Table 2. The lowest proportion of scans without any acute findings was found from maxillofacial scans (n = 3, 27%), while the highest proportion of scans without acute findings was found from imaging the cervical spine 156 (93%).

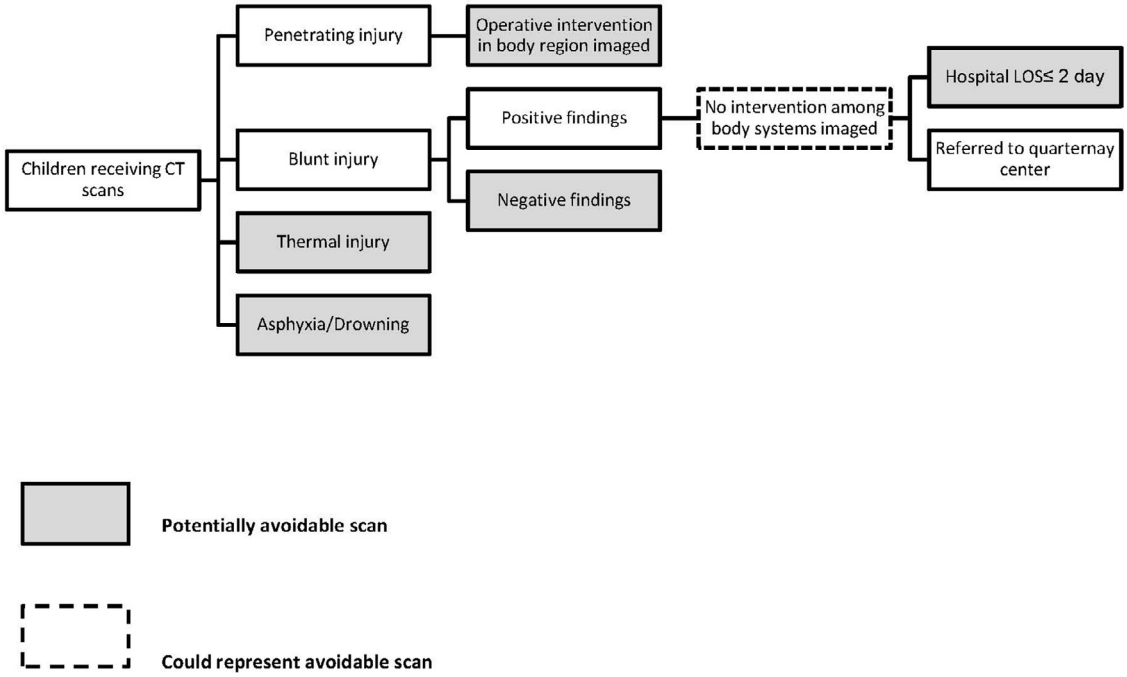

Fig. 1. Algorithm for determining potentially avoidable CT scans.

Table 1
Demographics for children with and without CT imaging.

Factor	Level	CT imaging	No CT imaging	*p*-value
N		826	804	
Age, median [IQR]		11 [6, 16]	13 [7, 17]	<0.001
Male sex, n (%)		598 (72.5%)	582 (72.4%)	0.97
Mechanism,	Blunt	752 (91.0%)	441 (54.9%)	<0.001
n	Penetrating	72 (8.7%)	352 (43.8%)	
(%)	Thermal	1 (0.1%)	10 (1.2%)	
	Drowning/Asphyxia	1 (0.1%)	1 (0.1%)	
ISS, median [IQR]		9 [4, 13]	4 [2, 9]	<0.001
Surgical intervention, n (%)		102 (12.4%)	181 (22.5%)	<0.001
ICU admission, n (%)		100 (12.1%)	32 (4.0%)	<0.001
Hospital length of stay in days, median [IQR]		5 [3, 9]	3 [2, 6]	<0.001
Referral to quaternary center, n (%)		113 (13.7%)	25 (3.1%)	<0.001
Outcome,	Died	6 (0.7%)	10 (1.2%)	<0.001
n	Referred	113 (13.7%)	26 (3.2%)	
(%)	Survived	-707 (85.6%)	768 (95.6%)	

Table 2
CT scan results by location.

