



CT scans to exclude spine fractures in children after negative radiographs may lead to increase in future cancer risk

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Abstract

Introduction National Institute for Health and Care Excellence guidelines recommend computed tomography (CT) scanning for children who fulfill the criteria of significant mechanism or focal spinal pathology. Resulting radiation might subsequently increase the risk of cancer.

Methods Children with spinal CT scans and radiographs from August 2015 to July 2017 were reviewed retrospectively. Data were obtained from the formal radiology reports and case notes. The radiation exposure and risk of cancer were estimated.

Results Thirty-five children had spine CT scans, and 757 spine radiographs were undertaken. Nine (25%) children had their spines scanned as a part of trauma series due to a severe mechanism of injury. Two patients (6%) had abnormalities in their radiographs prior to CT scans, and the rest were obtained to exclude injuries with negative radiographs. The mean radiation dose from CT scan was 20.3 (SD: 11.3) mSV. The relative risk of missing a spine fracture in a child with a normal radiograph was not statistically significant (RR1.14 95% CI 0.3–4.3 and $P=0.8$), and the NNT for detecting a spine fracture with a normal radiograph with further CT scan was 56. The mean lifetime additional cancer risk with CT scan in this group was 0.37%. A significant ($P<0.0001$) positive correlation between the radiation dose and increased cancer risk was found.

Conclusion Children with clinically suspected spinal fracture in the absence of red flag signs/symptoms and negative radiographs might be considered for alternative assessments or investigations to reduce the risk of CT-related radiation hazards.

Keywords CT scan · Children · Radiation · Cancer risk · Trauma · Spine

Introduction

Radiographs and computed tomography (CT) are frequently utilized to investigate the presence and severity of injuries in an emergency setting [1]. CT scans are now increasingly used for identifying major pathologies all over the world. However, concerns have been raised regarding the high radiation doses [2, 3]. Although the immediate benefits can be substantial in an emergency, there are data to support subsequent risks of future cancer risks [4–6]. It is estimated that 29,000 cancer cases could be related to exposure of

CT-associated radiation in the USA in 2007 [7]. This is responsible for around 1.5–2% of all diagnosed cancer cases in the USA [8]. These risks were based on the incidence of cancers in survivors of the atomic bomb in Japan [9]. However, questions have been raised to whether these data may not be applicable to a non-Japanese population with very low dose radiation exposure [10], but there is a substantial evidence to suggest that irradiation of the bone marrow and brain related to CT scans in all patients and especially amongst children does increase the risk of future cancer [11]. The risks of leukaemia and brain tumours are higher due to high radiosensitivity of these organs in childhood as musculoskeletal and brain CT scans are most frequently undertaken in this age group [12]. It is therefore imperative to be cautious about using CT scans in children even in setting of acute trauma. National Institute for Health and Care Excellence (NICE) guidelines published in the UK proposed evidence-based guidelines on the optimal management of different conditions suggesting that children with suspected head and neck injury, if a major head injury is excluded

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clinically, should undergo radiographs of the neck to start with. They recommend CT scan of the cervical spine to be obtained if there is any suspicion of abnormality in the initial radiographs, or the child who has a head injury requiring a CT scan undergoes a CT scan of the head [13]. It is therefore not unusual for children to have CT scans of head and neck or other parts of musculoskeletal system in the emergency department based either due to the mechanism of injuries as recommended by advanced trauma life support (ATLS) [14] protocols or NICE guidelines.

We questioned the effectiveness of this guidance in our practice; in particular, the additional diagnostic yield of additional CT scanning of the spine in the presence of normal radiographs and the absence of deformity or neurological deficit on clinical examination. We have reviewed our use of CT scan for the suspected trauma of the head and neck in children in our district general hospital. Firstly, we assessed the incidence of CT scans undertaken. The doses of radiation from the CT scans were calculated using special calculators, and finally, cancer risks to children over and above the normal natural radiation were estimated. We aimed to verify whether children exposed to CT scans of the spine with normal radiographs and clinical findings following trauma are prone to additional future risk of radiation-induced cancer.

