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Comparison of radiation exposure between pulsed and continuous fluoroscopy during PFN-A fixation of pertrochanteric fractures

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ABSTRACT

Aims: Fluoroscopy is widely used in orthopedic surgery but raises concerns regarding radiation exposure. This study aimed to compare radiation exposure between pulsed and continuous fluoroscopy modes during PFN-A (proximal femoral nail - antirotation) fixation of pertrochanteric femoral fractures.

Methods: In this retrospective cohort study, 102 patients treated with PFN-A for AO/OTA (Arbeitsgemeinschaft für osteosynthesefragen Foundation/Orthopedic Trauma Association) type 31A1.2 and 31A1.3 pertrochanteric fractures at a single institution between January 2024 and January 2025 were included.

Results: No significant differences were observed between groups in terms of fluoroscopy time, total radiation dose, DAP (dose-area product), or number of exposures. However, radiation exposure per image was significantly lower in the pulsed fluoroscopy group, as demonstrated by both dose per image ($p = 0.001$, $r = 0.32$) and DAP per image ($p = 0.002$, $r = 0.29$). In adjusted analyses, fluoroscopy mode remained a significant predictor of radiation exposure per image ($F = 9.07$, $p = 0.003$). Image quality was considered subjectively adequate based on intraoperative assessment, with no clinically relevant difference between the groups. Radiation exposure was also normalized per image. Statistical analyses were performed using the Mann–Whitney U test and ANCOVA.

Conclusion: Pulsed fluoroscopy does not significantly reduce total radiation parameters but is associated with lower radiation exposure per image during PFN-A fixation of pertrochanteric fractures. These findings indicate a reduction in radiation exposure per image without significant differences in total radiation parameters.

Keywords: Continuous mode, dose-area product, fluoroscopy, pertrochanteric fracture, pulse mode, PFN-A

INTRODUCTION

The use of fluoroscopy in orthopedics and traumatology has increased significantly. Fluoroscopy devices improve surgical precision and help reduce operative time, thereby minimizing potential morbidity for patients [1]. However, widespread use of fluoroscopy has raised concerns regarding radiation exposure for both the surgical team and patients [2]. Previous studies have shown that orthopedic surgeons may have a higher lifetime risk of developing cancer compared with other healthcare professionals due to cumulative occupational radiation exposure [3-5].

Several studies have investigated methods to reduce radiation exposure, focusing on factors such as surgical experience, patient positioning, the type of orthopedic implants used, the technical specifications of fluoroscopy devices, and the duration of the operation [1,6-9]. The radiation dose received during fluoroscopy should be minimized in accordance with the well-established ALARA principle (As Low As Reasonably Achievable) [10].

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The dose-area product (DAP) (Gy-cm^2) is defined as the absorbed dose multiplied by the irradiated area and reflects both radiation dose and exposed tissue volume. It is considered a more comprehensive indicator of radiation exposure than fluoroscopy time alone [9,11].

Pertrochanteric femoral fractures are common in the elderly population and are associated with significant morbidity and mortality. These fractures are typically treated with intramedullary fixation methods such as proximal femoral nail- antirotation (PFN-A) or cephalomedullary nails [6,12,13]. Given the frequent use of fluoroscopy during PFN-A fixation, radiation exposure remains an important concern in this procedure.

Although previous studies have evaluated pulsed and continuous fluoroscopy modes in various medical procedures, there is limited evidence regarding their use in orthopedic trauma surgery, and to our knowledge, no study has specifically compared these modes in PFN-A fixation of pertrochanteric fractures.

Therefore, the aim of our study was to compare radiation exposure between pulsed and continuous fluoroscopy modes during PFN-A fixation of pertrochanteric femoral fractures in the lateral decubitus position.

