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Decreasing Radiation Exposure in Pediatric Trauma Related to Cervical Spine Clearance: A Quality Improvement Project

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ABSTRACT

Study Design: Quality improvement project.

Objectives: Reduce the amount of radiation exposure in the pediatric trauma population 5 years of age and older in relation to cervical spine clearance.

Background: The evaluation of pediatric cervical spine injuries must be accurate and timely to avoid missed injuries. The difficult clinical examination in pediatric trauma patients necessitates the use of radiologic examinations to avoid missing catastrophic injuries. However, exposure to radiation at an early age increases the pediatric patients' risk of developing cancer (R. A. Kleinerman, 2006).

Methods: A retrospective chart review was conducted to assess radiation exposure in pediatric patients requiring evaluation for cervical spine clearance. Surgical staff and emergency department physicians received education on the risks related to pediatric radiation exposure and information related to the institution's diagnostic trends for cervical spine clearance. An algorithm was then developed to assist with determining the necessary imaging study for cervical spine clearance. Radiation exposure was monitored following initial education and use of the algorithm to determine its effect on radiation exposure.

Results: The retrospective chart review identified cervical spine computed tomography (CT) in 34%, with an average radiation exposure of 3.5 mSv. Following education and introduction of an algorithm, 18% of patients underwent CT for cervical spine clearance with an average radiation exposure of 3.2 mSv, representing a 47% decrease in the use of CT.

Conclusion: Staff education and the use of an algorithm show promise in the reduction of radiation exposure and provide safe, effective clearance of the cervical spine in pediatric trauma.

Key Words

Cervical spine, Cervical spine clearance, Pediatrics, Radiation, Trauma

The evaluation of pediatric cervical spine injuries (CSIs) must be accurate and timely to avoid missed injuries and decrease the adverse outcomes associated with prolonged cervical collar wear. Unintentional injury is the leading cause of death in children (Web-based Injury Statistics Query and Reporting System, 2017). Although CSIs account for less than 1% of documented injuries, a missed injury could result in devastating neurological deficits or even death (Leonard, Jaffe, Kuppermann, Olsen, & Leonard, 2014). A CSI should always be suspected until proven otherwise due to the devastating consequences.

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The authors declare no conflicts of interest.

Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's Web site (www.journaloftraumanursing.com).

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DOI: 10.1097/JTN.0000000000000340

Radiographs and CT scans are often utilized to clear CSIs in the pediatric trauma patient (Ropele, Blech, & Vander Lann, 2009). However, the risk of developing cancer due to radiation exposure is the greatest in patients exposed at an early age (Kleinerman, 2006). The concern of developing cancer due to radiation exposure has led many institutions to use CT scans in limited situations and target specific regions of the body in need of further assessment (McMahon et al., 2015). Until recently, patient size was not accounted for when obtaining a CT scan, which resulted in higher radiation exposure (Shah & Platt, 2008).

The amount of radiation absorbed is referred to as effective dose (Shah & Platt, 2008). An effective radiation dose from a single pediatric CT scan ranges from 5 to 60 millisievert (mSv; Shah & Platt, 2008). By comparison, a person receives approximately 2.4 mSv of radiation annually from natural sources (World Nuclear Association, 2012). However, even low doses of radiation in the range of 10–50 mSv can increase the risk of fatal cancer in a lifetime (Shah & Platt, 2008). Since the radiation dose is cumulative over a lifetime, recurrent exposure in the pediatric population is a valid concern (Frush, Donnelly, & Rosen, 2003).

Children have a greater risk of expressing negative outcomes from radiation exposure during their lifetime because of increased sensitivity to radiation and a longer life expectancy than adults. The thyroid gland is one of the most radiosensitive organs (Kleinerman, 2006). Jimenez, Deguzman, Shiran, Karrellas, and Lorenzo (2008) conducted a retrospective review of pediatric trauma patients to compare radiation exposure from CT scans versus plain radiographic films of the cervical spine. These researchers discovered that CT scans expose the thyroid to 90–200 times more radiation than plain radiographic films of the cervical spine. The potential for debilitating injury or death from a CSI coupled with the risks associated with radiation exposure makes pediatric cervical collar clearance a noteworthy health care challenge.

