

# What factors affect fluoroscopy use during Bernese periacetabular osteotomy for acetabular dysplasia?

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## ABSTRACT

Periacetabular osteotomy (PAO) is the treatment of choice for acetabular dysplasia in the skeletally mature. Little is known about factors affecting fluoroscopy use in PAO. Therefore, we strived to determine patient and surgery factors are associated with the amount of fluoroscopy time and radiation dose during PAO. We performed a retrospective review of 378 patients who underwent PAO between January 2012 and August 2017. The mean age was 21.7 years and 326 (86%) were females. A total of 85 patients underwent concomitant arthroscopy and 60 underwent open arthroscopy. We recorded fluoroscopy time in minutes and radiation dose area product (DAP) in  $\text{mGy}\cdot\text{m}^2$ . Multivariate general linear modeling identified independent predictors of fluoroscopy time and radiation dose. Mean fluoroscopy time was 1.21 minutes and mean fluoroscopy DAP was  $0.71 \text{ mGy}\cdot\text{m}^2$ . Multivariate predictors of increased fluoroscopy time were male gender ( $P = 0.001$ ), surgeon ( $P < 0.001$ ) and whether an arthroscopy was performed ( $P < 0.001$ ). Multivariate predictors of increased fluoroscopy DAP were increased body mass index (BMI) ( $P = 0.001$ ), surgeon ( $P < 0.001$ ) and whether an arthroscopy was performed ( $P < 0.001$ ). Patients undergoing hip arthroscopy concomitant to PAO are at higher risk of longer fluoroscopy time and higher radiation dose. Other factors affecting fluoroscopy time included male gender and surgeon, while radiation dose was further affected by surgeon and BMI. Our findings can facilitate discussion about the risk of radiation exposure during PAO.

## INTRODUCTION

Acetabular dysplasia is a common cause for hip pain in adolescents and young adults [1]. Over time, acetabular dysplasia causes overload of the acetabular rim and labrum leading to joint damage and osteoarthritis [2, 3]. In the skeletally mature, the Bernese periacetabular osteotomy (PAO) has been developed to reorient the acetabulum and improve the biomechanics of the hip joint [4–6]. PAO improves patient pain and function at mid- and long-term follow up [7, 8]. Changing the joint mechanics also theoretically preserves the patients' native hip and helps prevent joint degeneration [9].

The Bernese PAO is performed by completing osteotomies of the ileum, pubis and ischium, while maintaining posterior column integrity. Acetabular reorientation is then performed with or without intra-articular work [9]. PAO was originally described with plain radiography to assess correction [4]. However, many contemporary PAO surgeons use fluoroscopy to guide some osteotomy cuts and judge the correction of the acetabular fragment before final fixation [4, 10, 11]. Fluoroscopic measurements of acetabular position are accurate and reliable to judge the amount of correction [10, 11]. However, the use of fluoroscopy exposes both the patient and the surgeon to ionizing radiation [12,

13]. For both surgeon and patient safety, judicious use of fluoroscopy is recommended to follow the As Low As Reasonably Achievable principle of minimizing radiation exposure [14, 15]. Factors affecting fluoroscopy use in hip arthroscopy, pelvic trauma surgery and total hip arthroplasty have been reported recently [16–19]. A previous study prospectively investigated the amount of radiation exposure to the orthopedic surgeon during PAO in a small series of 23 PAOs [12]. Another study compared the radiation exposure during PAO between fluoroscopy and intraoperative radiography and concluded that fluoroscopy was able to decrease the exposure to the patient and surgeon [20]. However, to the best of our knowledge, there has not been a large study looking at patient and surgery factors that may affect the amount of fluoroscopy used during PAO.

Therefore, the purpose of this study was to investigate patient and surgeon factors affecting fluoroscopy use during PAO. We specifically asked: (i) What factors are associated with the amount of fluoroscopy time during PAO? (ii) What factors are associated with radiation dose from fluoroscopy during PAO?

## PATIENTS AND METHODS

### Patients

After receiving IRB approval for a retrospective review of our medical records and imaging database, we reviewed all patients at our institution undergoing PAO from January 2012 to August 2017. Patients were included if they had a diagnosis of symptomatic acetabular dysplasia as evidenced by lateral center-edge angle (LCEA) or anterior center-edge angle lower than  $20^\circ$  and complete set of preoperative radiographs and intraoperative recorded fluoroscopic data. Patients were excluded if they were over the age of 35 years (surgery was performed at a different facility), they did not have an anteroposterior (AP) pelvis radiograph preoperatively, they had a Perthes-like deformity, they had a diagnosis of skeletal dysplasia or they underwent a revision PAO. The surgeons used no intraoperative radiographs during the study period.

