Protocol to Clear Cervical Spine Injuries in Pediatric Trauma Patients

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EXECUTIVE SUMMARY

- In order to minimize the amount of ionizing radiation to which young trauma patients are subjected, a cervical spine clearance project was implemented. The aim was to increase the number of pediatric trauma patients clinically cleared and decrease the number of such patients undergoing cervical spine CT imaging when they met clinical clearance criteria.
- To accomplish the goals, a brief education program about the epidemiology of pediatric cervical spine injuries, radiation exposure risks, and safe and effective means available for cervical spine clearance to pediatric trauma providers was delivered. This was made possible through funds awarded by the AHRA & Toshiba Putting Patients First grant. Mean knowledge scores after the program increased significantly for all groups of providers.
- This study showed that after implementation of the cervical spine clinical clearance protocol, there was an increase of 35.7% in the number of patients who were clinically cleared based on the protocol's criteria. Additionally, a 24% decrease was seen in the number of pediatric patients undergoing CT scans of the cervical spine when they met criteria for clinical clearance of the cervical spine.

Children are considerably more sensitive to carcinogenic effects of ionizing radiation and have more time to express the increased risk of cancer as compared to adults.[1-2] Ionizing radiation doses delivered by computed tomography (CT) scans are between 100 and 500 times higher than conventional radiography and are in ranges linked to an increased risk of cancer.[3–4] CT scans have become the standard modality for evaluation of some common injuries.[5]

Cervical spine injury occurs in less than 1% of children who present with trauma.[6] The evaluation for such injuries often exposes pediatric patients to unnecessary levels of radiation through use of CT scans.[7] The projected lifetime attributable risk of solid cancer is highest for female patients under 5 years of age who underwent CT scans of the spine as compared to CT scans of the pelvis/abdomen, head, or chest. Two hundred seventy such scans among young females leads to one solid cancer.[8]

Protocols have been developed to facilitate safe clearance of pediatric cervical spines clinically or through use of modalities exposing children to less extreme forms of radiation if particular criteria are met. One such protocol, published by Sun and colleagues at the University of Iowa, involves clinical clearance of possible cervical spine injuries in pediatric trauma patients and use of film x-rays and MRIs when warranted. In this protocol, CT scans are suggested under limited circumstances and are targeted at a smaller anatomic region, thereby reducing the area exposed to ionizing radiation. Following the protocol resulted in no missed cervical spine injuries.[9]

Given concerns about the increasing risk of cancers later in life among children exposed to ionizing radiation, the long term aim was to increase the number of pediatric trauma patients clinically cleared when they meet clinical clearance criteria outlined by Sun et al.[9] To achieve this aim, in Study I providers were educated about the incidence of cervical spine injuries in children, radiation exposure risks, and safe and effective means available for cervical spine clearance. In Study II the impact of the education session and implementation of the cervical spine clearance protocol was assessed by comparing pre-protocol with post-protocol numbers of pediatric trauma patients who were clinically cleared when they met the protocol's criteria for clinical clearance of the cervical spine. It was hypothesized that with post-implementation there would be a 20% decrease in the number of pediatric trauma patients undergoing CT imaging while increasing the number of trauma patients cleared clinically by a concomitant number.

Study I Methods

Sample: Five trauma surgeons, four emergency medicine physicians, 24 pediatric residents, 14 emergency medicine residents, and 24 pediatric emergency medicine nurses were educated.

Procedure: The Our Lady of the Lake College Institutional Review Board (IRB) approved the study protocol. Pediatric emergency medicine physicians and trauma surgeons were educated during their mandatory monthly faculty meetings. The same training was delivered to pediatric and emergency medicine residents during required lecture blocks. Emergency department nurses were educated during a required meeting.

The training consisted of a Powerpoint presentation which covered issues related to choosing radiation doses as low as reasonably achievable (ALARA), the risks associated with radiation exposure in children, the increased use of CT scans and the amount of radiation associated with such scans, the epidemiology of cervical spine injuries in children, and introduction to a pediatric cervical spine clearance protocol.

