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Ionising radiation exposure in patients with circular frame treatment of distal tibial fractures

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ABSTRACT

Total radiation exposure accumulated during circular frame treatment of distal tibial fractures was quantified in 47 patients treated by a single surgeon from February 2007 until Oct 2010. The radiation exposures for all relevant radiology procedures for the distal tibial injury were included to estimate the radiation risk to the patient.

The median time of treatment in the frame was 169 days (range 105–368 days). Patients underwent a median of 13 sets of plain radiographs; at least one intra operative exposure and 16 patients underwent CT scanning. The median total effective dose per patient from time of injury to discharge was 0.025 mSv (interquartile range 0.013–0.162 and minimum to maximum 0.01–0.53). The only variable shown to be an independent predictor of cumulative radiation dose on multivariate analysis was the use of CT scanning. This was associated with a 13-fold increase in overall exposure.

Radiation exposure during treatment of distal tibial fractures with a circular frame in this group was well within accepted safe limits. The fact that use of CT was the only significant predictor of overall exposure serves as a reminder to individually assess the risk and utility of radiological investigations on an individual basis. This is consistent with the UK legal requirements for justification of all X-ray imaging, as set out in the Ionising Radiation (Medical Exposure) Regulations 2000 [1].

Introduction

Diagnostic patient radiation exposure, though commonplace in modern Orthopaedics, remains a theoretical hazard with regard to latent carcinogenic potential. The principle effects of radiation on human tissue are described as deterministic (predictable) or stochastic (random). It is the stochastic effects of medical imaging we are concerned with in this study, whereby the risk is assumed to increase in a linear-quadratic fashion with dose, with no threshold for such effects i.e. any exposure to ionising radiation could potentially cause cancer [2,3]. Chest and spine x-rays have been associated with an increased risk of breast cancer [4,5] and Paediatric CT scans have been associated with a small increased risk of leukaemia and brain tumours [6]. Increased rates of thyroid cancer have been observed in a cluster of orthopaedic surgeons exposed to radiation in operating theatres [7]. To put levels of radiation exposure during medical imaging into some perspective, typical values for a range of sources of exposure have been listed in Table 1 [8,9].

Complex trauma management may result in significant radiation exposure for the patient. Computed tomography scanning is frequently used to asses initial injury and healing, fluoroscopy is used extensively in operating theatres and serial radiographs are obtained during follow up. It has been anecdotally observed that complex trauma management using circular frame external fixation may result in excessive radiation exposure. Whilst studies have documented differences in operative exposure during different procedures [10], we are aware of no specific work evaluating the cumulative radiation dose resulting from the wide range of exposures required as part of this type of treatment [11,12]. Standard "as low as reasonably achievable" (ALARA) radiation protection principles should always be within the practising orthopaedic surgeons consciousness [13], since all medical imaging procedures must be justified and optimised. This is also a requirement of UK law under the Ionising Radiation

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Table 1
Comparison of radiation effective doses from different sources of exposure [8,9].

Source of exposure	Dose (mSv)
Sleeping next to someone	0.00005
Banana	0.0001
Dental x-ray	0.005
100 g of brazil nuts	0.01
Chest x-ray	0.014
Transatlantic flight	0.08
Nuclear power station worker annual exposure (2010)	0.18
UK average annual background radiation dose	2.7
Chest CT	6.6
Cornwall's average annual background radiation dose	7.8
Whole spine CT	10
Annual exposure limit for nuclear industry employees	20
Smoking 1.5 packs a day for 1yr	36
Level where changes in blood cells are observed	100
Single highly targeted dose used in conventional radiotherapy	2000
Dose that would kill approximately half of the recipients within a month	5000

(Medical Exposure) Regulations 2000 [1]. To achieve this goal an awareness of the contribution of different exposures to overall dose is vital.

The aim of this study was therefore to establish radiation exposure in distal tibial trauma patients treated by circular frame fixation and determine whether this is within recommended safe limits, whilst understanding the different contributions to this.

