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Peri-operative radiation exposure: Are overweight patients at increased risks?

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ABSTRACT

The aim of this study was to identify if there was a correlation between body mass index (BMI) and intra-operative radiation exposure. A retrospective review of 81 patients who had sliding hip screw fixation for femoral neck fractures in one year was completed, recording body mass index (BMI), screening time, dose area product (DAP), American Society of Anesthesiologists (ASA) grade, seniority of operating surgeon and complexity of the fracture configuration. There was a statistically significant correlation between dose area product and BMI. There was no statistically significant relationship between screening time and BMI. There was no statistical difference between ASA grade, seniority of surgeon, or complexity of fracture configuration and dose area product. Simulated stochastic risks were increased for overweight patients. Overweight patients are exposed to increased doses of radiation regardless of length of screening time. Surgeons and theatre staff should be aware of the increased radiation exposure during fixation of fractures in overweight patients and, along with radiographers, ensure steps are taken to minimise these risks. Whilst such radiation dosages may have little adverse effect for individual patients, these findings may be of more relevance and concern to staff that will be exposed to increased radiation.

Introduction

Ionising radiation is hazardous [1,2] and with the advent of more minimally invasive procedures intra-operative fluoroscopy use continues to increase [3,4]. Radiation protection officers continually audit and review local data and policy to minimise doses for radiological procedures to limit harm to patients and staff [5]. Even with judicious use of fluoroscopy, other factors such as the experience of the radiographer, and the fluoroscopic machine itself, can affect the risks from radiation. Furthermore, there is a wealth of observational and experimental data which reports the growing prevalence of obesity and the causal role of obesity in adverse health outcomes [6–9]. Whilst newer fluoroscopy machines require smaller doses to provide adequate images, they are almost universally used in automatic exposure mode. This means the fluoroscopy machine increases the tube voltage in order to provide optimum images, which increases the risk to overweight patients and the theatre staff. Many orthopaedic procedures are done under fluoroscopic control and whilst there is numerous evidence of quoted dose exposure in Orthopaedics [3,10], and some reports of increased cancer risk in Orthopaedic surgeons [11,12], there is little evidence regarding the effect of obesity, and the radiation doses to which an overweight patient population is subjected during orthopaedic procedures. This study was designed to examine if there was a correlation between body mass index (BMI) and intra-operative radiation exposure and screening time.

Methods and materials

We retrospectively reviewed prospectively collected data of all patients undergoing sliding hip screw fixation for neck of femur fractures over a 12-month period from August 2011 to 2012 at a District General Hospital. Dose-area product (DAP) was selected as a measure of radiation dose, and recorded along with fluoroscopic screening time. DAP is a quantity used in assessing the radiation risk from radiographic examinations and interventional procedures and is defined as the absorbed dose multiplied by the area irradiated. It is expressed as centi Gray cm sq ($cGycm^2$) and easily

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measured with the permanent installation of a DAP meter on fluoroscopic machines. It not only reflects the dose within the radiation field but also the area of tissue irradiated. Case-notes and radiographs were reviewed to collect data on patient's height, weight, ASA grade at the time of surgery, complexity of fracture configuration, operation performed and the grade of surgeon operating. All examinations were performed using Ziehm Mobile X-ray fluoroscopy machine. The surgical procedure was performed by surgeons of all grades, with a radiographer in attendance to operate the fluoroscopy machine and assist with the technical set-up. The fluoroscopy machine was used in automatic dose control mode for virtually all examinations.

82 patients had sliding hip screw fixation over the 12 months period. One patient was excluded from analysis as the recorded dose area product was erroneous. Of the remaining 81 patients who had a documented DAP measurement, 73 patients also had a screening time recorded. A statistician explored the collected data for normality of distribution. Analysis of variance was used to investigate the effects of surgeon grade, ASA, BMI, fracture configuration and operation on total DAP and total screening time. Linear regression analysis was used to determine the co-efficient of determination.

The concept of effective dose is used in radiation biology to compare the stochastic risks of a non-uniform exposure of ionising radiation with the risks caused by a uniform exposure to the whole body [13]. It accounts for the type of radiation and nature of each organ or tissue being irradiated. The effective dose is expressed in sievert (Sv) or millisievert (mSv), and is found by calculating a weighted average of the equivalent dose to different body tissues with the weighting factors designed to reflect the different radiosensitivities of the tissues. This permits comparison of risks among different individuals and among differing imaging modalities (e.g. comparison of effective dose of computed tomography and a chest X-ray) [14].