A 10-item pre- and post-education knowledge survey was developed based on themes identified from the literature as well as information relevant to the project. Surveys were administered immediately before and immediately following the education session for each of the provider groups. Data collection was done anonymously. Because statistical analysis required linking of data from the pre- and post- surveys for each respondent, participants were asked to create an anonymous identifier using a combination of letters and numbers which could be replicated on both surveys. The creation of unique codes enabled investigators to match pre- and post- surveys for each respondent while obscuring the respondents' identity from the investigators.

Results

Descriptive statistics are presented first followed by inferential statistics. Knowledge deficits were demonstrated at baseline. Descriptive statistics relevant to each survey item on the pre-test and post-test surveys can be found in Table 1.

TABLE 1. Percent of Respondents Answering Correctly or in Desired Direction

Question (correct response)	% Answering Correctly Pre-Test	% Answering Correctly Post-Test
Familiar with term ALARA. **(Yes)**	12.7	97.2
Cervical Spine trauma is rare in Pediatrics. **(True)**	56.3	97.2
Incidence of cervical spine injuries in pediatric trauma patients is **(Less than 5%).**	38.0	94.4
Literature supports reduced imaging as the use of CT can be harmful to children. **(True)**	85.9	88.7
Due to pediatric anatomy of the cervical spine, if an injury exists, it is more likely to occur in areas of the lower cervical spine (C4-C6). **(False)**	36.6	76.1
Incomplete ossification centers, underdeveloped spinal processes, and ligamentous laxity in children is why incidence of cervical spine injuries in pediatric trauma patients is lower. **(True)**	77.5	91.5
Cervical radiation exposure does NOT increase risk of developing thyroid cancer in pediatric patients. **(False)**	94.4	98.6
Cervical spine radiation with CT exposes the thyroid gland to 90-200 times more radiation than a plain radiograph. **(True)**	91.5	100
Spinal cord injuries without radiographic abnormality does NOT apply to patients < age 10. **(False)**	78.9	88.7
If a patient has normal cervical spine radiographs, but continues to be symptomatic, magnetic resonance imaging (MRI) could assist in identifying injuries. **(True)**	91.5	90.1

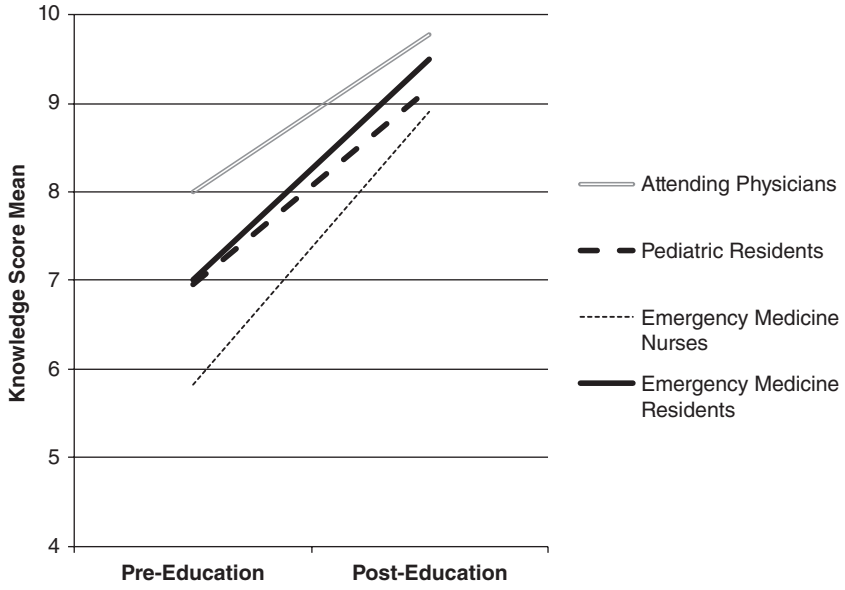

Figure 1 • Mean Knowledge Score as a Function of Time and Provider Group

The overall average number of items from the 10-item knowledge survey described above answered correctly at pretest was 6.73 (SD = 1.41) out of 10. Following the brief educational intervention, the overall mean number of knowledge items answered correctly was 9.23 (SD = .97) out of 10. All items were answered correctly by more than 75% of the respondents on the post-test.