Methods

We retrospectively reviewed all the trauma cases amongst patients younger than 18 years of age that presented to the emergency department over the last 2 years (August 2015 to July 2017). Children and adolescents who had radiological investigations of whole or part of their spine were identified. Their images were reviewed and case notes scrutinized in order to assess the indications and findings of the imaging. All patients under 18 years who underwent CT scans of their spine were included in this study. Children who presented with trauma but did not undergo any radiological imaging were excluded. We reviewed the case notes of patients who underwent radiographs on the initial presentation but not further investigations to exclude any subsequent late detection of injury in the spine. Patients were scanned in National Health System (NHS) electronic radiology system. All imaging undertaken with the same episode were identified. The data included age, sex, details of CT examination and body parts scanned. We noted whether CT scans were preceded or followed by further imaging during the same event. The radiation dose from these imaging studies was calculated using the website www.xrayrisk.com that is endorsed by the American Society of Radiologic Technologists [15]. These estimates are obtained from the effective dose of radiation as defined by the International Commission on Radiation Protection [2]. This is a theoretical dose calculated as a product

of organs exposed by radiation and tissue weighting factors. Data were collected and reviewed by an independent assessor who was not involved in managing any of these cases. We calculated the total effective radiation dose that each child was exposed to on each episode and included the radiation resulting from radiographs and CT scans undertaken. Doses were expressed in Milli Sieverts (mSv).

Results

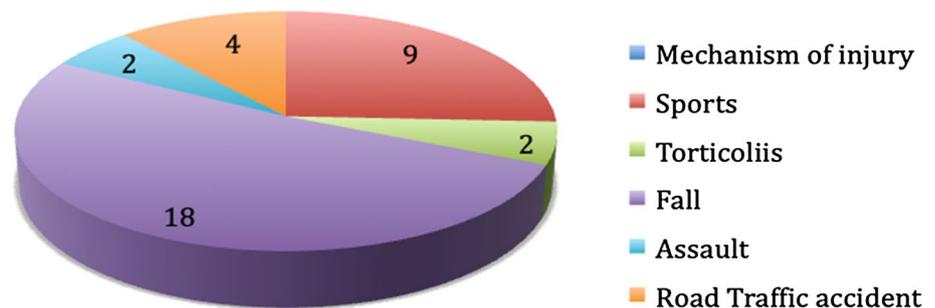
In the study period, 757 children were identified to have radiographs of the spine (cervical spine $n=295$; thoracic spine $n=210$; lumbar spine $n=262$). Of these cases, 35 patients had CT scans of the head and spine. Thirty-three CT scans were obtained as a part of head CT protocol (to include cervical spine due to mechanism of injury), and two cases were obtained due to abnormalities in the initial neck radiographs (Table 1). No patient had significant head injuries detected with the CT scans. The median age was 14 (range 4–17) years. There were 18 male and 17 female patients. Twenty-three patients were under 16 years age, and the rest were in adolescent age group. The common mechanisms of injury are presented in Fig. 1. There were nine major trauma cells based on the significant mechanism of injury. None of the children had any clinical evidence of head injury or peripheral neurological deficit indicating severe head or spinal cord injuries. In addition to those following the NICE guidance, nine patients had CT head and trunks scanned as a major trauma investigation protocol followed in our institution based on NICE guidelines [13] or ATLS protocols [14] severe mechanism of injury that adds to the dose of radiation. One patient (11%) had thoracic 10/11 levels wedge compression fracture (AO type A1). The rest of the scans were normal with no evidence of any injury to the spine or other organs scanned. Five patients (55%) had further radiographs of their appendicular skeleton for suspected limb injuries. All patients were admitted to hospital for observation or treatment of limb injuries. However, none needed any surgical intervention to their head or spine. Furthermore, none of the children were obtunded or unconscious on arrival. All had clinical assessment and evaluation of neurological status following ATLS guidelines. No case was found to have significant neurological deficit.

Thirty patients had CT scans of their cervical spine following NICE guidelines. Ninety-three percentage ($n=28$) of them had radiographs of their cervical spine prior to obtaining a CT scan. The rest CT scans included four lumbar spines and one thoracic spine. Only two patients in this group (6%) had some radiological evidence of abnormality to justify further investigation (CT). In the rest of the cases (94%), the CT scan was ordered based on the clinical finding of the midline neck tenderness with a negative radiograph.

Table 1 Region of the spine undergoing CT scans and their outcome including additional scans performed in patients who did not have CT trauma series

Patient no.	Region scanned	Outcome	Radiograph	Additional CT scans	MRI
1	L	Pars fracture L4	0	0	0
2	L	Pars fracture L5	0	0	0
3	C	N	1	0	0
4	C	N	1	0	0
5	L	N	0	0	0
6	L	N	1	0	0
7	C	N	1	0	0
8	C	N	1	0	1
9	C	N	3	0	0
10	C	N	2	0	0
11	C	Possible C6 fracture in radiograph excluded with CT	5	0	0
12	C	N	1	0	0
13	C	N	1	0	0
14	C	N	1	0	0
15	C	N	1	0	0
16	C/Th	N	1	0	0
17	C	N	1	0	0
18	C	N	1	0	0
19	C	N	1	0	0
20	C	Possible C7 fracture excluded with MRI	1	1	0
21	C	N	1	0	0
22	C	N	1	0	0
23	C	N	1	0	0
24	C	Possible C4 fracture excluded with MRI	3	0	1
25	C	N	2	0	0
26	C	N	1	0	0

