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ORIGINAL ARTICLE

Radiation exposure during proximal femoral nailing: Traction table versus conventional table

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ABSTRACT

Objectives: The aim of this study was to compare radiation exposure of the patient during the closed reduction and proximal femoral nailing (PFN) of the trochanteric region fractures of the proximal femur using a traction table (TT) or a radiolucent table (RT) in the supine position.

Patients and methods: Between June 2019 and December 2020, the study included 42 patients (19 males, 23 females; mean age: 81.2±9.5 years; range, 60 to 97 years) with trochanteric region fractures applied with closed reduction and PFN with the same implant type, 21 who underwent surgery on a TT (TT group), and 21 on a RT (RT group). The cumulative radiation dose was the primary outcome and was measured as the dose area product (DAP) in Gray cm^2 (Gycm^2). Intraoperative fluoroscopy times and amount of radiation exposure were compared between the two groups.

Results: There was no significant difference between the two groups in terms of sex, age, body mass index, fracture side, and the AO Foundation/Orthopaedic Trauma Association (AO/OTA) fracture classification (p>0.05). No statistically significant difference was found between the TT and RT groups in terms of the mean intraoperative fluoroscopy time (48.29±22.31 and 55.95±21.54 sec, respectively; p=0.264) and amount of radiation exposure (2.26±1.86 and 2.84±1.96 Gycm^2, respectively; p=0.332).

Conclusion: Both TT and RT with the patient positioned supine provide similar results for closed reduction and PFN of trochanteric region fractures, in terms of DAP as the most reliable measurement method. The main clinical relevance of this study is that radiation exposure of the patient need not be considered while selecting the operating table.

Keywords: Dose area product, operation table, proximal femoral nail, radiation exposure, trochanteric region fracture.

Trochanteric region fractures of the proximal femur are a significant problem in the elderly population and can lead to significant disability, morbidity, and mortality. In the trseatment of these fractures, closed reduction and internal fixation using intramedullary implants; proximal femoral nailing (PFN) or cephalomedullary nailing has become more widely used in the last two decades and is the predominant procedure in many countries.[1] With the increasing frequency of trochanteric region fractures,[1,2] it has become more likely that the orthopedic surgeons treating these patients would be exposed to greater amounts of medical ionizing radiation. In addition to awareness of the usage of personal protective equipment during the procedures, surgeons are seeking the optimal patient and C-arm positioning, and the use of different tables to minimize radiation exposure both for the patient and the staff.

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Proximal femoral nailing for trochanteric region fractures can be performed in the supine or lateral decubitus position using a conventional radiolucent table (RT) or traction table (TT). Several studies have compared the effects of these factors on treatment results, duration of preparation, operating time, and radiation exposure according to the number of fluoroscopy images and fluoroscopy time.[3,4] Fluoroscopy time and the number of fluoroscopy images are of limited use as a measurement of radiation exposure, as the radiation time depends on various technical parameters such as energy and intensity of the radiation beam, the orientation of the C-arm, size of the irradiated area, and the distance between the source and the irradiated area.

Dose area product (DAP) is defined as the absorbed dose multiplied by the area irradiated and, therefore, it reflects not only the dose within the radiation field, but also the area of tissue irradiated. The DAP is a practical tool providing a better indication of overall patient radiation exposure than fluoroscopy time.[5,6] To the best of our knowledge, there is no report comparing radiation exposure during hip nailing using the RT or TT with the objective measurement tool DAP in the literature. In the present study, we, therefore, aimed to compare the radiation exposure in Gycm^2 (DAP) during the nailing of trochanteric region fractures using the TT versus the RT in the supine position.

PATIENTS AND METHODS

This retrospective study was conducted at Gülhane Training and Research Hospital, Department of Orthopedics and Traumatology between June 1st, 2019 and December 31st, 2020. A total of 235 patients with trochanteric region fractures treated with PFN were identified. According to the inclusion and exclusion criteria presented in Table I, 193 patients were excluded and 42 patients (19 males, 23 females; mean age: 81.2±9.5 years; range, 60 to 97 years) were included in the study, comprising 21 patients treated on a RT and 21 patients on a TT. The patient demographic data, the AO Foundation/Orthopaedic Trauma Association (AO/OTA) fracture type, and operation details were retrieved from the patient files, operation records, radiographs, and fluoroscopy unit srecords. The fluoroscopy system (Philips BV Pulsera®, Mobile Fluoroscopy Unit, Philips Medical Systems, Eindhoven, Netherlands) was used in auto mode, which automatically sets the kilovolt and milliampere in all cases. Radiation exposure data were obtained from the "dose report" section of the manufacturer's software after each fluoroscopy procedure as the fluoroscopy time (sec) and cumulative radiation dose (DAP) in gray square centimeters (Gycm^2).