Pediatric anatomy is unique from adults, which results in differing injury patterns and locations of injuries (Leonard et al., 2014). The pediatric head in comparison with the body is larger than an adult's head to body. Pediatric patients have multiple ossification centers in the cervical spine and ligaments have more laxity than the adult population. Because of the differences, the majority of spinal cord injuries in pediatric patients are located in the cervical region and are associated with a higher incidence of mortality (Leonard et al., 2014). Leonard et al. (2014) conducted a 5-year retrospective review of children younger than 16 years at 17 pediatric emergency care applied research network hospitals. Only patients diagnosed with a CSI were included in the study with a goal to describe this injury in a large cohort for the pediatric population. It was found that 26% of patients younger than 2 years with a CSI had an outcome that ended in death. Whereas, 15.7% of patients aged 2–7 years and 3% of patients aged 8–15 years had a CSI that resulted in death. Mortality rates were highest in the younger patients, suggesting that their anatomy coupled with the challenges of clinical assessment was an indicator for their higher mortality rates. These results stress the importance of considering anatomical differences in pediatric patients when attempting to determine the location of the injury and the appropriate evaluation of that injury.

Anderson and et al. (2010) performed a literature review and found that there are no national guidelines for clearance of pediatric CSIs. Lack of evidence to support specific standards of care for clearance of the pediatric cervical spine in the traumatic setting continues to raise concern for providers (Anderson et al., 2010). Many centers have published guidelines for cervical spine clearance for pediatrics within their institution, but the majority of these protocols are based on adult research (Egloff, Kadom, Vezina & Bulas, 2008; Henry et al., 2013). The National Emergency X-Radiography Utilization Study (NEXUS) was developed for the adult population; however it is utilized in many pediatric cervical spine protocols. The NEXUS criteria are a validated tool that provides clinicians with five measures to help rule out a CSI. If all criteria are met, including: no neurological abnormalities, no evidence of intoxication, no midline cervical spine tenderness, no altered level of consciousness, and no other distracting injuries, the patient meets criteria for minimal risk of a CSI (Hoffman, Wolfson, Todd, & Mower, 1998; Hutchings & Willett, 2009). Patients who meet NEXUS criteria are identified as patients with a low risk of a CSI that could possibly be spared imaging for clearance (Hoffman et al., 1998).

Controversy continues regarding which imaging studies are the most sensitive in detecting CSIs in pediatric patients. However, CT scans have been shown to be more sensitive at identifying CSIs in the adult population (Holmes & Akkinepalli, 2005). Holmes and Akkinepalli (2005) conducted a meta-analysis to compare plain radiographs with CT scans in adult patients with CSIs. Randomized controlled trial studies comparing plain radiographs with CT scans for the detection of blunt CSIs or cohort studies of patients utilizing both plain radiographs and helical CT scans of the cervical spine to detect blunt CSIs were included in the meta-analysis. The literature search identified 712 studies but only seven met the inclusion criteria. The combined sensitivity of detecting CSI using plain films was 52%, but using CT scans showed a sensitivity of 98% in injury detection. The authors concluded that CT scans should be the first modality of imaging in adult patients with severe decreased mental status (Holmes & Akkinepalli, 2005). However, evidence was lacking to state that plain radiologic films should not be included on the initial screening for patients with less severe injuries (Holmes & Akkinepalli, 2005). With the concerns regarding radiation exposure in the pediatric population and lacking evidence to support use of plain radiographs as the first line of assessment of CSIs, more research is needed to determine whether plain radiographs are sensitive enough to detect CSIs in pediatric patients.

Although many pediatric cervical spine protocols are based on adult criteria, the implications for such protocols in the pediatric population are positive. Pediatric protocols currently in use have shown to decrease the time for cervical collar clearance and decrease the amount of missed injuries (Frank, Lim, Flynn, & Dormans, 2002; Lee, Sena, Greenholz, & Fledderman, 2003).

The literature shows a wide range of differences in protocols for the clearance of pediatric CSIs, mainly related to the preference of which imaging studies are utilized. However concerns have been voiced regarding radiation exposure in the pediatric population and the risk of developing cancer (Kleinerman, 2006). With the increased awareness of radiation risks in the pediatric population, institutions limit the use of CT scans and attempt to target specific regions of the body (McMahon et al., 2015).

Providers are now utilizing the NEXUS criteria and developing cervical spine protocols to identify patients with "no risk" of a CSI who could possibly be spared imaging for clearance (Hoffman et al., 1998). Lee et al. (2003) utilized plain radiographs as first-line radiologic imaging if clinically indicated following examination and showed a decreased time to clearance when utilizing a protocol. Anderson et al (2010) documented that 80% of the population included in the study had the cervical spine cleared by clinic examination combined with plain radiographs.