C cervical, Th thoracic spine, L lumbar spine, N normal

Fig. 1 The mechanism of injuries resulting in CT scans of spine

Three spine fractures (8.5%) were detected with CT scans. There were two acute pars fractures diagnosed with lumbar CT scans. However, there were two possible cervical spine fractures in the CT scans. One with C7 compression fracture (AO A1) was treated conservatively with a hard collar. The other suspected C4 fracture underwent an MRI scan that was negative. Three patients (8.5%) in this group had MRI scan of the cervical spine with a negative CT scan result. The indications of these scans were not clear in the two cases,

whilst in the third, this was done to exclude posterior ligament complex injury as suggested by the radiology team in the CT scan report. It was noted that 12 cases (34%) of CT scans were ordered out of hours by the attending registrar with no consultant input. The relative risk of missing a spine fracture in a child with negative radiograph was 1.14 (95% CI 0.3–4.3) $P=0.8$. The numbers needed to treat (NNT) of detecting a spine fracture in children with normal radiograph with a further CT scan in our series was 56. We estimated

the mean radiation that children were exposed to from the CT scans was 20.3 (SD 11.3) mSv (Table 2).

There was a significant positive correlation between the dose of radiation and risk of future cancer amongst exposed children in our group ($r=0.8$; 95% CI 0.7–0.9; $P<0.0001$). The mean lifetime risk with CT scan-induced malignancy in our patient group was 0.37% over their estimated lifetime risk from having cancer due to exposure to natural ultraviolet radiation that everyone is exposed to.

Table 2 The calculated radiation in each patient undergoing CT scans of the spine

Patient no.	Dose (mSV) CT	Dose X-ray (mSV)	Total rad	Risk of cancer (%)
1	5.6	0	5.6	0.07
2	5.6	0	5.6	0.08
3	6	0.2	6.2	0.10
4	6	0.2	6.2	0.11
5	5.6	0	5.6	0.12
6	5.6	1.5	7.1	0.15
7	6	0.2	6.2	0.20
8	16.4	0.2	16.6	0.21
9	16.4	0.81	17.2	0.22
10	16.4	0.8	17.2	0.23
11	16.4	0.8	17.2	0.23
12	16.4	0.2	16.6	0.24
13	16.4	0.2	16.6	0.24
14	16.4	0.2	16.6	0.26
15	16.4	0.2	16.6	0.26
16	26.4	0.2	26.6	0.34
17	16.4	0.2	16.6	0.34
18	16.4	0.2	16.6	0.34
19	16.4	0.2	16.6	0.37
20	16.4	0.2	16.6	0.37
21	16.4	0.2	16.6	0.37
22	16.4	0.2	16.6	0.38
23	16.4	0.2	16.6	0.41
24	16.4	0.8	17.2	0.41
25	16.4	3.1	19.5	0.42
26	16.4	0.2	16.6	0.44
27	37.4	0	37.4	0.47
28	37.4	0.8	38.2	0.51
29	37.4	0.8	38.2	0.53
30	37.4	0.2	37.6	0.57
31	37.4	0	37.4	0.78
32	37.4	0.6	38	0.79
33	37.4	0.6	38	0.82
34	37.4	0	37.4	0.86
35	37.4	0	37.4	0.86

Note that the exposure is increased with multiple radiographs and other regional CT scans that adds to the risk of future cancer

Discussion

We found that there is a low threshold both to obtain radiographs and to undertake CT scans in children in the absence of neurological deficits and spinal deformity based on dangerous mechanism in the emergency situation. The positive yields from these investigations were low, and alternative investigations without radiation like magnetic resonance imaging (MRI) was seldom used to exclude spinal injuries. We found a strong positive correlation between the dose of radiation in children and increased risk of cancer.

Based on Japanese nuclear bomb survival data [16], there is a threshold of radiation exposure above that the risk of radiation-induced cancer exists (0.045 per mSv exposure in children below 16 years of age) and the cumulative dose of the children in our study eclipses this threshold. Thus, our predictive model demonstrated exposure to CT-induced radiation induces a small but real additional cancer risk.