TABLE I
Inclusion and exclusion criteria

Inclusion
Trochanteric region fractures
Age ≥60 years
Low energy trauma (fall from the same level)
Closed reduction of the fracture
Treatment with the same manufacturers standard (short) PFN implant
Use of the same fluoroscopy system
Same fluoroscopy technician
Operations performed by surgeons with at least three years of experience in hip and trauma surgery
Exclusion
Open fractures or pathologic fractures (n=6)
High energy trauma (fall from a height, traffic accidents, gunshot injuries, and act of violence) (n=12)
Patients operated in the lateral decubitus position (n=8)
Fractures that required open reduction (n=23)
Treatment with other manufacturers PFN implants or any long PFNs (n=25)
Use of additional fixation materials (e.g., cables, cerclage wire) (n=9)
Multiple fluoroscopic studies in one session (multiple fractures) (n=8)
Fluoroscopic studies with insufficient identification entries (n=6)
Use of the other manufacturer’s fluoroscopy systems (n=30)
Another fluoroscopy technician/s (n=30)
Operations performed by surgeons without at least three years of experience in hip and trauma surgery (n=36)

PFN: Proximal femoral nail.

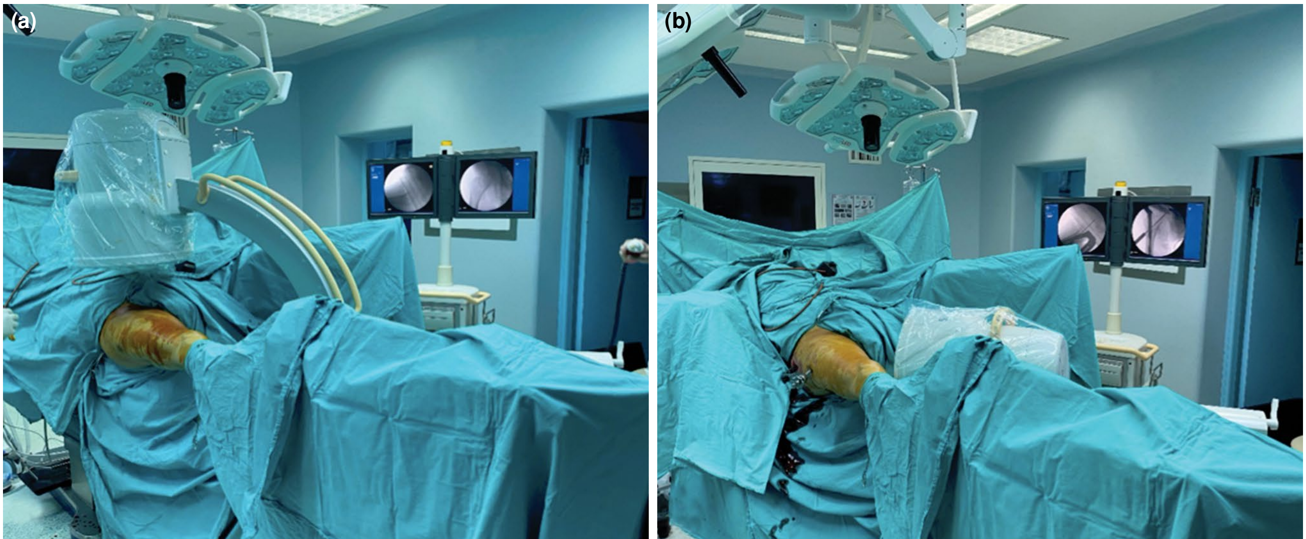

FIGURE 1. The C-arm positioning for the anteroposterior **(a)** and lateral **(b)** view at the traction table group. Note the leg support part of the operating table is removed, and the unaffected hip is flexed and abducted over a leg holder to obtain a lateral view.

