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The Effect of Patient Position on the Fluoroscopy Doses Received in Hip Fracture Surgery

Kalça Kırığı Ameliyatında Hasta Pozisyonunun Maruz Kalınan Floroskopi Dozları Üzerindeki Etkisi

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ABSTRACT

Aim: The study evaluates the impact of patient positioning on radiation doses received during fluoroscopy in proximal femoral nailing for hip fractures. With the increasing use of minimally invasive, imaging-guided procedures, it is crucial to assess radiation exposure risks to both patients and healthcare workers. Prior research indicates that various factors, including patient positioning, can influence radiation doses.

Materials and Methods: This study included patients who underwent proximal femoral nailing for hip fractures from January 2023 to May 2024. Patients' positions were supine on a traction table, lateral decubitus position on a radiolucent table. Fluoroscopy data, including fluoroscopy time, dose-area product (DAP), and radiation dose, along with patient demographics and body mass index (BMI), were analyzed.

Results: A total of 114 patients were included. There were no significant differences in demographic characteristics between the groups. The mean fluoroscopy time was 42.02±25.75 seconds, with no significant difference between positions. The mean radiation dose was 18.72±16.24 milligray (mGy), and the mean DAP was 3.50±3.07 Gy-cm², with no significant differences across positions. However, a statistically significant positive correlation was found between BMI values and dose mGy values (r=0.242, p=0.009). Similarly, a statistically significant positive correlation was observed between BMI values and DAP values (r=0.243, p=0.009). However, the mean number of fluoroscopic shots was significantly higher in the supine position compared to the lateral position.

Conclusion: Patient positioning did not significantly affect fluoroscopy time or radiation dose proximal femoral nailing procedures for hip fractures. However, the number of fluoroscopic shots was lower in the lateral position. High BMI was positively correlated with dose mGy and DAP values except for time. The findings highlight the importance of considering BMI in radiation dose management and suggest that the lateral position may be preferable for minimizing radiation exposure.

Keywords: Fluoroscopy, lateral, supine, traction

ÖZ

Amaç: Çalışma, kalça kırıkları için proksimal femur çivileme sırasında hastanın pozisyonunun floroskopi sırasında alınan radyasyon dozları üzerindeki etkisini değerlendirmektedir. Minimal invaziv, görüntüleme rehberliğindeki prosedürlerin artan kullanımı ile hem hastalar hem de sağlık çalışanları için radyasyon maruziyeti risklerini değerlendirmek önemlidir. Önceki araştırmalar, hasta pozisyonu da dahil olmak üzere çeşitli faktörlerin radyasyon dozlarını etkileyebileceğini göstermektedir.

Gereç ve Yöntem: Bu çalışmaya Ocak 2023 ile Mayıs 2024 tarihleri arasında kalça kırıkları için proksimal femur çivileme yapılan hastalar dahil edildi. Ameliyat sırasında hasta pozisyonları traksiyon masasında supin ya da radyolusent masada lateral idi. Floroskopi verileri, floroskopi süresi, doz-alan ürünü (DAP) ve radyasyon dozu ile hasta demografisi ve vücut kitle indeksi (VKİ) analiz edildi.

Bulgular: Toplamda 114 hasta dahil edildi ve gruplar arasında demografik özelliklerde anlamlı fark bulunmadı. Ortalama floroskopi süresi 42,02±25,75 saniye olup, pozisyonlar arasında anlamlı bir fark bulunmadı. Ortalama radyasyon dozu 18,72±16,24 miligri (mGy) ve ortalama DAP 3,50±3,07

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Gy-cm² olup, pozisyonlar arasında anlamlı bir fark bulunmadı. Ancak, VKİ değerleri ile doz mGy değerleri arasında istatistiksel olarak anlamlı bir pozitif korelasyon bulunmuştur (r=0,242, p=0,009). Benzer şekilde, VKİ değerleri ile DAP değerleri arasında da istatistiksel olarak anlamlı bir pozitif korelasyon gözlenmiştir (r=0,243, p=0,009). Sırtüstü pozisyonda floroskopi çekim sayısı lateral pozisyona göre anlamlı derecede daha yüksekti.