	Result	
Location	*Positive*	*Negative*
Head, n (%)	443 (63.7%)	252 (36.3%)
Cervical spine, n (%)	12 (7.1%)	156 (92.9%)
Maxillofacial, n (%)	8 (73%)	3 (27%)
Chest, n (%)	50 (40.7%)	73 (59.3%)
Abdomen/Pelvis, n (%)	83 (48.0%)	90 (52.0%)
Angiogram, n (%)	19 (35%)	35 (65%)
Total, n (%)	615 (50.2%)	609 (49.8%)

Interventions for patients with positive scans

Among patients with positive findings on CT head ($n = 443$), 31 (7%) underwent either intracranial pressure monitoring or surgery. CT of the cervical spine had positive findings in 12 (7%) with no patients undergoing spine surgery. Of 50 patients with CT chest findings, only 1 (2%) patient underwent bronchoscopy following thorax trauma. This patient was trampled by a cow over with injuries mainly to the abdomen and thorax. Of 173 patients with abdominal CT imaging, 83 (48%) had abnormal findings and 18 (10%) required operative exploration. Thirteen (16%) patients with abnormal findings on abdominal CT had exploratory laparotomy. Of 111 children undergoing whole body CT, 8 (7%) underwent thoracic and/or abdominal operations.

Potentially avoidable scans

Overall, 295 (36%) of children undergoing CT imaging had scans that were potentially avoidable, Fig. 3. An additional 388 (47%) of CT-imaged children had blunt injuries that did not require intervention during their hospital stay. Among 295 children where all CT imaging was potentially avoidable, there were 375 scans performed.

Discussion

Given the high burden and disproportionate mortality for pediatric trauma in LMICs, CT imaging's rapid and anatomically detailed results can increase the diagnostic abilities in such settings. Such technology, however, is not without risks, and strained re-

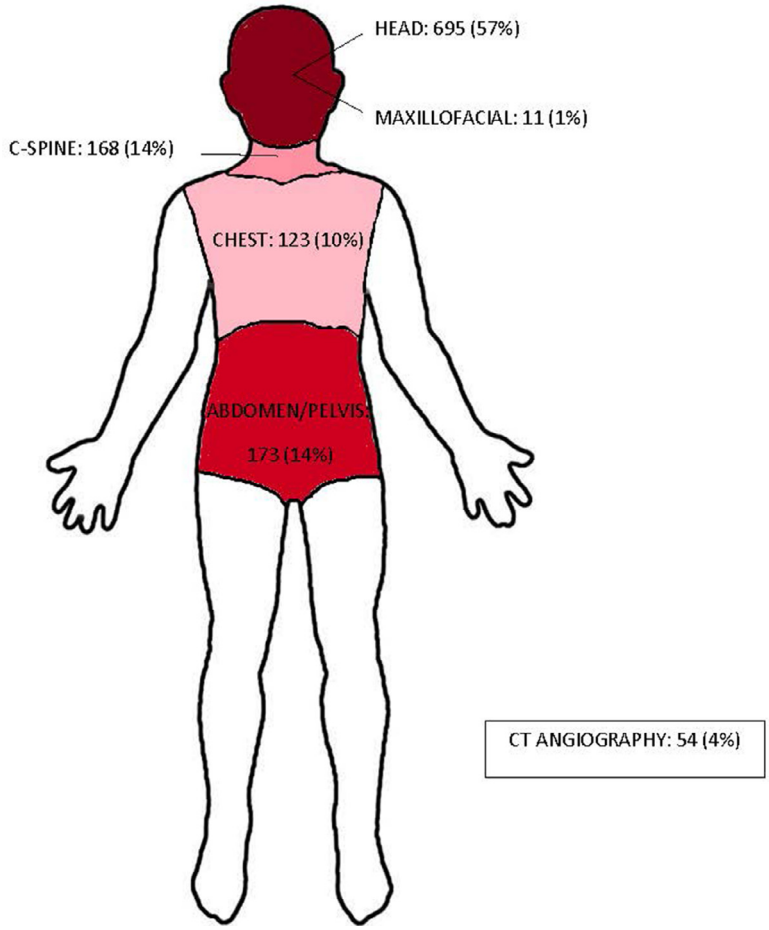

Fig. 2. Locations of CT imaging.