METHODS

This study was designed as a retrospective cohort study and was conducted at Kastamonu Education and Training Hospital between January 1st, 2024, and January 1st, 2025. A total of 182 patients were treated with PFN-A for pertrochanteric fractures. Patients with missing C-arm fluoroscopy data, patients with type 31A1.1 and 31A3 fractures, patients who underwent operations in positions other than the lateral decubitus position and patients with a history of previous hip surgeries were excluded from the study. Eighty patients were excluded on the basis of these criteria. All patients were operated on by five different surgeons, but had at least five years of experience with pertrochanteric fractures treated with PFN-A. Patient demographic data, Arbeitsgemeinschaft für Osteosynthesefragen Foundation/Orthopedic Trauma Association (AO/OTA)) Fracture classification and C-arm fluoroscopy data were retrieved from patient files. The fluoroscopy device (OEC Brivo 785 Essential (GE)) (**Figure 1**) was used in auto mode, with kVp and mA parameters adjusted automatically by the system. Pulsed fluoroscopy settings were applied according to the device's default preset configuration. After surgery, the dose report is acquired from the device menu. DAP (Gy·cm^2), time (seconds) and dose (mGy) are noted from the dose report, and the total number of exposures is noted for every case. Image quality was assessed subjectively by the operating surgeons during the procedures, without predefined standardized evaluation criteria. All patients underwent surgery in the lateral decubitus position on a radiolucent table. The selection of fluoroscopy mode (pulsed or continuous) was not randomized and was determined by the operating surgeon according to routine operating room practice. This non-random allocation may represent a potential source of selection bias. After proper positioning, the fractures were reduced via closed reduction manoeuvres, and anteroposterior and lateral views were obtained. PFN-A nails 200 millimeters long with 125 degrees of collodiaphyseal angle were used in all patients.

This study was approved by the institutional ethics committee (Kastamonu University Clinical Research Ethics Committee, decision/protocol number: 2024-KAEK-95, date: 06/11/2024).



Figure 1. *Image of fluoroscopy control panel and patient positioning*

Statistical Analysis

The Statistical Package for Social Sciences (SPSS) (IBM Corporation, Armonk, New York, USA) version 25.0 was used for the statistical analyses. Continuous variables were presented as mean ± standard deviation, and categorical variables as frequency and percentage.

The normality of the continuous variables was assessed using the Shapiro–Wilk test together with visual inspection of histograms and Q–Q plots. As the data did not follow a normal distribution, nonparametric statistical methods were applied for group comparisons. Differences between the pulsed and continuous fluoroscopy groups were evaluated using the Mann–Whitney U test. Effect sizes for the Mann–Whitney tests were calculated using the rank-biserial correlation coefficient (r).

To evaluate potential confounding factors affecting radiation exposure per image (DAP/ Number of exposures), an analysis of covariance (ANCOVA) was performed, including fluoroscopy mode as the main factor and BMI and sex as covariates. Interaction effects between fluoroscopy mode and sex were also tested. The

effect size for the ANCOVA model was reported as partial eta squared (η^2). A p-value < 0.05 was considered statistically significant.

RESULTS

The patient and fracture-related demographics are shown in **Table 1**. A total of 102 patients were evaluated for the final analysis. The mean age was 79.1 years. According to the AO/OTA fracture classification, 45 patients had pertrochanteric fractures with an intact lateral wall, and 57 patients had fractures involving posteromedial fragments with intact lateral walls. The mean BMI of the patients was 27.9. There was no significant difference in age or BMI (p=0.739, p=0.848, respectively). The fracture types did not differ between the groups (p=0.879). The female sex was predominant (p<0.001), but there was no difference in sex between the pulse and continuous groups (p=0.487).

Table 1. *Demographics*

	Pulse(n:53)	Continuous(n:49)	p value
Age (mean±SD)	79.3±8.54	78.8±9.78	0.739[a]
Sex			
Female (n:70)	38 (37.3%)	32 (31.4%)	
Male (n:32)	15(14.7%)	17 (16.6%)	0.487[b]
BMI (mean±SD)	27.7±5.01	28 ±5.05	0.848[a]
AO/OTA Fracture Type			
31A1.2 (n:45)	23 (22.3%)	22 (21.6%)	
31A1.3 (n:57)	30 (29.4%)	27 (26.4%)	0.879[b]

a: Mann-Whitney U test is performed, b: Chi-square test is utilized

The Shapiro–Wilk test demonstrated that the continuous variables were not normally distributed, so nonparametric statistical methods were applied in the analyses.