The choice of the operating table was made according to surgeon preference in all the cases in the study. The procedures were performed by four different experienced trauma surgeons, beyond the learning curve for PFN.[7] Each surgeon was assisted by a PGY-2 or PGY-3 resident and a scrub technician. Two surgeons preferred to use the TT for all of their cases and two surgeons preferred to use the RT for all of their cases. All operations were performed under spinal anesthesia, with the same fluoroscopy system and same fluoroscopy technician in response to the operating surgeon's instructions. Before each case, patient and fluoroscopy positioning were checked by the operating surgeon to obtain proper imaging. For the RT group, the affected extremity was prepared and draped. The leg support part of the operating table was removed, and the unaffected hip was flexed and abducted over a leg holder to obtain a lateral view of the affected hip. For the TT group, the affected extremity was prepared and draped after applying the traction boot, and the unaffected hip was prepared in the same fashion as for the RT group. The C-arm was positioned between the patient's legs for both groups (Figures 1 and 2).

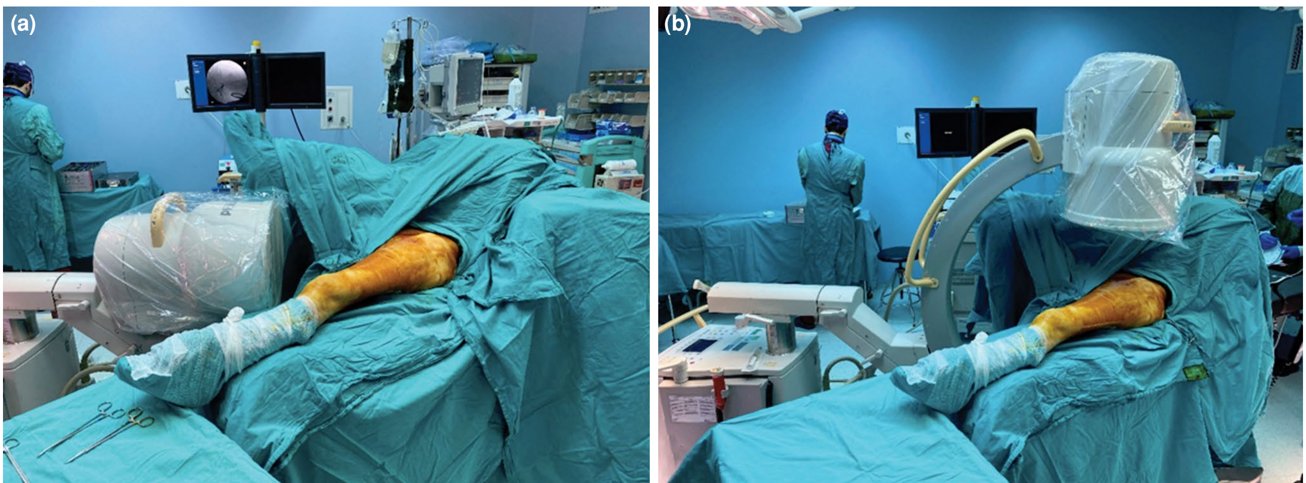

FIGURE 2. The C-arm positioning for the anteroposterior **(a)** and lateral **(b)** view at the radiolucent table group. The unaffected side is prepared in the same fashion as the traction table group.

TABLE II
Comparison of the traction table and the radiolucent table groups

	Radiolucent table (n=21)				Traction table (n=21)				
	n	%	Mean±SD	Range	n	%	Mean±SD	Range	*p*
Age (year)			81.3±10.7	60-97			81.1±8.5	62-92	0.949
Sex									0.096
Female	11	52.4			12	57.1			
Male	10	47.6			9	42.9			
Body mass index (kg/cm^2)			26.2±2.6	23.4-31.2			27.1±4.2	22-35.2	0.381
Side									0.095
Left	10	47.6			11	52.4			
Right	11	52.4			10	47.6			
AO/OTA fracture type									0.282
31A1	2	9.5			2	9.5			
31A2	13	61.9			17	81			
31A3	6	28.6			2	9.5			
Mean DAP (Gycm^2)			2.84±1.96				2.26±1.86		0.332
Mean fluoro time (s)			55.95±21.54				48.29±22.31		0.264

SD: Standard deviation; BMI: body mass index; AO/OTA: AO Foundation and Orthopaedic Trauma Association; DAP: Dose area product; Gycm^2: Gray square centimeters.