Furthermore, McMahon et al. (2015) showed a 24% reduction in the amount of CT scans ordered for cervical spine clearance after implementation of a cervical spine clearance protocol and providing radiation exposure education. Viccellio et al. (2001) utilized the NEXUS criteria and reported that all pediatric patients were identified who had a CSI. The NEXUS decision instrument reduced the number of radiographic studies by up to 20% in children who definitively meet the low-risk criteria. Sufficient evidence has been shown that clinical clearance with NEXUS criteria or utilization of plain radiographs as first-line imaging is a safe practice in the clearance of the cervical spine in pediatric patients with the main goal to reduce radiation exposure in a high-risk population (Anderson et al, 2010; Hoffman et al., 1998; Lee et al., 2003; Viccellio et al, 2001).

Along with the difficulties in clearing a pediatric cervical spine, the length of time spent in the cervical collar leads to adverse outcomes and increased cost, with skin breakdown being the most common (Powers, Daniels, McGuire, & Hilbish, 2006). Powers et al. (2006) performed a prospective, descriptive study to determine the incidence of skin breakdown related to cervical collars. A convenience sample of adult and pediatric patients admitted to a critical care unit who had a cervical collar in place longer than 24 hr were included in the study. In the sample population, 33 or 6.8% of the 484 patients were noted to have skin breakdown (Powers et al., 2006).

The most prevalent cause of pressure ulcer formation is related to immobility (Ackland, Cooper, Malham, & Kossmann, 2007). Ackland et al. (2007) performed a retrospective chart review and electronic medical record audit between October 2003 and March 2004 and showed that time to cervical collar clearance was an indicator of developing an ulcer. The risk of developing an ulcer increased by 66% for each day of cervical collar wear. Similar to Ackland et al. (2007), Chan et al. (2013) conducted a retrospective chart review of pediatric trauma patients to identify skin complications related to cervical collar wear. Chan et al. reported that 10% of patients (n = 35/365) developed skin complications related to cervical collar wear such as erythema or pressure sores. Interestingly, in this study, only one patient actually had a CSI (Chan et al., 2013).

Reducing the costs associated with cervical immobilization is another advantage for timely and accurate assessment. Radiographs and CT scans are the main modalities utilized during initial evaluation to clear CSIs in a trauma patient. Typically, cervical spine CT scans cost 10 times more than cervical spine radiographs. At the facility where the quality improvement (QI) project took place, cervical spine CT costs approximately $3,800 per scan whereas cervical spine radiographs cost $380. Furthermore, a reduction in CT scans will ultimately decrease overall hospital costs. Frank et al. (2002) implemented a cervical spine clearance protocol in the pediatric population and showed a reduction in hospital length of stay from 20.1 days to 15.5 days, therefore, reducing the cost by $7,700 per patient for the length of the hospital stay.

PURPOSE

The unique issues of pediatric cervical spine clearance and the risks related to radiation exposure were recognized at a Midwest Level 1 trauma center. Therefore, a QI project was developed to analyze radiation exposure in activated trauma patients 5 years of age and older with no neurological deficits or altered mental status. The QI project is one important step in the process of development and potential implementation of a cervical spine clearance protocol in a busy Midwest Level 1 pediatric trauma center.

METHODS

The project was deemed QI by the facility's institutional review board. The setting was a 39-bed emergency department (ED) located in a 314-bed freestanding Level 1 pediatric trauma center in the Midwest. The pediatric trauma center had approximately 1,293 admissions in 2016 for traumatic injuries and 218 trauma activations.

The sample population included all activated trauma patients 5 years of age and older with no neurological deficits or altered mental status. The age group was chosen because younger patients are more difficult to perform an accurate clinical assessment due to development, which could in turn increase the need for radiation exposure. A retrospective chart review for baseline data of all trauma activations from July 2016 until December 2016 who met the inclusion criteria of activated trauma patients 5 years of age or older was completed. Data collected included the patient's age, mechanism of injury, Glasgow Coma Scale score, and radiation exposure from cervical spine CT.