Table 2. *Dose, DAP, Time and Number of exposures*

	Pulse (Median (IQR))	Continuous (Median (IQR))	p value
Time (seconds)	31.1 (17.4)	33.6 (21.1)	0.121*
DAP (Gy · cm²)	2.06 (2.18)	2.33 (2.25)	0.065*
Dose (mGy)	11.1 (11.7)	13.2 (11.9)	0.054*
Number of exposures	60 (30)	58 (19)	0.137*
Dose/ Number of exposures	0.197 (0.112)	0.234 (0.150)	0.001*
DAP/ Number of exposures	0.0364 (0.0207)	0.0435 (0.0281)	0.002*

**Mann-Whitney U Test was applied*

For the pulse radiation group, the median time (seconds) was 31.1, the median DAP (Gy·cm²) was 2.06, and the median dose (mGy) was 11.1. For the continuous radiation group, the median time was 33.6, the median DAP was 2.33, and the median dose was 13.2. No statistically significant differences were observed between the pulsed and continuous fluoroscopy groups in terms of fluoroscopy time (p=0.121), total radiation dose (p=0.054), DAP (p=0.065), or number of fluoroscopic images (p=0.137). However, radiation exposure per image was significantly lower in the pulsed fluoroscopy group, as demonstrated by both dose per image (p = 0.001) and DAP per image (p = 0.002) with moderate effect sizes (r=0.32 and r=0.29, respectively).

In the ANCOVA analysis, after adjusting for BMI and sex, fluoroscopy mode remained a significant predictor of radiation exposure per image (F = 9.07, p = 0.003), with a moderate effect size (partial η^2 = 0.085). BMI also showed a significant association with radiation exposure per image (F = 5.05, p = 0.027), whereas sex was not significantly associated (p = 0.366).

DISCUSSION

To our knowledge, there are no studies specifically comparing continuous and pulsed modes of fluoroscopy in patients who underwent PFN-A for pertrochanteric fractures. Although there are existing studies in the literature involving both pulsed and continuous modes of fluoroscopy, none have specifically focused on hip fractures [14-17]. In this context, the study makes a significant contribution to the literature.

Another valuable aspect of this study is that it emphasizes the importance of understanding the different dosing modes of fluoroscopy devices and how they may affect dose exposure during surgery. The use and optimization of fluoroscopy settings may receive limited emphasis in orthopedic training programs [18]. It is believed that during residency training, sufficient information regarding these devices and their operational modes is not adequately conveyed.

With the increasing use of fluoroscopy devices, tools that have become almost an extension of the surgeon's body during orthopedic and trauma surgeries, there have also been a growing number of studies investigating the effects of the accompanying radiation exposure. In a study by Stecker et al., it was recommended that the fluoroscopy device be used at the lowest possible pulse mode setting whenever possible [19]. In the study by Sabat et al., who used fluoroscopically guided lumbar punctures, the authors compared pulse and continuous fluoroscopy modes and reported that radiation exposure

was reduced by approximately 6 times in pulse mode compared with continuous mode [14]. Similarly, Artner et al. compared these two modes in the sacroiliac joint and reported that the pulse mode resulted in a lower radiation dose [15]. Smith et al. focused on ureteroscopy and demonstrated that the pulse mode results in lower radiation exposure per image than the continuous mode [16]. In a cadaveric study by Yamashita et al., the use of pulse mode fluoroscopy (8 pulses per second) resulted in approximately 30% less radiation exposure to the cadaver and approximately 70% less exposure to the surgeon's hand and thyroid gland than did continuous fluoroscopy [17]. However, despite these findings, comparisons of pulsed and continuous fluoroscopy modes remain limited in orthopedic surgical practice. In the present study, no statistically significant differences were observed between groups in terms of total radiation dose, DAP, fluoroscopy time, or number of exposures. However, when radiation exposure was normalized per image, the pulsed fluoroscopy mode demonstrated significantly lower dose per image and DAP per image values compared with the continuous mode. This finding suggests that pulsed fluoroscopy may provide more efficient radiation use per image acquisition. Furthermore, adjusted analyses using ANCOVA confirmed that fluoroscopy mode remained a significant predictor of radiation exposure per image after controlling for potential confounders, supporting the robustness of this observation.

