PAEDIATRIC TRAUMA

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Ionising radiation exposure in paediatric trauma

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ABSTRACT

INTRODUCTION Trauma remains the highest cause of paediatric morbidity and mortality. These trauma patients incur radiation exposure during intraoperative management. Medical personnel have the responsibility to ensure observation of the 'as low as reasonably achievable' principle, a practice mandate that minimises ionising radiation exposure. The aim of this study was to quantify the difference in the amount of ionising radiation used by operating surgeons of different grades in paediatric trauma surgery.

METHODS Intraoperative imaging in paediatric trauma surgery between 2008 and 2010 at a UK trauma centre was analysed retrospectively, recording injury demographics, surgeon grade, radiation exposure (dose area product [DAP]) and screening time. A mobile image intensifier was used in all cases and the lowest dose rate was selected for all screening.

RESULTS A total of 782 trauma cases were analysed: 304 procedures (39%) were carried out by consultants, 127 (16%) by senior registrars and 351 (45%) by junior registrars. The mean screening time for consultants was 0.23 minutes (standard deviation [SD]: 0.21 minutes) while for senior registrars it was 0.24 minutes (SD: 0.27 minutes) and for junior registrars 0.47 minutes (SD: 1.5 minutes). The mean DAP for consultants was 58.49Gycm^2 (SD: 53.66Gycm^2). For senior registrars it was 87.2Gycm^2 (SD: 126.64Gycm^2) and for junior registrars it was 90.46Gycm^2 (SD: 180.02Gycm^2). This equates to a 51% increase in screening time and a 35% increase in DAP by a junior registrar compared with a consultant.

CONCLUSIONS Significantly lower screening times and radiation exposure was found in procedures performed by consultants compared with registrars (p<0.001). Given the harmful and unknown long-term effects of ionising radiation exposure in children, we recommend increasing consultant presence in paediatric trauma theatres.

KEYWORDS

Trauma – Paediatric – Orthopaedic – Ionising – Radiation – Exposure

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A greater number of children are being exposed to repeated diagnostic imaging. The effects of this increased medical exposure are not fully understood and concerns have been raised about the potential harm caused.[1]

Medical personnel should observe the 'as low as reasonably achievable' (ALARA) principle: a procedure should only be performed when indicated and when a procedure is performed, one should minimise or avoid radiation whenever possible (ie use ultrasonography where possible).[2] Radiation exposure during orthopaedic procedures using fluoroscopy is influenced by many factors including the type and difficulty of the procedure, patient position, radiation protection used and the experience of the surgeon.[3]

Paediatric patients provide a unique challenge during surgery owing to their size. There is a risk for a severalfold increased radiation exposure due to the large size of the image intensifiers relative to the patient size. Potentially, this can bring the surgeon very close to or even within the beam as well as exposing a larger proportion of the child's body to radiation. There is also a greater need for use of magnification to acquire images.

This is of particular significance since children are up to ten times more sensitive to radiation damage than adults.[1] Consequently, children may be expected to be sensitive to even low levels of radiation since they are developing and undergoing rapid cellular division, making their deoxyribonucleic acid vulnerable to damage.[4] As they live many years after the exposure, it gives a chance for the deleterious effects to manifest in life.[5] This is compounded by the fact that cancer risk from medical irradiation accumulates across the lifespan and radiation related cancers involve a latency period of many years or decades from exposure.[4]

Radiation is associated with two types of risk. Stochastic risks are the effects of chance mutations. They occur at random but can occur with a higher probability based on radiation exposure. These have been linked specifically to the development of leukaemia, solid organ and thyroid cancers.[6] The other type of risk is deterministic, having a predictable effect related directly to the quantity of radiation exposure. An example of this is radiation burns.[6] Current models suggest a linear relationship between dose and biological effect with no safe threshold.[7]

The effects of surgical experience on radiation exposure have not been reported previously in a paediatric setting. In an adult setting, studies have focused on intertrochanteric hip fractures and ankle fracture fixation. This showed that the experience of the operating surgeon is an independent factor for determining radiation exposure to patients for hip fracture fixation.[3]

Fluoroscopy use has increased in the field of orthopaedics, and there is also a consideration for the effects of radiation exposure to the surgeon and operating theatre staff. However, this has been discussed in other studies and is not mentioned here. The aim of this study was to review the ionising radiation exposure to paediatric trauma cases undergoing surgery at our trauma centre and investigate whether this is affected by operating surgeon experience.