In this study, the effective dose was calculated for each patient using a PC-based X-ray Monte Carlo program, PCXMC, which is based on fluoroscopic view angles, patient weight and height, field size, and focus to skin distance. We simulated the procedures and used a 23 cm field size, a 60-cm focus-skin distance and a 60-kV beam to further characterise the fluoroscopic exposure which were based on measurements from actual cases. We performed this simulation for an average male and female patient undergoing hip fracture fixation with low and high body mass index and finally in a younger male patient. Effective dose values from the PCXMC software were used to calculate the radiation-induced lifetime attributable risk for cancer incidence and cancer mortality in each patient, based on the risk estimates recently published in the BEIR VII report on the health risks from exposure to low levels of ionising radiation [15].

Results

There were 81 patients included in the study. There were 63 females and 18 males. Mean patient age was 78.5 (range 28–96). Mean patient BMI was 24 (range 12.1–40.1). Thirty-one patients (38%) had a BMI $\geq$25 kg/m^2, defined as overweight, of which eight patients (10%) had a BMI $\geq$30 kg/m^2, the criterion for obesity. The median dose area product (DAP) was 252.8 cGycm^2 (range 23.2–967 cGycm^2). As Table 1 shows, for the patients with a BMI of less than 25, the median DAP was 192 cGycm^2 which was almost half the mean DAP for patients with BMI equal to or greater than 25, which was 358 cGycm^2.

Median screening time was 68 s (range 26–146 s). In the normal BMI group, the screening time averaged 62 s compared to 76 s in the overweight group. The median American Society of Anesthesiologists (ASA) grade, which is used to classify physical status of pre-operative cases was 3 (severe systemic disease) as recorded in Table 2. The surgical procedure was performed by the Consultant Surgeon or Staff Grade in 39 cases (48%), junior Orthopaedic Trainee (ST1–3) in 24 cases (30%), senior Orthopaedic Trainee (ST4–8) in 18 cases (22%). The majority of fractures were basicervical/2 part trochanteric fractures (41%) or comminuted trochanteric/subtrochanteric fractures (51%).

Table 1
DAP and screening time compared for normal and overweight BMI.

Median	BMI <25 (n = 51)	BMI ≥25 (n = 30)
DAP (cGycm^2)	192	358
Screening time (s)	62	76

There was a statistically significant correlation between dose area product and body mass index as shown in Fig. 1 with a coefficient of determination (R^2) of 0.246 ($p \leq 0.001$). Despite there being a trend of longer screening times with increasing body mass index, as shown in Fig. 2, this correlation was not as strong as DAP (coefficient of determination = 0.119, p = 0.003).

Table 5 outlines the significance of between subject effects on dose area product with only BMI achieving significance. There was a trend towards increased dose and longer screening times with junior surgeons (Table 3) and more complex fracture configurations (Table 4). However, these were not statistically significant (p = 0.240 and 0.340, respectively). Likewise, there was no statistical difference between ASA grade and dose area product.

Calculating the effective dose, and quantifying the stochastic effects, of a 75-year-old female with a high BMI (30), who by calculation would have an expected 11.7 years of remaining life, the risk of exposure-induced cancer death (REID) from this sliding hip screw fixation is: 0.000512%. To view this differently, the loss of life expectancy (LLE) would be 30 min. In comparison with a 75-year-old female with low BMI (20), the risk of exposure-induced cancer death is 0.0004% and the loss of life expectancy (LLE) is be 24 min – a 20% reduction. Even for a young 20-year-old male with a high BMI (30), the risk of exposure-induced cancer death is only 0.000881% with a loss of life expectancy of 1 h 42 min.

Discussion

Our study is the first to report, from an orthopaedic viewpoint, the DAP measurements and stochastic risks of the radiation exposure in a cohort of patients undergoing orthopaedic hip fracture fixation and how this is effected by body mass index. Our study confirms the strong link between radiation exposure and body mass index. This has been specifically assessed in other surgical specialities such as cardiac intervention, with obese patients receiving more than twice the effective dose of normal weight patients [16]. There is a single study that assessed the peri-operative risk to an orthopaedic patient undergoing fracture

Table 2
Dose area product (DAP) and screening time divided by ASA grade.

			Median	Percentile 25	Percentile 75	Valid N
ASA	2	Total DAP (cGycm^2)	189.30	160.80	313.10	22
		Total screening time (s)	62	44	97	21
	3	Total DAP (cGycm^2)	180.75	124.70	325.30	47
		Total screening time (s)	65	47	85	43
	4	Total DAP (cGycm^2)	234.70	123.90	354.55	12
		Total screening time (s)	81	55	89	11