Published data indicate a substantial increase in the incidence of thyroid cancer and a borderline increase in all other cancers after brain or neck/spine CT scan [17] and reported 1 case of brain cancer out of 10,000 children exposed to a dose of 10 mSv during a scan when followed up for 10 years [12]. Our study found the mean exposure of 20.3 mSv that is over the threshold of 10 mSv and hence exposes these children to increased risk by 0.9 times. Furthermore, the positive yield of neck/spine fractures based on the mechanism of injury is quite low. This was based on NICE guideline-based indications of children who needed CT with suspected polytrauma or dangerous mechanism of injury, strong clinical suspicion of spinal injury despite normal radiographs [13].

The other important aspect of radiation in children relates to the age at exposure. The highest risk is amongst children less than 5 years old, and the risk rapidly declines after 20 years of age. This risk rises exponentially in children less than 1 year [8]. These risks are attributed to multiple factors including reduced body size compared to the dose of radiation, increased life expectancy and age-specific risks associated with the unit doses of radiation they are exposed to [18–20]. Many children had to undergo multiple radiographs of other body areas with suspected trauma like limbs that adds to their radiation dose.

Radiation exposure in human tissue causes damage in two different mechanisms. The cumulative or deterministic effect causes damage such as skin changes and tissue necrosis when patients are exposed to high doses over a short period of time [21]. Stochastic effect on the other hand causes cell mutations due to exposure to low doses over a long period of time (at least 5 years from exposure

and sometimes few decades) as is commonly associated with radiation-induced diagnostic investigations [7]. The severity is not related to a threshold dose of radiation and is related to duration of exposure. The suggested mechanism of radiation-related cancer involves either ionizing radiation of water molecules in the cells to produce hydroxyl radicals that result in DNA mutation or directly affecting DNA to cause point mutation leading to cancer [8]. The natural radiation exposure for an individual is around 1 mSv. A transatlantic flight at 35,000 feet for 6 h can expose one on around 0.18 mSv (0.003 mSv/h).

The advantages of CT scans include the speed of scanning and the absence of sedation/anaesthesia requirements amongst children that is often needed for a magnet resonance imaging (MRI scan) [22], and the latter is seldom available out of hours in district general hospitals in the UK. MRI scans are more suitable investigations when spinal injuries are suspected with good information on soft tissue injuries as well as bony injuries which often reveal as bone oedema. Although unstable cervical spine injuries are better detected with CT scans, it is unlikely that these will be missed in the initial radiographs and most of these patients will be subjected to whole-body CT due to the severity of injury on presentation [23].

None of the patients with negative radiograph but with a dangerous mechanism of injury were found to have a significant spine injury. Careful consideration should be given whether the investigation is actually needed and whether there is an alternative technique to provide the same data with less radiation like obtaining an MRI rather than CT scan. If the investigation is deemed essential then a modality with less radiation should be chosen as obtaining a radiograph followed by MRI scan if appropriate [24]. When faced with possible spine injury in a child, we suggest the initial radiographs of the neck and spine unless a trauma scan is indicated. If the radiographs fail to detect any bony injuries, further discussion between the emergency departments, orthopaedic/spinal team and radiology department should consider alternative radiation-free assessment or investigations such as an MRI scan or clinical observation if appropriate.

There are several limitations of this study. Firstly, the retrospective nature of the data might lead to a bias as some patients with the initial missed injury might have attended other hospitals subsequently and the decision to undertake investigations depended on the seniority of the attending doctor from emergency and orthopaedic teams. Secondly, the website used in our study does indicate that the calculated risks can imprecise amongst children. However, we feel that the dose estimates does give an idea of the general level of radiation risk over and above that from normal exposure to the environment. Thirdly, due to the establishment of level-one trauma centres in England, children with severe

polytrauma often bypass the district general hospitals and attend these hospitals. This might explain the low yield of positive findings amongst our cohort as children with low suspicion of severe trauma attended district general hospital and there was selection bias to start with. Finally, many children with negative radiographs were admitted for clinical observation and discharged after 24–48 h after being asymptomatic. We cannot comment whether these children could have been discharged with a further non-radiating scan like MRI on the same day or clinical observation can be utilized an alternative effective tool to exclude major spinal injuries compared to immediate CT scans.

We appreciate that MRI is not widely available in many centres especially after hours or over weekends. It is therefore recommended that the attending surgeon should make the decision to obtain a CT scan urgently or to wait for availability of an MRI scan depending on the clinical examination and his/her expertise. Furthermore, it is to be noted that these inferences are applicable to children with relatively low energy injuries and no clinical sign of neurological deficit and/or deformity in the spine. We recommend urgent investigations whether any red flags indication spinal cord injury are present on the initial clinical assessment amongst children with trauma.

Conclusion

We propose that children with clinically suspected spinal fracture in the absence of red flag signs/symptoms and negative radiographs might be considered for alternative assessments or investigations to reduce the risk of CT-related radiation and its associated hazards.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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