Methods

Intraoperative imaging in paediatric trauma theatres between 2008 and 2010 at our trauma centre was analysed retrospectively. This information was obtained from logs kept for each individual case. The patient and injury demographics, surgical procedure, surgeon grade, radiation exposure (dose area product [DAP]) and screening time were recorded.

The surgeons were divided into three categories: consultants, senior registrars (minimum three years' experience as a registrar) and junior registrars (less than three years' experience as a registrar). The most senior scrubbed surgeon defined the operating surgeon in this study.

Cases were grouped by anatomy of injury and type of surgery (either manipulation under anaesthesia, use of K-wire stabilisation or open reduction internal fixation). Data were excluded if there was particular difficulty, mention of a more complex procedure (such as multiple fractures and revision cases) or if a complication had arisen leading to prolonged screening (such as difficulty or failure of reduction requiring a change from the initial planned procedure).

The Fluorostar 2 mobile image intensifier (GE Healthcare, Chalfont St Giles, UK) was used in all cases and the lowest dose rate was selected for all screening except for the final images. The DAP is measured through the ionisation chamber in the mobile image intensifier, which intercepts the entire x-ray field.[8] The dose is then dependent on the field size, capture time and dose delivered by the x-ray beam, expressed as $Gycm^2$.

Standard lead protection was used for all patients and staff. This included lead aprons fitted with a lumbar support belt of between 0.25mm and 0.5mm lead equivalence and a thyroid shield.

Statistical analysis

An Excel® spreadsheet (Microsoft, Redmond, WA, US) was used to collaborate the data. Statistical analysis was performed with a two-tailed unpaired t-test using InStat® (GraphPad Software, La Jolla, CA, US).

Table 1 Number of procedures

Anatomy of injury	MUA alone	MUA + K-wire	ORIF	External fixation	Total
Ankle	21	3	29	1	**54**
Tibia/fibula	13	1	12	5	**31**
Other lower limb	3	11	20	0	**34**
Elbow	48	65	40	0	**153**
Forearm (radius/ ulna)	89	13	38	0	**140**
Wrist	241	54	30	0	**325**
Hand	16	11	15	0	**42**
Other upper limb	0	0	3	0	**3**
Total	**431**	**158**	**187**	**6**	**782**

MUA = manipulation under anaesthesia; ORIF = open reduction internal fixation

Results

A total of 825 paediatric trauma cases were performed between 2008 and 2010. Of these, 782 trauma cases were analysed after exclusions, with 304 procedures (39%) carried out by consultants, 127 (16%) by senior registrars and 351 (45%) by junior registrars.

A breakdown of the operative data by type of surgery is shown in Table 1. As expected, the majority of trauma cases in this group (85%) were of the upper limb and, in particular, the wrist. Of the lower limb trauma, fractures of the ankle were most common.

Taking account of the most common injuries (Table 2), only with surgery to the wrist was there a significantly higher operative radiation exposure by junior registrars compared with consultants, with a mean DAP of $41.75Gycm^2$ for consultants versus $90.16Gycm^2$ for junior registrars (p=0.0001). Interestingly, there was no significant difference in the operative radiation exposure for surgery to the ankle, elbow and forearm between consultant and junior registrar surgeons.

The overall mean operative screening time for consultants was 0.23 minutes and that for a junior registrar was 0.47 minutes across all cases (Table 3). This equates to a 104% increase in screening time between these groups (p=0.0058).

The mean DAP during all cases performed by consultants was $58.49Gycm^2$ and that for a junior registrar was $90.46Gycm^2$ (Table 3). This equates to a 55% increase in radiation exposure between these groups (p=0.0030).

There was no difference in mean screening times between consultant surgeons and senior registrars (p=0.6717). However, comparing the radiation exposure during cases, significantly more exposure could be attributed to senior registrars (p=0.001).

