Establishing the radiation risk from fluoroscopic-assisted arthroscopic surgery of the hip

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Abstract

Purpose The purpose of the study was to quantify patient exposure to ionising radiation during fluoroscopic-assisted arthroscopic surgery of the hip, establish a risk profile of this exposure, and reassure patients of radiation safety during the procedure.

Methods We retrospectively analysed the dose area products for 50 consecutive patients undergoing arthroscopic hip surgery by an experienced hip arthroscopic surgeon. The effective dose and organ dose were derived using a Monte Carlo program.

Results The mean total fluoroscopy time was 1.10 minutes and the mean dose area product value was 297.2 cGycm². We calculated the entrance skin dose to be 52 mGy to the area where the beam was targeted (81 cm²). The mean effective dose for intra-operative fluoroscopy was 0.33 mSv, with a SD of 0.90 Sv.

Conclusion This study confirms that fluoroscopic-assisted arthroscopic surgery of the hip is safe with a low maximum radiation dose and supports its continued use in preference to alternative imaging modalities.

instrumentation into the joint space, minimising risk to the acetabular labrum and articular cartilage [3–6]. Fluoroscopic guidance of any interventional procedure requires the transmission of ionising irradiation to the patient and the surrounding environment, placing the patient at risk from deterministic and stochastic radiation effects [7]. In the United Kingdom this practice requires compliance with the Ionising Radiation (Medical Exposure) Regulations 2000 which state that reference levels should be established for all medical treatments that require exposure to ionising radiation [7]. Arthroscopic surgery of the hip is reliant on fluoroscopic guidance and in complex cases can potentially demand a prolonged screening time. The purpose of this study was to quantify patient exposure to ionising radiation during the procedure, establish a risk profile of this exposure, and reassure patients of radiation safety during the procedure. We hypothesise that the ionising radiation dose delivered to patients during hip arthroscopy is within a reasonable and safe limit.

Introduction

The indications for arthroscopic surgery of the hip are steadily increasing as surgical techniques and instrumentation evolve to address previously unrecognised pathology in the central, peripheral and lateral compartments of the hip [1, 2]. It is currently commonplace to use intra-operative fluoroscopic screening when distracting the hip and passing

Patients and methods

We retrospectively analysed the radiation exposure of 50 consecutive patients undergoing elective hip arthroscopy by a fellowship trained senior arthroscopic hip surgeon. The surgical technique and data analysis are described below.

Surgical and fluoroscopic technique

Arthroscopic surgery of the hip at our institution is performed in the lateral position (Fig. 1) using the Hip Positioning System (Smith and Nephew, Memphis, USA) to secure the patient. Longitudinal traction is applied to the leg with a padded post in the groin providing counter-

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Fig. 1 Theatre set-up with patient in the lateral position

traction which also helps to lateralise the hip. The foot is well-padded prior to placement in the bound traction bindings to protect against iatrogenic peripheral nerve injury and the perineum is inspected to ensure pressure is not exerted directly upon it. The C-arm (Siemens Siremobil Compact L, Siemens, Camberley, UK) is placed with the beam generator located posterior to the patient and adjacent to the surgeon, positioned to produce an anteroposterior view of the hip joint with the C-arm tilted out of the operative field. The hip is gradually distracted until the silhouette of the labrum can be seen on the monitor, and a Seldinger technique is used under fluoroscopic guidance to create the first access portal [8]. A 70° arthroscope is placed and the second portal is made under direct vision anterior to the initial portal. The traction is released to view the peripheral compartment while the hip is flexed to relax the anterior capsule facilitating access. Fluoroscopy guides portal access, positioning of instruments across the femoral and acetabular impingement lesions and ensures penetration outside the hip capsule is prevented so as to reduce risk to adjacent structures.