Sonuç: Hasta pozisyonu, kalça kırıkları için proksimal femur çivileme prosedürlerinde floroskopi süresi veya radyasyon dozunu önemli ölçüde etkilemedi. Ancak, lateral pozisyonda floroskopik çekim sayısı daha düşüktü. Bulgular, radyasyon dozu yönetiminde VKİ önemini vurgulamakta ve radyasyon maruziyetini en aza indirmek için lateral pozisyonun tercih edilebileceğini önermektedir.

Anahtar Kelimeler: Floroskopi, lateral, sırtüstü, traksiyon

INTRODUCTION

Minimally invasive, imaging-guided interventional procedures are increasingly being used in medicine as their benefits to patients have been proven[1]. It has become a necessity to evaluate the risks that may occur in patients and healthcare workers due to the effect of ionizing radiation and to monitor the radiation dose in fluoroscopy equipment[1-3]. In 2009, the Society of Interventional Radiology defined radiation dose thresholds as peak skin dose > 3000 milligray (mGy), reference point air kerma > 5000 mGy, dose-area product (DAP) > 500 Gy-cm² or fluoroscopy time (FT) > 60 minutes[4].

The amount of radiation to which individual surgeons are exposed is influenced by many factors. These factors include the type and difficulty of the surgical procedure, the position of the patientand the radiation protection measures used[5,6]. It should be kept in mind that not only surgeons but also other health care providers in the operating room are at risk for scatter radiation exposure[6,7].

The use of C-arm fluoroscopy in intraoperative orthopedic procedures has become an important toolin modern orthopedic surgical practice. This method increases the surgeon's technical competence as well as reducing patient morbidity and length of hospital stay[8-10].

Radiation exposure among orthopedic surgeons varies widely; however, when radiation exposure is considered on a single case basis, an annual radiation exposure of 20 mSv is easily achievable without lead shielding. A cumulative radiation exposure of 1 Sv (1000 mSv) increases an individual's risk of developing a solid tumor at any age by 60%[11]. In logistic regression analysis, working as an orthopedic surgeon is known to significantly increase tumor risk[12]. Studies have shown that hematological and chromosomal abnormalities, dermatological conditions, cataract development and the spread of malignancies are linked to exposure to ionizing radiation, which causes free radical formation and DNA chain breakage[13]. Epidemiologic data collection is difficult for various reasons. According to data from the Life Span Study, the risks associated with low dose exposure are low; therefore, large sample sizes are required[14]. For this reason, the potential radiation risk should not be underestimated and safe working practices should be adopted by healthcare institutions[11-13].

Many studies have been conducted to reduce fluoroscopic radiation dose[9,10,15]. Significant reductions have been achieved by adjustments in operating modes compared to conventional modes, and different results have been obtained with mini C-arm fluoroscopy[9,13,15]. Virtual fluoroscopy can improve the accuracy of C-arm positioning and save time and radiation dose in the operating room[16]. It has been shown that real-time visualization of radiation exposure during the operation can reduce radiation exposure even in the highest exposure cases[17]. Surgical techniques, the approach (anteroposterior), the position of the patient during the procedure, the experience of the surgeon performing the procedure, and the patient's body structure have been shown to have an impact on fluoroscopy doses[18-21].

Proximal femoral nailing (PFN), one of the most commonly used applications of fluoroscopy in thesurgical treatment of hip fracture, can be performed in the supine position using a traction table[3,22], a radiolucent table, or a conventional surgical table[23] or in the lateral decubitus position[24].

Identifying procedures associated with significantly high radiation doses should allow for more tactical dose management strategies that can reduce the likelihood of radiation exposure to patients and limit the cumulative radiation exposure of physicians[1].

This study aims to determine the effect of ionizing radiation based on fluoroscopy in three different positions: under traction, supine and lateral positions on the radiolucent surgical table in PFN applications, which is one of the most common treatment modalities for the rapidly increasing elderly population worldwide and thus the predicted increase in hip fracture cases[3].