The operating surgeon made the fracture reduction in a closed manner for both groups and maintenance of the reduction was performed by the surgical assistant for the RT group, and using the traction boot system in the TT group.

Radiation exposure data obtained after each fluoroscopy procedure included the images from the very first image during C-arm positioning to the last image after implantation of the PFN, including images obtained during the reduction maneuvers for both groups. The same implant type from the same manufacturer (200 mm in length, trochanteric entry nail) was applied to utilize a trochanteric entry point in all cases. Nail diameter, lag screw length, and distal locking screw lengths were selected on a case-by-case basis. The implant system targeting arm was used for distal locking screw insertion for all of the cases. An appropriately sized end cap was used in all the patients.

Statistical analysis

The study power analysis and sample size calculation were performed using the G*Power version 3.1.9.6 software (Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany).

Statistical analysis was performed using the IBM SPSS for Mac version 26.0 software (IBM Corp., Armonk, NY, USA). Continuous variables were expressed in mean ± standard deviation (SD) or median (min-max), while categorical variables were expressed in number and frequency. Conformity of continuous variables to normal distribution was tested using the Shapiro-Wilk test, and in the comparison of two independent groups, the Student t-test was used. To compare categorical variables, the Pearson chi-square test was used. A p value of <0.05 was considered statistically significant.

RESULTS

The patient data are shown in detail in Table II. There was no significant difference between the two groups in terms of sex, age, body mass index (BMI), fracture side, and AO/OTA classification (p>0.05). According to the AO/OTA classification,[8] 71.4% of the patients (n=30) were evaluated as type 31A2 (multifragmentary pertrochanteric, lateral wall incompetent fracture), 19% (n=8) as type 31A3 (intertrochanteric [reverse obliquity] fracture) and 9.5% (n=4) as type 31A1 (simple pertrochanteric fracture).

For the RT group, the mean DAP value was 2.84±1.96 Gycm^2, and the mean fluoroscopy time was 55.95±21.54 sec. For the TT group, the mean DAP value was 2.26±1.86 Gycm^2, and the mean fluoroscopy time was 48.29±22.31 sec. There was no statistically significant difference between the two groups in terms of the DAP (p=0.332) and the fluoroscopy time (p=0.264). According to the post-hoc power analysis, the number of patients in both groups provided adequate power for the comparison between the groups of DAP (effect size, 0.3040820; α err prob, 0.332; post-hoc power, 0.937; p=0.332) and the fluoroscopy time (effect size, 0.3492114; α err prob, 0.264; post-hoc power, 0.948; p=0.264).

DISCUSSION

As a variable number of fluoroscopic images may be required during hip fracture nailing, radiation exposure is a matter of concern for both the surgical team and the patient. The most important finding of the current study was that there was no significant difference between the TT and RT in respect of intraoperative fluoroscopy time and amount of radiation exposure. To reduce the risks, any medical radiation exposure must be justified and optimized.[9] Radiation doses during all imaging procedures must be kept "As Low As Reasonably Achievable" (the ALARA principle); in other words, the surgeon should make an effort to obtain an optimum quality image at the lowest radiation dose to the patient.[10]

Roux et al.[11] reported a mean 0.79 (range, 0.31 to 1.75) Gycm^2 DAP value and a mean fluoroscopy time of 32 sec to apply standard short PFN for trochanteric region fractures (n=15) without distal locking by using a fracture table with shoe traction. Rashid et al.[12] reported a median 1.04 Gycm^2 DAP value (median time 49 sec, n=75) for short PFN for trochanteric region fractures, but further details such as patient positioning and operating table were not shown. In a randomized-controlled trial of 89 patients by Roukema et al.,[13] a mean of 0.57 (range, 0.278 to 0.991) Gycm^2 DAP value was reported with a mean fluoroscopy time of 53 sec to apply a standard or long gamma nail. Further details such as long/short PFN distinction, patient positioning, and operating table were not reported. Kalem et al.[14] reported a mean of 3.5±1.2 Gycm^2 DAP value (mean time 58.1±19.4 sec, n=23) and mean 7.3±4.5 Gycm^2 DAP value (mean time 98.9±55.4 sec, n=17) in a study comparing two fluoroscopy devices for the treatment of AO/OTA type 31A1 trochanteric region fractures using a standard PFN implant in a supine position on a RT. The mean fluoroscopy times for the RT and TT groups of the current study are comparable to the findings reported in the aforementioned studies,[11-13] although the mean DAP values are higher. This comparison again indicates why fluoroscopy time is not an adequate measurement tool for reporting or comparing the overall patient radiation exposure.