Calculation of effective dose and entrance skin dose

The dose area product (DAP) was collected from the image intensifier for each procedure and used to calculate the effective dose and skin entrance dose. A 23-cm field without collimation was used for all cases with a fixed beam filtration of 3 mm aluminium based on measurement. A focus-to-skin distance (FSD) of 63 cm was used for the purpose of calculations derived from measuring the mean FSD for ten patients, resulting in an irradiated beam area on the patients' surface of 81 cm².

A dose area product (DAP) meter, integral to the image intensifier, measures the DAP in units of cGyCm², where DAP is defined as the integral of the product of the dose and

the radiation beam area. Radiation dose data, including total screening time and dose area product, were obtained from the hospital computed radiology information system database (CRIS; Healthcare Software Systems, Derby, UK).

The effective dose provides an estimate of the risk of radiation-induced malignancy due to stochastic effects in later life following exposure of a given level of radiation. The effective dose and organ dose were derived using a PC-based Monte Carlo simulation (PCXMC 2.0 computer program; STUK [Radiation and Nuclear Safety Authority], Helsinki, Finland) [9]. This programme calculates the absorbed doses to 29 organs and tissues, and then calculates the remitting effective dose using tissue weighting factors from ICRP Publication 103 [10]. These calculations assumed a tube voltage of 90 kVp and used a standard hermaphrodite phantom measuring 178.6 cm and 73.2 kg. The entrance skin dose (ESD), i.e. the amount of radiation absorbed at any given point on the skin, was also calculated by dividing the DAP by the irradiated beam area at the surface of the patient and then applying a back scatter factor of 1.43 [11]. A radiation threshold of 2 Gy needs to be exceeded before significant radiation induced skin damage is evident [7]. The gonadal dose for male and female patients was also calculated.

The increased risk of carcinogenesis (both non-fatal and fatal) due to exposure to ionising radiation for the population as a whole was estimated by multiplying the patient effective dose by the excess mortality coefficient of $5.5 \times 10^{-2} \text{ Sv}^{-1}$ (Table 2) [12].

Results

Fifty consecutive patients underwent arthroscopic surgery of the hip at our institution under fluoroscopic guidance. There

were no exclusions and 28 female and 22 male patients were included in the study. The mean total fluoroscopy time was 1.10 minutes and the mean DAP value was 297.2 cGycm². We calculated the entrance skin dose to be 52 mGy to the area where the beam was targeted (81 cm²). The mean effective dose for intra-operative fluoroscopy was 0.33 mSv, with a SD of 0.90 Sv.

For female patients the radiation dose to ovaries and uterus was calculated, and for the male patients we calculated the radiation dose to the testes and prostate. The risk for serious hereditary ill health occurring in the first two generations after parental irradiation is estimated by multiplying gonadal dose by a risk factor of 10⁻² Gy⁻¹ [13]. Table 1 summarises the results and Table 2 includes data on the calculated risk of fatal carcinogenesis or severe hereditary disorder following fluoroscopic-guided hip arthroscopy. The mean total body dose in male and female patients was 0.514 mGy and 0.423 mGy, respectively.

Discussion

Complications from arthroscopic surgery of the hip can occur as a consequence of traction, iatrogenic damage while establishing portals to the hip and injudicious use of surgical instrumentation [14]. This is the first study to attempt to quantify the ionising radiation exposure and risk of patients undergoing fluoroscopic-assisted hip arthroscopy. A recent study, comprising 1,054 patients who had undergone hip arthroscopy, reported an overall complication rate of 1.4 %, with a 2.8 % rate of inadequate visualisation emphasising the importance of safe portal placement [14, 15]. However, complications arising from exposure to ionising radiation are not documented in this series, which only considered intra-operative and early surgical complications.