Two education strategies were completed during a 7-week time frame, which included formal education related to the project and introduction of a cervical spine algorithm as a visual cue. Table 1 identifies the retrospective chart review of patient demographics as "predata," and the "postdata" includes the combined patient demographics of each education strategy. Initially, the trauma team, which consists of surgical fellows and ED staff, was

TABLE 1 Patient Demographics

	Predata (*n* = 58)	Postdata (*n* = 16)
Mean age (years)	12.1	11.9
Mean Glasgow Coma Score	14.8	14.9
Mechanism of injury, n (%)		
Motor vehicle accident	21 (36.2%)	7 (43.7%)
Gunshot wound	20 (34.4%)	N/A
Other	6 (10.3%)	3 (18.8%)
Fall	5 (8.6%)	2 (12.5%)
All-terrain vehicle	2 (3.4%)	N/A
Bike injury	2 (3.4%)	N/A
Burn	2 (3.4%)	N/A
Bike vs. car	N/A	2 (12.5%)
Crush	N/A	2 (12.5%)

given a formal presentation regarding the intention of the project and information related to the risks of pediatric radiation exposure. Following the educational sessions, observations were made for a 3-week time frame. Data were collected and included patient age, mechanism of injury, type of radiographs, and amount of radiation exposure from cervical CTs.

The initial education was reinforced with the use of a cervical spine algorithm that provided a visual cue for the trauma team to reference when evaluating a patient in the trauma bay for a CSI. The algorithm, which is shown in Supplemental Digital Content Appendix A, available at: http://links.lww.com/JTN/A3, included applying NEXUS criteria to determine whether the cervical spine could be cleared by clinical examination only. If the patient did not meet NEXUS criteria, then the first line for imaging would be cervical spine radiographs. After implementation of the algorithm, observations were made over a 4-week time frame. Data collected included patient age, mechanism of injury, type of radiographs, and amount of radiation exposure from cervical spine CTs.

RESULTS

During the retrospective chart review, 58 patients met inclusion criteria. Out of the 58 patients, 34% of patients obtained CT scans of the cervical spine with a mean dose of 3.5 mSv. Baseline data also demonstrated that 12% of patients had plain cervical radiographs during initial trauma evaluation. Refer to Table 2 for results.

Following the education to the trauma team, five patients met inclusion criteria with one patient undergoing cervical CT for clearance. In addition, one patient was cleared clinically and one patient was cleared with the use of cervical radiographs during trauma evaluation. However, two patients received cervical spine CT scans at an outside facility, with one patient having an identified odontoid fracture on the image. Refer to Table 2 for results.

After the inclusion of the cervical spine algorithm to augment the initial education, two of the 11 patients who met inclusion criteria underwent cervical spine CT for clearance. Furthermore, five patients were cleared following plain radiographs and three patients were cleared

TABLE 2 Radiographic Images Obtained for Cervical Spine Clearance

	Predata (*n* = 58)	Posteducation (*n* = 5)	Postalgorithm (*n* = 11)
Mode of clearance, n (%)			
CT	20 (34%)	1 (20%)	2 (18%)
Cervical radiography	7 (12%)	1 (20%)	5 (45%)
Clinical examination	UD	1 (20%)	3 (27%)
Outside facility CT	UD	2 (40%)	1 (9%)

Note. *CT = computed tomography; UD = unable to determine.*

by clinic examination only. One patient during this time frame did receive a cervical spine CT scan at an outside facility, which demonstrated a cervical injury. See Table 2 for results.

An analysis of data indicated the following results after completion of education: a 41% decrease in CT scans and a 66% increase in radiographs for cervical spine clearance. Once the cervical spine algorithm was utilized, the percent decrease of CT scans was an additional 10% and an increase of radiographs by 125%. It was noted that clearance by clinical examination showed a percent increase of 35% when comparing data between education and utilization of the cervical spine algorithm. Overall, when comparing the predata and the combination of both education strategies, a 47% decrease in CT scans was seen and a 275% increase in radiographs was noted. Following the conclusion of data collection, all diagnostic studies were further evaluated by radiology showing no cervical injuries. These findings correlate with the literature and demonstrate that pediatric trauma patients can be safely cleared by clinical examination only or by utilizing cervical spine radiographs as first-line imaging.

Radiation exposure dose was obtained from the radiology department following any CT studies and then the mean radiation dose was calculated. After data were analyzed following both interventions, the mean radiation exposure from cervical spine CTs was 3.2 mSv with the largest radiation exposure being 5.1 mSv. Therefore, radiation exposure postinterventions did slightly decrease by 0.3 mSv when compared with retrospective data. However, it was noted that the 2 patients who underwent cervical spine CTs followed the algorithm that was provided to the trauma team and the radiological examinations obtained were appropriate based on clinical assessment. Refer to Table 3 for radiation exposure results.