For the inferential statistical analyses on knowledge change, the data of one nurse who arrived to the education session late and completed only the posttest was dropped. Additionally, data from the two physician groups [trauma surgeons (n = 5) and emergency medicine physicians (n = 4)] was combined due to the small numbers in each group. A mixed Analysis of Variance (ANOVA) was used to determine if average knowledge scores, defined as the number of survey items answered correctly, differed due to group (ie, attending physicians, emergency medicine residents, pediatric residents, and nurses), time (pre-post), and the interaction between time and group.

First, as hypothesized, there was an increase in knowledge following the educational intervention ($F_{(1,66)} = 193.39$, $P < .0001$). There were also significant differences among groups regarding average knowledge scores ($F_{(3,66)} = 7.41$, $P < .0001$). Post-hoc analyses using the Tukey Honest Significant Difference Test determined that nurses had significantly lower knowledge scores than did the combined group of attending physicians ($P < .0001$), emergency medicine residents ($P = .02$), and pediatric residents ($P < .05$). The other three groups did not differ significantly from one another. Lastly, as shown in Figure 1, there was a significant interaction between group and time on knowledge scores ($F_{(3,66)} = 2.76$, $P = .05$).

Study II Methods

Sample: All patients between birth and 10 years of age presenting to the Pediatric Emergency Department with Level I or Level II trauma activations from March to December 2013 (pre-protocol) and from March to December 2014 (post-protocol) were included in the study. Because Study I involved anonymous data and data from Study II did not include information identifying physicians and nurses who treated the children, it is impossible to determine which, if any, post-protocol patients in Study II were treated by providers not educated in Study I. It is likely that the vast majority of patients treated during this time period were treated by physicians and nurses trained during Study I.

Procedure: The protocol was approved by Our Lady of the Lake College IRB. In February 2014 a modified version of the evidence-based cervical spine clearance protocol developed by Sun et al specific to the pediatric population was implemented.[9] The algorithm allowed one to clinically clear the cervical spine if the Glascow Coma score was 15, the patient was able to communicate at a developmentally appropriate level, there was no neck pain, no neurological deficit, no intoxication, and no distracting injuries. If, however, any of these criteria were not met and no head CT scan was ordered, then anterior-posterior and lateral X-rays of the cervical spine were recommneded. If the patient had normal radiologic findings yet continued to be symptomatic with cervical spine tenderness or decreased range of motion, the attending physician could order an MRI. Consults with the spine service were encouraged if there were any abnormalities found on imaging. Finally, if any of the criteria were not met and a head CT scan was ordered, then a CT of the cervical spine and anterior-posterior and lateral X-rays of the cervical spine were recommended. Of note, CT imaging of the C-spine from

There was an increase in knowledge following the educational intervention. There were also significant differences among groups regarding average knowledge scores.

TABLE 2. Characteristics of Patients Presenting to the Pediatric Emergency Department with Level I or Level II trauma

	Pre-Protocol (n = 43)	Post-Protocol (n = 32)
Mean Age	5.51 years	4.66 years
Sex	n(%)	n(%)
Male	30 (69.8%)	18(56.2%)
Female	13 (30.2%)	14 (43.8%)
Activation Level	n(%)	n(%)
I	14 (32.6%)	15 (46.9%)
II	29 (67.4%)	17 (53.1%)

TABLE 3. Characteristics of Patients Meeting the Protocol's Criteria for Clinical Clearance

	Pre-Protocol (n = 7)	Post-Protocol (n = 6)
Mean Age	6.29 years	5.33 years
Sex	n(%)	n(%)
Male	6 (85.7%)	4 (66.7%)
Female	1 (14.3%)	2 (33.3%)
Activation Level	n(%)	n(%)
I	1 (14.3%)	1 (16.7%)
II	6 (85.7%)	5 (83.3%)

C1-C7 used in this study was an exception to the protocol used in the Sun et al study, where cervical CT imaging included only CT of the occiput to C3. This exception was made to ensure that there were no missed cervical injuries during the first phase of the study.

Reminders of the protocol were sent via email, pocket cards detailing the protocol were shared with each provider, and a poster detailing the protocol was displayed in the trauma bay in the Pediatric Emergency Department.