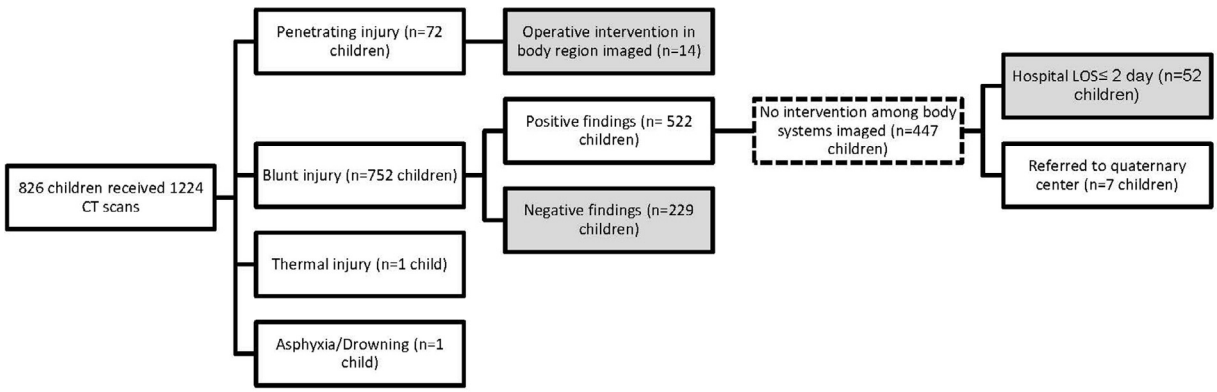

Fig. 3. Children with potentially avoidable CT scans.

sources further urge appropriate use of CT. HICs have decreased the rate of unnecessary CT among children, aiming to minimize radiation exposure. In our study, over half of injured children underwent CT imaging. CT scans of the head, cervical spine, chest, and abdomen often demonstrated normal findings and infrequently required interventions. Accordingly, one in three children underwent imaging that was potentially avoidable.

HICs introduced the As Low As Reasonably Achievable (ALARA) concept toward CT imaging in the early 2000s in response to the rapid proliferation of CT imaging and overuse among children. At that time, Fenton et al. reported more than 85% of pediatric trauma patients had CT imaging of the head, chest, or abdomen [5]. More recently, a review of pediatric patients in the National Trauma Databank showed 20% receiving CT imaging of the head, 5% undergoing CT of the chest, and 9% having CT scan of the abdomen [10]. Our results are much closer to the height of CT overuse for pediatric trauma in the late 1990s and early 2000s in the United States.

One should, however, question whether "overuse" as defined in our study is applicable in more resource-strained contexts. It is certainly possible that CT scans enabled earlier discharge in some pediatric patients, by virtue of reassuring negative results. Such discharges might ease the burden of busy trauma services in low- and middle-income country settings. Additionally, negative findings also guide important management decisions. One such example is CT angiography to exclude a vascular injury, where both negative and positive findings provide clinically actionable information. While we considered all CT angiography unavoidable, we can imagine scenarios in which the injury presentation or mechanism might necessitate use of CT in order to guide therapy. Therefore, our study may overestimate the number of potentially avoidable scans.