A significant radiation dose can cause local skin damage and systemic absorption by body organs potentially leading to DNA changes, altered DNA damage response mechanisms and ultimately cellular dysplasia and malignancy [7]. The entrance skin dose (ESD), defined as the absorbed dose to the patient in the area of skin targeted by the beam, is of priority concern [7]. Various direct and indirect methods are available to determine the radiation dose delivered to

Table 2 Risks for fatal carcinogenesis and severe hereditary disorders following intra-operative fluoroscopy in arthroscopic hip surgery

Gender	Risk of fatal cancer per 10 ⁶ patients	Risk of hereditary disorders per 10 ⁶ patients
Female	0.006	0.0602
Male	0.006	0.1005

the patient's skin and other body organs during fluoroscopy [7]. We used dose-area product measurements, the integral of the product of the dose and radiation area, collected by the DAP meter at the collimator point to determine the entrance skin dose and organ dose using a computer generated phantom model, which is an accepted and validated method [16–18]. The thresholds for radiation induced local skin erythema, epilation and delayed skin necrosis are 2 Gy, 7 Gy and 12 Gy, respectively, and these are substantially higher than the exposures of 0.29 mGy and 0.39 mGy seen in females and males, respectively, in our series [7, 13]. The gonadal and effective dose delivered to patients undergoing fluoroscopic arthroscopy of the hip was determined and the corresponding radiation risks are included in Table 1. The gonadal dose and the risk of hereditary genetic disturbances was higher in male patients, increasing their overall risk, with an equal risk of carcinogenesis in male and female patients. The nominal risk for cancer induction and genetic disorders has been reported to be 20 % (200,000/million) and 6 % (60,000/million), respectively [19]. Although both the risk of fatal carcinogenesis and the risk of hereditary disorders are negligible in this procedure compared to nominal risk, extended fluoroscopic exposure times in complex cases, and repeat procedures could increase risk substantially. Furthermore, the risk should not be disregarded when treating obese patients when the increased DAP rate and higher ESD would result in a greater radiation burden.

Ultrasound-guided arthroscopy of the hip has been proposed as an alternative to fluoroscopy [20]. While ultrasound does not emit ionising radiation and offers the ability to provide real-time and 3D imaging, it also requires the presence of a skilled operator alongside the surgeon to provide ultrasonic guidance for arthroscopic surgery of the hip. This is not an appropriate technique to replace fluoroscopy given the low dose of radiation demonstrated by our study and the clear practical limitations of using ultrasound as an alternative.

This study addresses the risk to the patient from fluoroscopic radiation but the risk to the orthopaedic surgeon performing these procedures is also relevant. Previous data reveals the effective dose to the orthopaedic surgeon working tableside during a typical fluoroscopic-guided hip procedure was 2.5 mSv when a lead equivalent apron and thyroid shield were used [21]. A previous study used a

Table 1 Summary table

Mean doses	Female	Male
Effective dose (mSv)	0.328	0.328
Entrance skin dose (mGy)	52.0	52.0
Gonadal dose (mGy)	0.602	1.005
Total body dose (mGy)	0.423	0.514

anthropomorphic phantom model to simulate the radiation dose to operating room personnel during image-guided orthopaedic surgery of the hip and lumbar spine and concluded that procedures with a dose area product of $<0.38 \text{ Gy m}^2$ would not exceed the corresponding effective dose limit [21].

Our study does have several limitations. First, this is a small sample size and patients were treated by a single surgeon in a single centre, though we consider the results to be generalisable to other surgeons performing arthroscopic hip surgery having used a standard operative technique on commonly occurring pathology. Second, the type and complexity of the cases performed, the patient morphology and increasing operator experience varied throughout the period of the study. We also acknowledge that surgeons of differing experience will choose to use fluoroscopy to a varied extent during any single procedure influencing radiation exposure. Third, the experience of the radiographer operating the image intensifier in our study varied. Jorgensen et al. found that the radiation dose significantly reduced when an experienced endoscopist performed an ERCP in a retrospective review of 9,052 patients [22].

Conclusion

This study confirms that fluoroscopy-assisted arthroscopic surgery of the hip is safe in non-complex cases with a low maximum radiation dose and supports its continued use in preference to alternative imaging modalities. Further research is required to determine the effect of obesity, prolonged or repeated procedures and surgeon inexperience on the radiation dose delivered to the patient and operating room personnel.

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