MATERIALS AND METHODS

Ethics committee approval for this retrospective study was obtained on with Kastamonu University Clinical Research Ethics Committee (decision no: 2024-KAEK-2 date: 17.01.2024). The study included patients who underwent PFN for hip fracture in the orthopedics and traumatology clinic of Kastamonu Training and Research Hospital between January 2023 and May 2024, when fluoroscopy data were started to be recorded in the hospital system. Surgical procedures were performed in patients who underwent fluoroscopy-guided traction table, lateral decubitus position and supine position on radiolucent table.

We excluded patients with pathologic fractures that might increase the use of fluoroscopy, reoperation, non-union or implant revision, cases of multiple trauma and surgery for fractures at othersites (requiring two or more fluoroscopies in the same surgical procedure) as exclusion criteria. Other hip fracture surgical techniques were also specifically excluded from the analysis. The analysis included a comprehensive review of hospital records and electronic data. The intertrochanteric antegrade nail with integrated compression screws, 130°, 20 cm nail was used for proximal fixation for all patien.

Fluoroscopy data, FT in seconds, DAP, number of shots (NS) and dose were evaluated along with patient demographics and body mass index (BMI). FT was defined as the total time fluoroscopy was used during the intervention. DAP was defined as the dose in air in a given plane multiplied by the areaof the entire x-ray beam emitted from the x-ray tube and is gray (Gy)-cm². Dose is defined as the total dose amount and its unit is mGy. 1 mGy is equal to 0.001 Gy[1].

Gy refers to the absorbed dose and does not take into account energy type or tissue type. It can be used to express the biological effects of high dose exposure. Sievert (Sv) represents the biological equivalent dose and includes effects on specific tissues. Conversion from Gy to Sv is done using unitless weighting factors for energy and tissue type, the radiation weighting factor for all photon radiation, including x-rays, is 1[11].

The portable C-Arm fluoroscope used to acquire real-time images of the patient during the procedures was an OEC Brivo 785 Essential. The C-arm fluoroscopy system was set to automatic mode; all technical factors, including kilovolt peak and milliampere values, were automatically adjusted to optimize image quality[25].

Statistical Analysis

In this study, statistical analyses were performed with NCSS (Number Cruncher Statistical System) 2007 Statistical Software (Utah, USA) package program. In addition to descriptive statistical methods (mean, standard deviation, median, interquartile range), the distribution of variables was examined with the Shapiro-Wilk test, one-way analysis of variance was used for intergroup comparisons of normally distributed variables, and Tukey multiple comparison test was used for subgroup comparisons, Kruskal-Wallis test was used in intergroup comparisons of variables that did not show normal distribution, Dunn's multiple comparison test was used in subgroup comparisons, chi-square and Fisher's exact test were used in comparisons of qualitative data, and Pearson correlation test was used to determine the relationship between variables. The results were evaluated at a significance level of $p<0.05$.

RESULTS

A total of 114 patients participated in the study. The mean age of all patients was 78.81±10.52 years and 74 (64.9%) of them were female. The positions used in hip fracture operations were lateral, supine, and traction positions at the rates of 45.60%, 39.50%, and 14.90%, respectively. BMI values were 27.39±4.59 in the lateral group, 27.83±3.98 in the supine group, and 25.51±4.33 in the traction group. No statistically significant difference was observed between the lateral, supine and traction groups in terms of mean age, gender distribution and BMI (p=0.331, p=0.101, p=0.171, respectively).

The mean FT was 42.02±25.75 seconds in all patients. There was no statistically significant difference in the mean FT between the lateral, supine, and traction groups (p=0.062). The mean fluoroscopic dose was calculated as 18.72±16.24 mGy and DAP as 3.50±3.07 Gy-cm² in all patients. There was no statistically significant difference between the lateral, supine and traction groups in terms of mean dose and DAP (p=0.515, p=0.507, p=0.524 respectively).

The mean number of fluoroscopic shots was calculated as 67.01±31.01 when all patients were included. A statistically significant difference was observed between the lateral, supine and traction groups in terms of the mean NS taken (p=0.003). All these parameters are listed in Table 1.