SYSTEM CHANGES

This QI project identified a process change for the manner in which cervical spine radiographs were obtained. Initially, patients would undergo cervical spine imaging in the radiology suite. However, many patients still required CTs for other diagnostic purposes due to potential injuries, which required moving the patient to another radiology suite and bed. Multiple patient transfers caused an increase in time for the trauma workup and created safety concerns. After this barrier was discovered, a decision was made to obtain the cervical radiographs in the trauma bay with the portable x-ray machine.

The QI project also identified educational opportunities for the trauma team regarding the interpretation of cervical spine radiographs. Many members of the trauma team voiced concern with the interpretation of cervical spine radiographs in relation to CT scans.

The data analysis of the education strategy revealed an opportunity to refine the diagnostic ordering practices and improve the communication between the members of the trauma team. Instead of the intended cervical radiographs, cervical spine and head CT scans were often ordered. Debriefing following a trauma revealed that the culture of the institution was to order a cervical spine CT scan if the patient would be undergoing a head CT for evaluation in the activated trauma patient. Communication and continued education regarding the risks related to radiation exposure were identified as potential solutions for addressing the institution's culture.

DISCUSSION

This QI project demonstrated the importance of collaboration and education when promoting a practice change. Also, the use of a visual cue as provided with the cervical spine algorithm assisted with decreasing variations in the evaluation of the cervical spine. However, educating all potential trauma team members involved in the process should be considered. Unfortunately, the radiology technicians were not included in the initial education sessions, which resulted in confusion and push back in the beginning of the project. In addition, the radiology technicians were concerned with the quality of the portable images that were obtained at the bedside in the trauma bay. The surgical staff provided individual education to the technicians when this situation occurred.

Multiple meetings occurred with QI staff and the trauma team prior to the implementation phase of the project in order to identify barriers that may have impacted the project and process. The identified barriers included provider bias toward current practice, no current standardized protocol, communication among staff, equipment concerns, and techniques for capturing

TABLE 3 Radiation Exposure

	Predata (n = 58)	Posteducation (n = 5)	Postalgorithm (n = 11)	Combined Strategies (n = 16)
Mean radiation dose	3.5 mSv	5.1 mSv	2.3 mSv	3.2 mSv
Largest exposure	24.8 mSv	5.1 mSv	2.4 mSv	5.1 mSv

radiographs. Identifying possible barriers prior to implementation of the project assisted with brainstorming strategies to circumvent these issues as they presented. See Supplemental Digital Content Appendix B, available at: http://links.lww.com/JTN/A3, for a fishbone diagram of the identified barriers.

During the data collection phase, it was noted that the amount of radiation exposure correlated with patient size, which may have skewed pre- and postdata. The amount of radiation exposure in relation to the age of the patient was not taken into account when figuring the average radiation. The correlation may have directly impacted final results and contributed to the small change in radiation exposure following the interventions.

The length of time patients spent in cervical collars was not collected pre- or postimplementation of this QI project. The lack of these data made it impossible to determine the relationship between the length of time spent in a cervical collar and the selected mode of radiologic imaging for cervical spine clearance.

Data on missed CSIs when using radiography as first-line imaging were not collected, which is a limitation to the project. However, the literature review indicated the incidence of missed injuries with the use of radiography, as first-line imaging is low. However, with future studies, documenting missed injuries with the use of radiography will be imperative.

CONCLUSION

Staff education and the use of a cervical spine algorithm show promise in the reduction of radiation exposure and provide safe, effective clearance of the cervical spine in pediatric trauma. This QI project demonstrated an overall decrease in CT scans by 47% and increase in radiographs by 275%. Furthermore, a reduction in radiation exposure of 0.3 mSv was also noted. Future studies will focus on pre- and postdata after implementation of a cervical spine protocol and documentation of potential missed injuries due to the practice change as well as impact on skin breakdown, time to clearance, and cost analysis. Also, modifications to the electronic medical record to include a standardized protocol would assist with provider compliance with future studies. Continued multidisciplinary commitment, reinforcement of a cervical spine clearance protocol, and active engagement of staff will lead to continued success in radiation reduction in pediatric trauma patients.

Acknowledgments

The authors thank Robert Waddell, Dr. David Juang, Kate Gibbs, MHA, CCLS, Dr. Richie Sola, and Dr. Katrina Weaver.

KEY POINTS

- Involvement of stakeholders and providing education prior to a quality improvement study are imperative for success.
- The use of a cervical spine clearance algorithm proved to be safe and effective at reducing radiation exposure in the pediatric trauma population.
- A cervical spine clearance algorithm leads to consistency among providers in assessment and management of pediatric trauma patients with a suspected CSI.

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