Materials and methods

Fifty patients commencing treatment for acute distal tibial fracture between February 2007 and October 2010 were identified from the senior author's database of frame patients. One patient who died from unrelated causes was subsequently excluded from the study, and two patients incorrectly classified as distal tibial fractures were also removed, leaving a total of forty seven patients for evaluation.

Data on patient demographics, injury and treatment was collected from patient notes and the prospective frame database including length of treatment, age, Gustilo-Anderson classification if an open injury [14,15] and whether a temporary monolateral external fixator had been applied pre-operatively. Two authors independently classified the fractures according to the universal AO classification and compared their results. Where there was disagreement in grading (3 out of the 47 fractures, 6% discordance) an agreement was found following discussion.

Radiation exposure data was acquired from a central radiation dose database, cross-referenced with the hospitals Picture Archiving and Communications System (PACS). Routine outpatient follow up for these patients was at 2 weeks post operatively, then every 4–6 weeks until frame removal and finally at 6 weeks and 1 yr post frame removal. The number of radiology procedures was recorded from the time of injury until discharge, including all relevant plain radiographs, CT scans and theatre screening episodes. Radiation doses held on the central database are recorded in Dose Area Product (DAP) values for each individual plain film and theatre screening procedure and Dose Length Product (DLP) for CT scans. These were converted to 'effective dose' using published factors [16]. This figure is related to the risk of radiation induced stochastic effects, and is measured in milli-severts (mSv). Where in occasional cases, specific radiation exposure was not recorded for an individual study, the mean radiation dose for the equivalent investigation from the study group (see Table 2) was used. The only exception was of a plain knee radiograph for which the study samples values were too low for a reasonable average to be valid, so an average value for all such examinations performed in the trust was used. From this data an overall cumulative radiation dose for each patients entire treatment episode was calculated.

Cumulative radiation exposure data was non-normally distributed (Shapiro-Wilks test $p < 0.0001$). Therefore subsequent analysis undertaken using 'analyse-it' software for Microsoft Excel, used non-parametric methods and central tendency is expressed as a median. Univariate analysis was undertaken of the association between different overall radiation exposure and various factors using a Mann Whitney-U test, a Kruksall-Wallis test or Spearmans rank correlation as appropriate. These factors were then entered as predictor variables into a multiple linear regression analysis with overall cumulative radiation dose as the outcome. Statistical significance was assumed at the $p < 0.05$ level.

Results

The median patient age was 45 yrs (range 17–77), there were 31 males and 16 females. 30 patients were treated using a Taylor Spatial Frame (TSF smith&nephew^{TM}), whilst in 17 a standard Ilizarov Frame (smith&nephew^{TM}) circular fixator was utilised. 25 patients underwent some form of progressive axis correction, whilst in 22 a static frame was used. The median time of treatment in the frame was 169 days (range 105–368 days). The median number of plain imaging radiographic procedures used from time of injury up until discharge was 13 (Table 3).

Table 2
Average effective doses for frame patient imaging.

Plain radiograph	Knee	Ankle	Tibia/Fibula	Single long leg AP	Both long legs AP	CT tibia
Mean (mSv)	0.0004	0.0007	0.0009	0.009	0.021	0.16
2xSEM (mSv)	0.00003	0.00009	0.00006	0.002	0.004	0.03
N	289	111	353	35	4	8

AP – Anteroposterior.
CT – Computerised Tomography.
SEM – Standard Error of the Mean.

Table 3
Numbers of relevant plain imaging radiological episodes during treatment. Range in (Min–Max).

	Knee AP/Lat	Ankle AP/Lat	Tibia/Fibula AP/Lat	Long leg film unilateral AP	Long leg film bilateral AP	Total X-ray episodes
Median (range)	0 (0–2)	3 (0–10)	8 (4–18)	0 (0–1)	0 (0–7)	13 (8–31)