Currently, there are no standard radiation exposure doses for most of the trauma surgeries requiring fluoroscopic imaging, including PFN for trochanteric region fractures.[12] Variability in the DAP values for PFN can be attributed to several factors such as the experience of the surgical team,[15-17] patient BMI,[18,19] implant type and additional exposure for resident teaching.[19] Higher DAP values in our study compared to the aforementioned studies[11-13] can be attributed to these reasons. Nevertheless, the calculated effective doses from DAP in the current study (using the 0.16 mSv/Gy per cm converting factor described by McParland[20]) were 0.45 and 0.36 mSv, for the RT and TT groups, respectively. Considering that the effective dose for a routine chest X-ray is 0.02 mSv,[11] these values are equivalent to 22.5 and 18 chest X-rays for the RT and TT groups, respectively. Despite the relatively higher DAP values in our study, the mean effective doses for both groups are less than 1% of the recommended limit on the dose from occupational exposure (20 mSv/year).[21]

The PFN for "trochanteric region fractures" can be performed in both supine and lateral decubitus positions using a conventional RT or TT. All these factors have their advantages and disadvantages perioperatively; however, the final functional outcomes are usually similar.[3,4] Crawley and Rogers[22] reported that hip and spine interventions account for 99% of the total collective dose from commonly selected procedures. Orthopedic surgeons should primarily focus on these procedures for reducing the radiation exposure risk, both for the surgical team and the patient. In this context, the focus of this study was on PFN and operating table selection, and the data resulting from the study demonstrated that TT and conventional table had similar radiation exposure rates.[23]

Nonetheless, there are some limitations to the current study, primarily the retrospective design, but it can be considered that this design prevented performance bias as stated by Buxbaum et al.[15] Prospectively knowing the study details could affect the operating surgeons' choice of operating table or fluoroscopy usage intraoperatively. Another limitation is the relatively low case numbers within the specific fracture subtypes, precluding statistical analysis for comparison according to the radiation exposure. The exclusion of the high energy traumas, fractures requiring open reduction or use of additional fixation materials (e.g., cables, cerclage wires) from the study groups may create a limitation. A further limitation was that four different surgeons performed the operations. Several studies have reported that the experience of both the surgeon and the surgical team has influence on radiation exposure.[15,16] However, our hospital is a training center with a large case volume and, therefore, it was not possible for all the surgeries to be performed by the same surgeon and same surgical team. Nevertheless, this limitation can be considered to have been minimized by only including the patients operated by surgeons with experience beyond the learning curve for PFN.

There are some strengths of the current study compared to other studies focusing on radiation exposure during hip fracture surgeries. There are currently three different fluoroscopy system available and three different fluoroscopy technicians on call at our operating room. To eliminate the exposure differences that may result from the ease of use of the fluoroscopy system and the fluoroscopy technician's experience, the patients included were only those where the same system was used by the same fluoroscopy technician. Furthermore, to eliminate exposure differences which may result from the use of different implant types or standard/long PFNs, only the patients with the same standard implant type from the same manufacturer were included.

In conclusion, the results of this study show that radiation exposure is similar with the use of TT or RT with the patient positioned supine for closed reduction and PFN of a trochanteric region fracture. The clinical relevance of this study is that the selection of operating table (TT versus conventional table) should not be considered in terms of radiation exposure. Nevertheless, there is a need for further, multi-center randomized-controlled trials to provide more definitive data on this subject. Furthermore, this study can also be considered to provide data for future multi-center, large-scale studies for the establishment of diagnostic reference limits for PFN.

Ethics Committee Approval: The study protocol was approved by the Gülhane Training and Research Hospital Ethics Committee (Date: 11.30.2020/no: 2020-475). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: A written informed consent was obtained from each patient.

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

Author Contributions: Study conception and design: A.B.B., D.Ç.; Data collection: A.B.B., Ç.N., H.Z.; Analysis and interpretation of results: A.B.B., E.E.B., Ç.N., H.Z.; Draft manuscript preparation: A.B.B., Y.E., D.Ç.; All authors reviewed the results and approved the final version of the manuscript.

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