As seen in Table 2, the mean NS of the supine group was statistically significantly higher than that of the lateral group (p=0.001) and there was no statistically significant difference between the other groups (p>0.05). In Table 2, statistical differences among three groups are seen. According to the Pearson correlation test results, seen in Table 3, no statistically significant correlation was found between age values and BMI, time, dose mGy, DAP and NS values (p>0.05). There was also no statistically significant correlation between BMI values and FT values (r=0.144, p=0.125).

However, a statistically significant positive correlation was found between BMI values and dose mGy values (r=0.242, p=0.009). Similarly, a statistically significant positive correlation was found between BMI values and DAP values (r=0.243, p=0.009). A statistically significant positive correlation was also observed between BMI values and NS (r=0.212, p=0.024).

Table 1. Comparison of patient characteristics and fluoroscopy parameters among lateral, supine, and traction groups

		Lateral		Supine		Traction		p-value
Age	Mean±SD	77.73±12.37		78.91±8.85		82.12±8.05		0.331†
Gender	Male	18	(34.62%)	11	(24.44%)	9	(52.94%)	0.101+
	Female	34	(65.38%)	34	(75.56%)	8	(47.06%)	
Height (cm)	Mean ± SD	164.73±8.35		163.51±8.15		167.18±8.39		0.299†
Weight (gr)	Mean ± SD	74.56±13.97		74.27±11.11		71.29±12.21		0.639†
BMI (w/h^2)	Mean ± SD	27.39±4.59		27.83±3.98		25.51±4.33		0.171†
FT (seconds)	Mean ± SD	36.52±20.7		47.5±26.95		44.38±33.64		0.062‡
	Median (IQR)	31.1 (22.41-44.66)		41.88 (26.66-64.76)		35.88 (26.44-45.06)		
Dose (mGy)	Mean ± SD	16.68±12.46		19.76±15.25		22.23±26.45		0.515‡
	Median (IQR)	12.37 (8.57-20.84)		17.02 (8.77-24.52)		15.98 (8.39-23.76)		
DAP (Gy-cm^2)	Mean ± SD	3.12±2.36		3.69±2.87		4.18±5.03		0.507‡
	Median (IQR)	2.28 (1.6-3.9)		3.14 (1.64-4.55)		3 (1.55-4.44)		
FS	Mean ± SD	56.94±22.75		77.44±35.17		69.53±32.87		0.003‡
	Median (IQR)	54 (43-62)		72 (52-104)		63 (42.5-91)		

†One-way analysis of variance (ANOVA), ‡Kruskal-Wallis test +chi-square test, BMI: Body mass index, FT: Fluoroscopy time, DAP: Dose-area product, FS: Fluoroscopy shot number, IQR: Interquartile range, SD: Standard deviation

Table 2. Statistical differences of mean number of shots in between lateral, supine and traction groups

	p*
Lateral / supine	0.001
Lateral / traction	0.119
Supine / traction	0.372

*Dunn's multiple comparison test

Statistically significant positive correlations were found between time, dose (mGy), DAP and NS. Strong correlations were found particularly between time and dose (r=0.891), time and DAP (r=0.888), time and NS (r=0.749), dose and DAP (r=0.999), dose and NS (r=0.564), and DAP and NS (r=0.561) (p=0.0001).

DISCUSSION

This study is the first to evaluate the use of fluoroscopy and ionizing radiation in the same research for three different patient positions-traction, supine and lateral for PFN procedures in hip fractures. In terms of ionizing radiation levels, no significant difference was found in FT, dose and DAP values in the three different patient positions. No statistically significant difference was found between the groups in terms of demographic characteristics such as age, gender, height, weight, and BMI; therefore, the groups were equalized. In the comparison between supine and lateral positions on the radiolucent table, the NS was significantly lower in the lateral position, while no difference was found in the surgeries performed on the traction table.