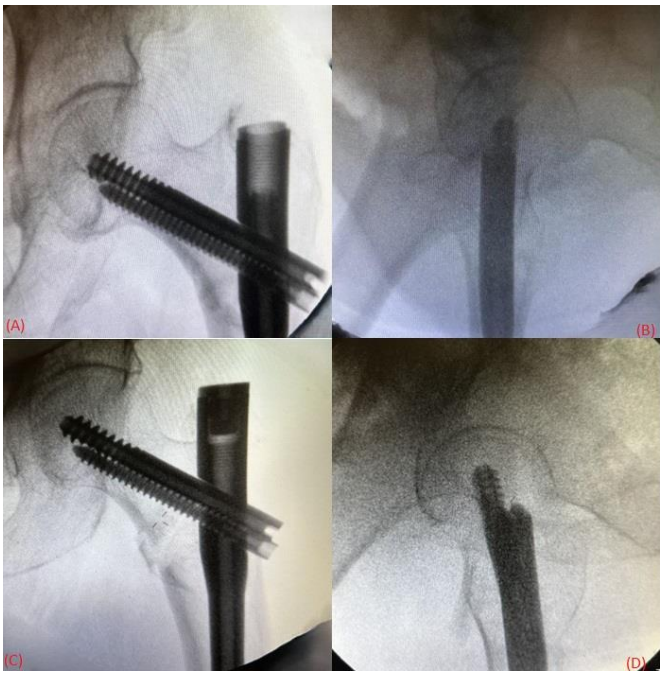


Figure 2. *A: Pulse mode AP (Anteroposterior) view, B: Pulse mode lateral view, C: Continuous mode AP view, D: Continuous mode lateral view*

One of the strengths of our study lies in the comparable distributions of fracture types between the pulse and continuous groups. Previous studies have shown that more complex pertrochanteric fractures are associated with an increased number of fluoroscopic shots compared with simpler fracture types [20,21]. When comparing image quality between pulsed and continuous fluoroscopy modes, no clinically relevant difference was observed based on subjective intraoperative assessment (**Figure 2**). Smith et al. compared the image qualities of these two modes by asking surgeons if the quality of images acquired in pulse mode was sufficient to perform the procedure and reported no difference in image quality between pulse and continuous fluoroscopy modes [16].

Considering that fluoroscopy devices are typically set to operate in continuous mode by default and that switching to pulse mode requires manual selection, the clinical implications of these findings are significant. By simply pressing a button on the device, pulse mode can be activated easily. This selection may improve radiation efficiency during image acquisition when used appropriately. The moderate effect size observed in our analysis suggests that the use of pulsed fluoroscopy may provide a clinically relevant improvement in radiation efficiency during PFN-A fixation. Given that fluoroscopy is frequently used in orthopedic procedures, even small reductions in radiation dose per procedure may result in a meaningful decrease in cumulative occupational exposure over time.

Our study enrolled 102 patients, and we found no significant differences in demographic variables between the groups. This is another strength of our study and enhances the reliability of our findings. Moreover, even though the study is retrospective in nature, the use of the same fluoroscopy device and technician, along with the homogeneity of patient characteristics, supports the validity of the results.

However, our study has several limitations. The retrospective design may limit the generalizability of the findings. In addition, fluoroscopy mode selection was not randomized and was determined according to routine operating room practice, which may introduce selection bias. Although the image quality of the two fluoroscopy modes was subjectively reported to be similar, the retrospective design of our study did not permit a blinded or standardized assessment of image quality. Future studies should include multiple observations in a blinded manner. The degree of radiation exposure of the surgeons during the procedures was not evaluated in this study. Furthermore, procedures were performed by

multiple surgeons, and potential surgeon-related variability was not adjusted for in the analysis. As this was a single-center study, the findings may not be generalizable to other institutions with different clinical practices. Future prospective studies with dosimeter-based measurements are needed to assess the long-term cumulative occupational exposure of surgeons.

Our study demonstrated that pulsed fluoroscopy is associated with reduced radiation exposure per image parameters during PFN-A fixation of pertrochanteric fractures, and the findings should be supported by larger, prospective, and multicenter studies. Furthermore, research involving different devices and various surgical procedures would be valuable for evaluating the effectiveness of pulse mode under a broader range of conditions. Although the surgeon's radiation exposure was not directly measured in this study, these findings may suggest a potential benefit for overall radiation safety.

CONCLUSIONS

Pulsed fluoroscopy does not significantly reduce total radiation parameters but is associated with lower radiation exposure per image during PFN-A fixation of pertrochanteric fractures. These findings suggest that pulsed fluoroscopy may improve radiation efficiency during image acquisition in orthopedic practice.

ETHICAL DECLARATIONS

Ethics Committee Approval

The study protocol was conducted in accordance with the Declaration of Helsinki and approved by Kastamonu University Clinical Research Ethics Committee on 06.11.2024 with decision number; 2024-KAEK-95.

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Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Financial Disclosure

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