The risk of fatal cancer secondary to radiation from a CT scan performed in childhood is as high as 1 per 1000 pediatric CT scans [3]. As life expectancies continue to climb in MICs like South Africa, such risks become more important to consider. With one in three children experiencing potentially avoidable radiation exposure, this analysis demonstrated several targets for intervention to reduce CT imaging. First, CT imaging of the head appeared to infrequently require intervention in either the form of surgery or intracranial pressure monitoring. CT over-imaging of the head could be reduced by use of clinical decision rules, such as the Pediatric Emergency Care Applied Research Network (PECARN) rule for imaging of minor head trauma. PECARN has already been validated in sub-Saharan Africa and shown to reduce the number of scans without any clinical detriment [11]. Of course PECARN requires that the center can safely observe a child with head trauma [10]. Second, CT scans of the cervical spine in our study were rarely positive and, even when findings were present, rarely prompted surgical intervention. Clinical decision analysis estimates that the probability of pediatric cervical spine injury should be nearly 25%, much higher than that seen in our study, to make a CT first screening the preferred evaluation strategy [12]. Screening with spine radiographs could reduce this source of radiation, and decision rules and algorithms have shown measurable decreases in CT imaging for blunt trauma without measurable increases in bleeding or mortality [11]. Over half of chest and abdominal CT scans in our study failed to demonstrate acute findings; and, when injuries were present, few required operative interventions.

In addition to limiting CT imaging locations with high yield targets and decision tool-support, minimizing repeated scans is important as CT technology proliferates in a country like South Africa. Referring centers will often perform scans prior to transfer, but anywhere from 9% to 18% will require repeating [5]. Furthermore, pre-transfer CT scan appears to delay definitive treatment in many cases and provides little additional clinical information. Unfortunately, we do not have data regarding CT imaging performed at referring centers. Additionally, scans repeated after the initial scan at our institution are not reliably captured. Future quality projects should examine both pre-transfer and repeated CT rates.

A final note-worthy strategy for CT imaging reduction harnesses the adaptability and range of imaging technologies. CT scanners should be calibrated for pediatric patients with size-based adjustment to imaging parameters [3]. Another technology-based solution is more frequent use of ultrasound. When combined with clinical assessment, ultrasound can provide reliable and safe diagnosis of solid organ injuries. Less than 1 in every 10 patients in our study had an ultrasound performed. Ultrasound has seen increased use in pediatric emergency departments as CT use has declined in the United States [6]. Efforts in South Africa would suggest that point-of-care ultrasound such as focused assessment with sonography in trauma (FAST) is easily implemented and provides valuable clinical information [13]. Ultrasound, however, can be challenging in LMICs because of a dearth of specialized technicians, appropriate training, and equipment [7]. Newer sonographic advancement such as contrast-enhanced ultrasound also have the potential to decrease the need for CT imaging in the future, but may be inaccessible because of current economic and technological inequalities between HICs and LMICs.

This retrospective study has several limitations worth mentioning. The impact of CT imaging results on medical decision making or referral to higher centers of care is not captured in this analysis. We, however, have data on interventions performed for the anatomic locations imaged including intracranial pressure monitoring, angiography, and surgical intervention, utilizing these interventions as a marker for those scans which revealed clinically actionable information that might not have been accessible at the bedside or laboratory. While this limitation might suggest that we have overestimated the number of children with potentially avoidable scans, we believe that this number is likely an underestimate because of other limitations of the analysis. As mentioned before, we do not have data regarding repeated scans pre-transfer, during hospitalization, or at our referral quaternary hospital. Additionally, our algorithm used to determine potentially avoidable imaging looks at the patient level rather than scan level. It is likely and suggest by our results that some patients with multiple scans could have avoided additional radiation by eliminating some of the locations imaged. Finally, CT use also depends on the trauma population. As a tertiary referral center, PMTS cares for children with more severe injuries, making a higher rate of CT use potentially acceptable. Over triage of pediatric trauma patients has been highlighted as a problem in the United States [14] and neighboring countries such as Malawi [15]. The number of patients in our study who had CT scans with negative results and a LOS$\leq$2 days suggests possible over triage. The appropriateness of triage is beyond the scope of this article but is an important area of future work.

Conclusion

Use of CT during evaluation of pediatric trauma is common in an MIC center, and as observed in HICs, is potentially unnecessary. A high rate of normal findings and low rates of intervention following head, cervical spine, and abdominal CT suggest potential overuse of this resource. Targets for quality improvement include use of clinical decision rules, avoidance of low yield CT imaging, and expanded ultrasound capabilities.

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