Table 2 Radiation exposure during surgery of most common fracture sites

Anatomy	Mean dose area product in Gycm^2			Difference
	Consultant	**Senior registrar**	**Junior registrar**	
Ankle	108.66 (SD: 71.10) *n*=30	–	160.53 (SD: 167.54) *n*=24	*p*=0.131
Elbow	87.41 (SD: 55.47) *n*=73	47.59 (SD: 35.30) *n*=20	108.41 (SD: 151.01) *n*=60	*p*=0.273
Radius/ulna	54.29 (SD: 44.76) *n*=65	24.25 (SD: 7.46) *n*=10	61.65 (SD: 56.97) *n*=65	*p*=0.414
Wrist	41.75 (SD: 34.90) *n*=101	55.62 (SD: 78.14) *n*=28	90.16 (SD: 58.96) *n*=196	***p*=0.0001**

SD = standard deviation

Table 3 Mean screening times and radiation exposure

	Consultant	**Senior registrar**	**Junior registrar**
Number of cases	304 (39%)	127 (16%)	351 (45%)
Screening time in minutes	0.23 (SD: 0.20)	0.24 (SD: 0.27)	0.47 (SD: 1.50)
Radiation exposure (dose area product) in Gycm^2	58.49 (SD: 53.66)	87.20 (SD: 126.64)	90.46 (SD: 180.02)

SD = standard deviation

Discussion

The necessity to use intraoperative fluoroscopy in the management of paediatric trauma will always be present. Consequently, the risks of exposure to ionising radiation need to be understood and minimised where possible.

The causes of childhood cancer are poorly understood but appear to be multifactorial, involving acquired genetic mutations acquired during pre and postnatal carcinogenic exposures. Ionising radiation is a well established and consistently reported risk factor for childhood cancers.[9]

In 2005 the International Commission on Radiological Protection recommended an acceptable level of radiation exposure at 1mSv per year.[10] In context, the lifetime attributable risk of cancer was approximately 0.8% for patients exposed to a 100mSv scan.

Several points need to be taken into consideration to reduce paediatric radiation doses. The routine implementation of the ALARA principle involves multiple safety and dose management practices. This involves eliminating unnecessary imaging (avoiding repeated or redundant images) and recognising when alternative modalities are available to meet clinical objectives. Other factors include dose planning, calibration, patient preparation, positioning and shielding patients. Magnification should be kept to a minimum and the beam should be angled away from radiosensitive organs.[11]

To our knowledge, this is the first study to demonstrate that the experience and training of the operating surgeon is one of the most important factors in determining the exposure to ionising radiation during intraoperative fracture management in a paediatric population. The overall ionising radiation exposure due to fluoroscopy was significantly higher for procedures carried out by surgeons with less than three years of experience at registrar level than for consultant surgeons. The same applies to intraoperative screening time. This implies that more x-rays are taken during cases, resulting in a higher radiation exposure by the more junior trainees.

According to our data, the most common procedures carried out were on the wrist, followed by the elbow, forearm and ankle, which is to be expected from previous population-based epidemiological studies.[12] On closer analysis of these data, there was only a significant difference in the exposure to radiation during procedures carried out for wrist fractures and, in particular, for manipulation under anaesthesia alone. This could be due to episodes of continuous screening, or the need for multiple images owing to lack of confidence or technical skill at a junior level.

We also found that it was the less common or more complex procedures (mainly surgery of the tibia/fibula, femur and hip) carried out by trainees that accounted for the large difference in exposure and screening times. This suggests that these procedures should either be carried out or be more strictly supervised by more senior surgeons.

Although senior registrars demonstrated similar screening time during cases to consultants, there was still a significantly higher radiation exposure. This could be explained by the nature of image or resolution required and the anatomy imaged, which may require higher penetration.

Radiographers can play an important role in the attempt to minimise radiation by warning against inadvertent fluoroscopy. Consideration could be given to sound an alarm beyond a certain screening time or live readouts in the room to remind theatre staff about limiting fluoroscopy time.[2]

It has been suggested that patient radiation doses should be noted in patient records.[9] Children undergoing multiple procedures should have a cumulative dose history documented in their medical record, which should be in the form of a chart that is updated on each visit to the radiology department. This should be easily locatable at the front of the medical records. A discussion of the risks of radiation exposure with the patients/guardians should also be undertaken during the consent process.[2]

Conclusions

It is important to remember that some of these paediatric trauma patients are exposed to radiation during the continuum of care. As a result, all efforts to control the amount of exposure should be in place where possible.

Owing to the importance of training opportunities, it is recommended that more consultant or senior surgeon support should be given to trainees, in the form of their presence in the operating theatre, especially for less common procedures or those deemed complex. Furthermore, radiation safety awareness training should be incorporated early on in the training programme.

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