Of the 557 PAOs performed during the study period, 378 were included after application of the above criteria (Table I). There were 326 (86%) females and 199 (53%) right hip PAOs. The average age was 21.7 years (standard deviation [SD] 6.5, range 10–35). The average body mass index (BMI) was  $24.5 \text{ kg}\cdot\text{m}^{-2}$  (SD 4.4, range 16–42). About 42 (11%) were considered obese (BMI > 30). The mean LCEA was  $10.5^\circ$  (SD 8.4, range  $-35^\circ$  to  $28^\circ$ ). A total of 85 patients (22%) underwent concurrent arthroscopy at the time of PAO and 60 patients (16%) underwent concurrent open arthrotomy to treat intra-articular

**Table I. Patient inclusion and exclusion**

Number of patients/hips	Description
557	Periacetabular osteotomies from 2012 to 2017
73	Excluded due to diagnosis other than dysplasia (retroversion/FAI, perthes, skeletal dysplasia, etc.)
98	Excluded due to age over 35 years
3	Excluded due to no fluoroscopy dose report in system
4	Revision cases excluded
1	Excluded due to no available preoperative radiographs
378	Periacetabular osteotomies included in the study

FAI: femoroacetabular.

pathology. Surgery was performed by one of three surgeons (Blinded) Surgeon 1 performed 161 PAOs (15 years of experience), surgeon 2 performed 198 PAOs (20+ years of experience) and surgeon 3 performed 19 PAOs (5 years of experience, surgeon 3 had 3.5 years of experience outside the system where he performed approximately 60 PAOs).

### Data collection

Patients' medical records were reviewed for all demographic and clinical variables. Patient age at time of surgery, height and weight were recorded and BMI was calculated. A BMI of greater than  $30 \text{ kg}\cdot\text{m}^{-2}$  was considered obese. Operative reports were reviewed for side of surgery, whether a concomitant arthroscopy or open arthrotomy was performed, and the surgeon performing the surgery. Standing AP pelvis radiographs obtained during the preoperative evaluation were used to measure the LCEA as previously described [21]. A fellowship trained hip surgeon performed the measurements (blinded). The imaging database was reviewed and the total fluoroscopy time in minutes and dose area product (DAP) in  $\text{mGy}\cdot\text{m}^2$  were recorded as the outcomes of interest. Briefly, radiation can be reported via different units [15]. The biologic effect of ionizing radiation, or the effective dose, is reported in Sieverts. For radiography, one sievert corresponds to approximately one gray (Gy), which is a physical quantity of radiation irrespective of biologic effect [15]. The DAP reports the area of the patient tissue affected by the ionizing radiation and is therefore reported as  $\text{mGy}\cdot\text{m}^2$ .

**Table II. Fluoroscopy time and fluoroscopy DAP by surgeon during PAO**

	Number of PAOs during study period	Fluoroscopy time (min)		Fluoroscopy DAP (mGy·m <sup>2</sup> )	
		Mean (SD)	Range	Mean (SD)	Range
Surgeon 1	161	0.92 (0.34)	0.3–2.4	0.44 (0.42)	0.03–3.66
Surgeon 2	198	1.32 (0.49)	0.5–3.5	0.75 (0.50)	0.04–2.57
Surgeon 3	19	2.60 (0.85)	1.6–4.9	2.49 (2.35)	0.15–10.00

*P* < 0.001 for all between surgeon comparisons.

### Statistics

The primary outcomes of study were fluoroscopy time in minutes and radiation dose as measured by the DAP, both continuous variables. Differences in these outcomes between categorical variables (gender, presence of arthroscopy, presence of arthroscopy, side of surgery and obese versus non-obese) were determined by students *t*-test after testing for equal variances. Differences between the three surgeons were tested with an analysis of variance with a post-hoc Tukey's test. Bivariate relationships between continuous predictor variables (age, BMI and LCEA) and outcomes were determined using Pearson's correlation coefficient (PCC). For multivariate models, preliminary data analysis tested the applicability of linear assumptions. Binary predictor variables were coded as dummy variables (0/1) for modeling. A multivariate analysis was then performed using general linear regression modeling and including all predictor variables in the final model. *P* values of less than 0.05 were considered significant. All calculations were completed using SPSS 22.0 (SPSS Inc, Chicago, IL).