With the aging of the world population, hip fractures are more common in the community and among healthcare workers[22,24]. This study shows that the lateral position should be preferred in these cases to reduce surgical time and lower the NS. Considering the preparation time and complications of the traction table, it is emphasized that the lateral decubitus position is important in terms of low NS[26]. In our study, a significant positive correlation was found between time, DAP and dose and the NS.

Numerous studies have compared and evaluated the use of fluoroscopy in PFN applications by comparing only the NS[27-30]. However, issues such as radiation exposure and especially tissue damage should also be addressed, and such data can be expressed in Gy or Sv[11]. For this reason, it may be appropriate to evaluate parameters such as DAP, FT, and dose in studies such as ours, since it should be evaluated with a single parameter as stated by Bilekli et al.[31].

In the study by Bilekli et al.[31] a comparison of FT in hip fracture surgery according to supine and traction table positions was made and the mean time was found as 55.95 seconds for supine position and 48.29 seconds for traction table. In our study, these times were 47.5 seconds and 44.38 seconds, respectively, and the supine FT was found to be similarly high.

In a study by Zehir et al.[32], the mean duration of PFNA fluoroscopy in the supine position was reported to be 2.0 minutes, which is significantly different from 47.5 seconds in our study. Buxbaum et al.[33] reported the lowest FT as 76.45 seconds in hip fractures. Duramaz and İlter[34] reported the mean and median FT as 34 seconds for both, with the same

Table 3. Correlations between patient characteristics and fluoroscopy parameters*

		Age	BMI	FT	Dose	DAP	FS
Age	r		-0.096	-0.063	-0.094	-0.096	-0.053
	p		0.309	0.505	0.317	0.310	0.578
BMI	r	-0.096		0.144	0.242	0.243	0.212
	p	0.309		0.125	**0.009**	**0.009**	**0.024**
FT	r	-0.063	0.144		0.891	0.888	0.749
	p	0.505	0.125		0.0001	0.0001	0.0001
Dose	r	-0.094	0.242	0.891		0.999	0.564
	p	0.317	**0.009**	0.0001		0.0001	0.0001
DAP	r	-0.096	0.243	0.888	0.999		0.561
	p	0.310	**0.009**	0.0001	0.0001		0.0001
FS	r	-0.053	0.212	0.749	0.564	0.561	
	p	0.578	**0.024**	0.0001	0.0001	0.0001	

Pearson correlation tests, BMI: Body mass index, FT: Fluoroscopy time, DAP: Dose-area product, FS: Fluoroscopy shot number

surgical model. Patil[35] reported the mean FT as 72.6 seconds in PFN applications. In our study, the median was 34 seconds and the mean was 44 seconds on the traction table, which is significantly different from these two studies.

In a study by Kalem et al.[36], FT of PFNA application in the supine position with two different fluoroscopy devices (device A and B - these two fluoroscopy devices of the same brand and software, but with different image intensifier sizes) was reported to be 58.1 seconds and 98.9 seconds, respectively. In our study, this time was found to be 47.5 seconds with the same device model device B. In addition, while the mean DAP value in the supine position was reported as 7.3 in the same study, it was found to be 3.69 in this position in our study.

In the study of Bilekli et al.[31], the mean DAP was 2.84 in the traction position and 2.26 in the supine position, whereas in our study, these values were 4.18 and 3.69, respectively. Unlike our study, this study did not focus on dose values. In addition, it was thought that the differences between BMI values in the same study could explain the differences in DAP values. While the mean BMI values were 23.4 and 22 in Bilekli et al.[31] study, they were 27.8 and 25.5 in our study. In the literature, increased FT was associated with higher BMI and increased DAP value was also associated with higher BMI[37]. In our study, high BMI was positively correlated with dose mGy and DAP values except for time.

In the study by Rashid et al.[38], the mean FT for short PFN procedure was reported as 49 seconds and the median DAP was 1.40 Gy-cm². In our study, the median DAP value obtained in the lowest lateral position was 2.28 Gy-cm² and the median FT was 31 seconds. In terms of the NS, the mean number of fluoroscopy images in Rashid et al.[38] study was 109, whereas in our study, 54 shots were found in the laterel position. Despite the differences in FT and NS, the DAP mismatch remains unclear as more information on other details, such as patient position and operating table, was not provided.