A retrospective chart review was conducted using the Trauma List generated in the Pediatric Emergency Department and the Trauma Registry to identify patients between birth and 10 years of age presenting with Level I or Level II trauma activations from March to December 2013 (pre-protocol) and from March to December 2014 (post-protocol). Information was collected on identified patients' condition, whether the patient's cervical spine was clinically cleared, their imaging status, and findings related to the protocol.

Results

There were 43 Level I or Level II trauma patients less than age 11 during the pre-protocol phase in March through December 2013 and there were 32 Level I or Level II trauma patients less than age 11 during the post-protocol phase in 2014 during the same months. Table 2 presents details of the sample's demographics.

The two samples were not significantly different from one another regarding average age (t (73) = 1.27, $p > .05$), distribution of sex (χ^2 (1) = 1.59, $p > .05$), and distribution of activation level, (χ^2 (1) = 0.41, $p > .05$).

In order to meet criteria for clinical clearance, the following six criteria must have been met. These included a Glasow Coma Score (GSC) of 15, no neck pain, no neurological deficit, no intoxication, no distracting injuries, and ability to communicate at a developmentally appropriate level. If the patient's GCS score was less than 15 or there were positive findings concerning any of the findings listed above, imaging was required. Sixteen percent (n = 7) of the pre-protocol sample of 43 met the protocol's criteria for clinical clearance of the cervical spine while 19% (n = 6) of the post-protocol sample of 32 met the same criteria. Characteristics describing those who met the protocol's criteria for clinical clearance of the cervical spine are presented in Table 3.

Considering patients who met the protocol's criteria for clinical clearance of the cervical spine pre- vs post-protocol, the two samples were not statistically different from one another regarding average age (t(11) = 0.58, $p > .05$), sex distribution (Fisher Exact Probability Test, p-value = 0.56), and distribution of trauma activation level, (Fisher Exact Probability Test, p-value = 1).

As illustrated in Table 4, the aim of at least a 20% decrease in the number of pediatric trauma patients undergoing cervical spine CT imaging and a concomitant increase in the number of trauma patients cleared clinically when the satisfied criteria for such clearance was met. There was an increase of 35.7% in patients meeting criteria for clinical clearance of the cervical spine who were actually clinically cleared. Specifically, one of seven (14.3%) patients meeting criteria for clinical clearance of the cervical spine were clinically cleared pre-protocol while three of six (50%) patients meeting

TABLE 4. Clearance Methods in Patients Meeting Criteria for Clinical Cervical Spine Clearance

	Clinical Clearance	X-Ray only	CT of Head & CT of Cervical Spine	CT of Head, CT of Cervical Spine, & X-Ray
Pre-Protocol	1 (14.3%)	2 (28.6%)	4 (57.1%)	0 (0%)
Post-Protocol	3 (50%)	1 (16.7%)	1 (16.7%)	1 (16.7%)

these criteria were clinically cleared post-protocol.

Additionally, there was a 24% decrease in the number of patients undergoing CT scans of the cervical spine when they met criteria for clinical clearance of the cervical spine. Four of seven (57.1%) patients pre-protocol and two of six (33.3%) patients post-protocol implementation who met criteria for clinical clearance of the cervical spine were not clinically cleared but instead had a CT scan of their cervical spine due to having a CT of the head ordered. One such patient also had an X-ray of the cervical spine. Finally, two patients pre-protocol and one patient post-protocol who met criteria for clinical clearance instead had an x-ray of their cervical spine.

Discussion

Cervical spine injuries are rare among young children, though the mechanisms which cause them occur with relative frequency.[10] There may be dire repercussions associated with missing a cervical spine injury, thus physicians often use extreme caution when clearing the cervical spine.[11] While imaging can detect osseous fractures, it generally fails to detect soft tissue injuries which are much more common types of cervical spine injuries.[12] In this study, a total of four cervical spine injuries were detected. Two injuries occurred in each of pre- and post-protocol periods. The four injuries were detected with MRIs. All of the injuries found in the cervical spines of the pediatric trauma patients in this sample were soft tissue or ligamentous injuries. Three of the four injuries occurred in the c1-c2 region. The fourth injury was a mild interspinous ligament sprain at c4-c5. Among imaging technologies, CT scans present the greatest concern given the high levels of ionizing radiation associated with this technology and the estimated increase in lifetime cancer risk associated with the scans.[13-14] In this study, CT scans of the cervical spines did not reveal any injuries.