## RESULTS

### What factors are associated with the amount of fluoroscopy time during PAO?

The mean fluoroscopy time in the cohort was 1.21 minutes (SD 0.6, range 0.3–4.9). Male patients had more fluoroscopy time compared with females (1.39 versus 1.18 minutes, *P* = 0.019). There was no difference in fluoroscopy time between right and left PAOs (1.22 versus 1.20 minutes, *P* = 0.674). There was no difference in fluoroscopy time between obese and non-obese patients (1.25 versus 1.21 minutes, *P* = 0.658) and there was no correlation between BMI and fluoroscopy time (PCC = 0.034, *P* = 0.515). There was no correlation between severity of dysplasia, as measured by the LCEA, and fluoroscopy time (PCC = -0.001, *P* = 0.981). PAOs in which an arthroscopy was performed had more fluoroscopy time compared with those that did not (1.65 minutes versus 1.08 minutes,

**Table III. Multivariate model of independent predictors of fluoroscopy time during PAO**

Predictor variable	Regression coefficient	95% Confidence interval	<i>P</i> value
Age	-0.003	-0.889 to 0.375	0.375
Male gender	0.203	0.080 to 0.325	0.001*
BMI	0.000	-0.010 to 0.010	0.981
Right side	0.000	-0.082 to 0.083	0.997
Arthroscopy	0.524	0.418 to 0.631	<0.001*
Open arthroscopy	-0.008	-0.128 to 0.112	0.900
LCEA	-0.004	-0.009 to 0.002	0.172
Surgeon			<0.001*
Surgeon 1	Reference	Reference	Reference
Surgeon 2	0.263	0.171 to 0.354	<0.001*
Surgeon 3	1.688	1.487 to 1.889	<0.001*

\**P* < 0.05.

*P* < 0.001), however there was no effect of having an arthroscopy on fluoroscopy time (1.35 minutes with arthroscopy versus 1.19 without, *P* = 0.054). There was a significant difference in fluoroscopy time between the three surgeons (Table II). On multivariate testing, independent predictors of increased fluoroscopy time were male gender, surgeon and concomitant hip arthroscopy (Table III).

### What factors affect the radiation dose from fluoroscopy during PAO?

The mean fluoroscopy DAP was 0.71 mGy·m<sup>2</sup> (SD 0.81, range 0.03–10.0). There was no difference in fluoroscopy DAP between gender (male: 0.89 mGy·m<sup>2</sup> versus female: 0.68 mGy·m<sup>2</sup>, *P* = 0.086). There was no difference in fluoroscopy DAP between right and left PAOs (0.76 versus 0.64 mGy·m<sup>2</sup>, *P* = 0.158). Obese patients had a higher

**Table IV. Multivariate model of independent predictors of fluoroscopy DAP during PAO**

Predictor variable	Regression coefficient	95% confidence interval	P value
Age	-0.001	-0.011 to 0.011	0.971
Male gender	0.185	-0.015 to 0.385	0.069
BMI	0.027	0.011 to 0.043	0.001*
Right side	0.086	-0.048 to 0.221	0.207
Arthroscopy	0.395	0.222 to 0.568	<0.001*
Open arthrotomy	0.074	-0.121 to 0.270	0.454
LCEA	-0.002	-0.010 to 0.006	0.672
Surgeon			<0.001*
Surgeon 1	Reference	Reference	Reference
Surgeon 2	0.189	0.040 to 0.338	0.013*
Surgeon 3	1.989	1.662 to 2.316	<0.001*

\* $P < 0.05$ .

fluoroscopy DAP compared with non-obese patients (1.05 versus 0.66 mGy·m<sup>2</sup>,  $P = 0.030$ ), and a correlation between BMI and fluoroscopy DAP was noted (PCC = 0.183,  $P < 0.001$ ). There was no correlation between severity of dysplasia, as measured by the LCEA, and fluoroscopy DAP (PCC = 0.040,  $P = 0.434$ ). PAOs in which an arthroscopy was performed had higher fluoroscopy DAP compared with those that did not (1.02 versus 0.62 mGy·m<sup>2</sup>,  $P < 0.001$ ), however there was no effect of having an arthrotomy on fluoroscopy DAP (1.00 versus 0.65 mGy·m<sup>2</sup>,  $P = 0.080$ ). There was a significant difference in fluoroscopy DAP between the three surgeons (Table II). Multivariate analysis showed that independent predictors of increased fluoroscopy DAP were surgeon, concomitant hip arthroscopy and BMI (Table IV).

## DISCUSSION

Although fluoroscopy is commonly used during PAO, only small case series have reported radiation exposure from intraoperative fluoroscopy [12, 20]. Those studies did not have enough power to detect other factors that may influence fluoroscopy usage during PAO. Our study identifies factors affecting both the amount of fluoroscopy time during PAO as well as the fluoroscopy radiation dose, reported as the DAP. We found that the two independent factors affecting both time and DAP were the surgeon performing the surgery and whether an adjunctive arthroscopy

was performed. In addition, male gender was associated with increased fluoroscopy time and patient BMI was associated with increased DAP.