In the study of Roukema et al.[39] on hip fractures, the reported dose value related to the use of fluoroscopy was 3.5 mGy, while in our study, this value was determined as the lowest 16.68 mGy.

In addition, while the mean fluoroscopy duration was 53 seconds in Roukema et al.[39] study, the lowest duration was 36.52 seconds in our study. The DAP value was reported as 0.0572 mGy-m² in Roukema et al.[39] study, whereas the lowest value was 3.12 Gy-cm² (0.312 mGy-m²) in our study. The significant differences between these studies are due to factors such as different surgical techniques and materials used.

It is thought that the lower DAP values between the study of Bilekli et al.[31] and Roukema et al.[39] study may not be explained only by differences in BMI and surgical method. It is seen that only automatic mode was defined as the operating mode of fluoroscopy and the data of continuous or pulsed modes were not available in any study. Pulsed mode is known to reduce radiation exposure up to 64% compared to continuous mode[40]. It is thought that these factors may influence these differences. In our study, it was observed that all surgeons worked in the same fluoroscopy device with a continuous mode.

This study showed that patient position did not make a difference in terms of fluoroscopy use andionizing radiation in PFN applications in hip fractures. The lowest NS was observed in the lateral position and a positive correlation was found between BMI and dose and also BMI and DAP. These findings emphasize the necessity of preoperative BMI determination and exposure reduction measures in terms of patient and worker safety (exposure to ionizing radiation). The evaluation of BMI as a risk factor for high DAP exposure may require consideration of measures to reduce risks. The widespread use of fluoroscopy devices in medical imaging and surgical procedures raises concerns about potential radiation exposure of staff and patients[6,7]. Therefore, ongoing collaboration and communication between operational staff and radiation professionals is necessary to ensure safe and effective use of the devices[10]. Radiation professionals play an important role in training personnel, promoting the correct use of protective equipment, and ensuring up-to-date safety protocols. This collaboration helps to minimize long-term health risks by reducing radiation exposure and improve the safety of medical practices[11,38].

Bundy et al.[1] stated that most of the cases exceeding the radiation threshold value determined in their study were performed by non-radiologists. This situation emphasizes the importance of training of radiation professionals and points to the errors of personnel who are not trained in radiation physics, biology, and dose reduction techniques.

Study Limitations

The limitations of our study include the fact that the duration of surgery was not evaluated, it was a single centered study, and different surgeons were involved. However, it is important that surgeons used their best technique in the study. Since the focus of our study was to show the effect of patient position on fluoroscopy dose, it is thought that whether the device operates in pulse or continuous mode has no effect on the data and conclusions obtained. There is a need for prospective randomized controlled studies to evaluate the effect of different modes of fluoroscopy in the future. In surgeries performed without a traction table, the fact that the radiation-producing part of the scopy device under the table provides less radiation to be released should not be overlooked, which is a handicap that this study did not evaluate.

CONCLUSION

The risk of exposure to high radiation doses increases significantly, especially in prolonged procedures. Therefore, it is important to improve safety measures and implement effective dose control methods to minimize radiation doses. It should be noted with this study that the NS is lower in the lateral decubitus position compared to other positions, and that BMI is related to ionizing radiation. Future research should be directed towards improving safety standards in this area.

Ethics

Ethics Committee Approval: Ethics committee approval for this retrospective study was obtained on with Kastamonu University Clinical Research Ethics Committee (decision no: 2024-KAEK-2 date: 17.01.2024).

Footnotes

Informed Consent: Retrospective study.

Authorship Contributions

Surgical and Medical Practices: F.U., M.A.S., Concept: F.U. M.A., A.E.Ş., Design: M.A., B.A., M.A.S., Data Collection or Processing: F.U., M.A.S., A.E.Ş., Analysis or Interpretation: M.A., B.A., Literature Search: M.A., B.A., Writing: F.U., M.A., B.A.

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