Several publications have indicated that asymptomatic pediatric trauma patients are at very low risk of cervical spine injury and can be safely cleared clinically or with other imaging technology that exposes patients to much lower doses of radiation, such as plain films.[9,15–16] In the pre- and post-protocol samples, a thorough chart review indicated that none of the patients who met criteria for clinical clearance of the cervical spine had injuries of the cervical spine presenting after the patient was discharged.

It is important that healthcare providers involved in the care of pediatric trauma be educated about the epidemiology of pediatric cervical spine injuries, the risks and limitations associated with CT scans used to clear cervical spines, and the use of other safer modalities for clearing the pediatric cervical spine in order to encourage use of such safe cervical spine clearance rules. The work here adds to the knowledge base given that a search of the literature revealed only one study on provider knowledge deficits regarding the nature and frequency of pediatric cervical spine injuries.[17] In Study I, the surveyed healthcare providers in the reported study demonstrated important knowledge deficits at baseline. It is unlikely that providers will embrace new protocols for clearing the cervical spine in pediatric trauma patients for whom the risk of cervical spine injury is quite low without addressing their knowledge gaps. This study demonstrated a significant increase in knowledge resulting from a brief educational intervention. Though nearly one-third of knowledge items were answered incorrectly by more than half of all participants at pretest, scores were nearly perfect following the educational session. All items were answered correctly at posttest by at least 75% of the participants. This knowledge base sets the stage for practice change, which was the focus of Study II.

As would be expected, attending physicians demonstrated the greatest knowledge concerning cervical spine injuries at both baseline and following the educational intervention. Emergency medicine residents started with approximately the same knowledge level as pediatric residents. This non-significant difference remained following the educational session. Nurses working in the Pediatric Emergency Department had the lowest level of knowledge of the four groups, both at baseline and following the intervention. Furthermore, post-hoc tests indicated that nurses' knowledge level was significantly lower than that

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of physician groups combined and each of the resident groups. Given that physicians are charged with making decisions regarding cervical spine clearance, these findings are not surprising.

There are several limitations to Study I. First, the knowledge gains studied were immediate in nature. It is unknown whether these changes were sustained over a longer period of time. Knowledge improvements often diminish over time, though knowledge scores some time after an educational intervention tend to be higher than pretest scores.[18-19] However, with reinforcements of knowledge, these gains should be maintained over time. The change in provider behavior demonstrated in Study II suggests that the knowledge gains among providers were long lasting and translated into behavior change. Second, the knowledge scale was developed based on the literature and training materials used in the intervention. However, the test was not rigorously validated for general use. While knowledge gains were statistically significant, the ultimate goal of the educational intervention is to change behavior such that more children with trauma who are at low risk of cervical spine injury are cleared clinically rather than through use of CT scans.

Study II focused on behavior changes as a result of the training and protocol implementation and indicates that the project goals were met. Specifically, among patients who met the protocol's criteria for clinical clearance of the cervical spine, there was an increase of 35.7% in clinical clearance and a decrease of 24% in cervical spine CT scans.

Often the only criterion not met for clinical clearance among the groups of pediatric trauma patients both during the pre- and post-protocol periods was that they had a distracting injury. This criterion was somewhat problematic as there is no operational definition of what is meant by a distracting injury given by Sun et al.[9] In 2013, the algorithm used by the University of Iowa, and upon which this project was modeled, was modified and "distracting injuries" was removed from the criteria list.[20] This has important implications moving forward with a cervical spine clearance protocol and will require further education of emergency department and trauma providers.

Study results are limited by the small sample size accrued during the project period. Calculations of percentages are easily influenced with small sample sizes. Larger sample sizes would allow a better interpretation of the effect of the protocol. Cases will continue to be accrued over time to enhance conclusions. Changing the management of medical issues requires much effort. Provider education must be ongoing and would benefit from a champion among the providers. Future efforts regarding cervical spine clearance will include regular presentations of data to providers and additional novel reminders of the protocol.

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