Fluoroscopy time and radiation dose were both dependent upon surgeon and the presence of an adjunctive arthroscopy. The strongest effect was by that of the surgeon performing the case. We found that our novice surgeon with five years of experience with PAO had the highest use of fluoroscopy compared with the more experienced surgeons. This likely illustrates the learning curve related to a complex surgery such as a PAO. In a prior study, surgical experience has been associated with reduction in operative time during PAO [22]. Smith et al. [19] reported fluoroscopy use during hip arthroscopy of a junior surgeon and found that there was a decrease in amount of fluoroscopy time with increased experience. Similar findings have been reported in the learning curve for direct anterior hip replacement, with fluoroscopy use decreasing with increased surgeon experience [23]. There was also a significant difference between the two senior surgeons in the study, which likely represents the variability in fluoroscopy use even among senior surgeons. This may be due to more or less invasive incisions or surgeons' preference to use more fluoroscopy to make them more comfortable performing the case. Recently, arthroscopy has more commonly been performed along with PAO as both a diagnostic tool and to address intra-articular pathology, such as labral tears and femoral cam lesions, which are both common in dysplastic hips [24–26]. Fluoroscopy is often used to obtain access to the joint and to judge femoral resection during osteochondroplasty. While the effective dose to the patient is likely low, the increased fluoroscopy time used during a combined arthroscopy and PAO should be considered when contemplating this combined approach.

Fluoroscopy time during PAO was also dependent upon patient gender. It is possible that anatomic differences make the surgery more difficult in male patients. This is likely multifactorial, including factors like male patients having more dense bone which increases the difficulty of the osteotomies and more robust musculature which can make exposure more challenging. Notably, one study found a high proportion (15%) of adverse events and anterior femoroacetabular impingement (FAI) signs in males after PAO [27]. In a large multi-center study, male sex showed a trend towards increased complications in PAO [28]. These studies support the concept that the surgery may be more difficult in males.

Other than surgeon and the presence of an adjunctive arthroscopy, fluoroscopy radiation dose was dependent upon patient BMI. This is supported by prior studies looking at fluoroscopically guided injections into the sacroiliac



joint, hip and spine [29–31]. In these studies, increased patient BMI led to increased fluoroscopic radiation dose but not an increased fluoroscopy time similar to our results. This is likely because fluoroscopy machines work through automatic exposure control. In short, this means that the tube voltage and tube current are automatically adjusted to provide a clinically useful image [30, 32]. This leads to a higher radiation dose in large patients to maintain image resolution. Given that BMI did not affect fluoroscopy time, it is not likely that the patient habitus caused the need for more fluoroscopy due to operative difficulty, but the higher dose was needed to an adequate image to safely complete the osteotomy.

Our study has limitations. This is a retrospective review of our institutional database of patients undergoing PAO, therefore we were only able to report what was available in the medical record. We were unable to include patients over the age of 35 because those patients had their surgeries at another local hospital. We did not have patient or surgeon dosimeters and therefore were unable to calculate true patient and surgeon radiation exposure. In addition, there may have been some variation based on the fluoroscopy machine that was used in each individual surgery, but this was not recorded in the medical record and therefore could not be controlled for in the analysis.

This study identifies factors that influence the amount of fluoroscopy used and the subsequent radiation dose during PAO. Fluoroscopy time and the radiation dose were directly influenced by the surgeon performing the procedure and whether an arthroscopy was performed. The most junior surgeon in the group used the highest amount of fluoroscopy, which likely represents the learning curve related to performing a PAO. Fluoroscopy time was also increased in males and younger patients, likely representing the increased difficulty in these patients at performing the osteotomy and reorienting the acetabular fragment. Fluoroscopy radiation dose was increased in patients with higher BMI, likely caused by increased dose per capture to provide a diagnostic quality image while penetrating the patient's soft tissue. Our findings allow the treating surgeon and patients to understand factors that affect fluoroscopy use in PAO. They also provide a framework for the quantity of fluoroscopy used during this procedure. Further prospective studies with dosimeter measurements would be useful to calculate accurate patient radiation exposure during PAO.

#### ETHICAL REVIEW BOARD STATEMENT

Boston Children's Hospital approved the human protocol for this investigation, and each author certifies that all investigations were conducted in conformity with ethical principles of research.

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#### CONFLICT OF INTEREST STATEMENT

None declared.

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