Acta Orthop. Belg., 2021, **87**, 305-311

ORIGINAL STUDY

Comparison of fluoroscopy time in short and long cephalomedullary nailing for 31A2 intertrochanteric hip fractures

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There is no study that has compared the radiation exposure during short (Short PFN) and long proximal femoral nailing (Long PFN) for 31A2 intertrochanteric hip fractures. The objective of the present study was to compare the radiation exposure time in short and long proximal femoral nail during the treatment of 31A2 intertrochanteric hip fractures. This prospective cohort study was carried out in a University teaching hospital. Sixty one consecutive patients with 31A2 intertrochanteric femur fracture treated with proximal femoral nail were included in the study. The distal locking in the short PFN was performed using the locking zig and distal locking in the long PFN was performed using the free hand perfect circle technique. The same mobile image intensifier (Multimobil 5E, Siemens, Erlangen, Germany) was used in the entire study. The outcome measure was the fluoroscopy exposure time (seconds) which was measured directly from the image intensifier. Thirty patients underwent fixation with short PFN and 31 patients underwent fixation using long PFN. The mean fluoroscopy exposure time in short PFN cohort was 189.5 seconds ± 26 (range : 150-250 seconds) and the mean fluoroscopy exposure time in long PFN cohort was 283.4 seconds ± 43.8 (range : 200-400 seconds). The mean fluoroscopy exposure time was 93.9 seconds shorter in the short PFN cohort and this difference was statistically significant (p < 0.0001 ; 95% CI : 75.4 to 112.3). The radiation exposure to the operating team is significantly less during treatment with short PFN in 31A2 intertrochanteric fractures.

Keywords : radiation exposure ; fluoroscopy ; hip fractures ; intertrochanteric fractures ; intramedullary nailing ; cephalomedullary nailing.

INTRODUCTION

The use of C-arm or fluoroscopy is associated with radiation exposure to the patient and also to the operating surgeon and the assistants. At the cellular level, radiation exposure leads to generation of free radicals and can induce apoptosis *(1)*. One type of biological effect is termed "deterministic effects"

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No benefits or funds were received in support of this study.
None of the authors have a conflict of interest.

and it appears after a specific threshold is breached. Cataract, infertility due to damage to gonadal cells and dysfunction of bone marrow in the operating surgeon are examples of "deterministic effect" *(1,2)*. Second type of biological effect is termed "stochastic effect" and this effect is not related to breaching of any specific threshold. Cancer and leukaemia are examples of "stochastic effects" *(1)*. The ALARA (**A**s **L**ow **A**s **R**easonably **A**chievable) principle was devised to bring awareness amongst theatre personnel like operating surgeons, fluoroscopy operating technicians and radiographers regarding the judicious use of radiation emitting devices like C-Arm and fluoroscopy *(3)*.

As per 2007 edition of the AO/OTA alphanumeric classification, 31A2 and 31A3 fractures have been classed as unstable fractures whereas 31A1 fractures are classified as stable fractures *(4,5,6,7)*. The 31A2 fracture has been observed to be a commonly occurring fracture pattern *(8)*. The 31A2 fracture is prone for high incidence of malunion due to shortening, medialization of the femoral shaft and high risk of fracture of the lateral wall of the proximal femur particularly if the fracture is treated with dynamic (sliding) hip screw *(9)*. Hence, proximal femoral nailing is the recommended surgical procedure for 31A2 fracture *(15,10,11)*.

The cephalomedullary nail is a popular choice amongst orthopaedic surgeons for internal fixation of intertrochanteric hip fractures *(12)*. Cephalomedullary nails are preferred to treat 31A2 and 31A3 fractures whereas dynamic hip screw is used to treat 31A1 fracture *(6,13)*. 31A2 fractures can be treated either with short or long PFN because both are acceptable options. Boone et al observed in their retrospective study that though most of the patients with 31A2 fractures were treated with long Gamma cephalomedullary nail, there was no difference in the incidence of periprosthetic fracture in the long or short Gamma cephalomedullary nail cohorts thereby challenging the anecdotal notion that long cephalomedullary nails reduce incidence of periprosthetic femur fractures *(14)*. Studies have shown that the cumulative radiation exposure is lesser during dynamic hip screw (DHS) fixation compared to fixation using the short cephalomedullary nail for intertrochanteric femur fractures *(15,16)*.

There are few studies which have statistically compared the radiation exposure using short and long cephalomedullary nailing for intertrochanteric hip fractures. Moreover, to the best of our knowledge there is no study which has evaluated the fluoroscopy exposure time after short or long proximal femur nailing of 31A2 fracture pattern. Hence, the aim of the present study was to compare radiation exposure in 31A2 fractures using fluoroscopy exposure time during short or long proximal femoral nail (PFN).

PATIENTS AND METHODS

This prospective observational case cohort study was undertaken after obtaining approval from the Institutional research ethics committee. All patients gave informed consent for participating in the study. The study was conducted at a University teaching hospital and tertiary level trauma centre.

All surgical procedures were performed on the fracture table in the supine position. All surgical procedures were performed by consultant orthopaedic surgeons or by orthopaedic registrars under the direct supervision of the orthopaedic surgeons. The decision to use short or long PFN was based on the preference of the operating orthopaedic consultant and also availability of the implant. All nails had similar designs with 2 proximal cephalocervical screws and 2 distal screws. The distal locking in the short PFN was performed using the locking zig and distal locking in the long PFN was performed using the free hand perfect circle technique. The total length of the short PFN was 240 mm whereas the long PFN had a total length varying from 340 mm to 420 mm with 20 mm increment. Both short and long PFNs had proximal diameter of 13.5 mm and the distal diameter of the nails varied from 9 mm to 11 mm with increment of 1 mm.

The same mobile image intensifier (Multimobil 5E, Siemens, Erlangen, Germany) was used in the entire study. The fluoroscopy screening time was displayed on the image intensifier and was recorded by the radiographer. The primary outcome measure was the fluoroscopy exposure time (seconds).

Patient demographic features such as age, gender, injured side and type of fracture (AO/OTA alphanumeric classification-2007 edition) were recorded. The radiographic classification (AO/OTA classification) was undertaken by the trainee doctor and was verified by the senior orthopaedic surgeons.

Numerical data was presented as mean and standard deviation whereas categorical data was presented as proportion and percentage. Independent sample test was used to evaluate the significance of difference in age between the long and short PFN. Chi-square test was used to evaluate the statistical significance of difference in demographic characteristics like gender, side affected and fracture types classified by AO/OTA classification. Independent sample test was used to evaluate statistical significance for difference of overall fluoroscopy exposure time and also between various patterns of fractures as per AO/OTA alphanumeric classification and the level of significance was set at 5%. IBM SPSS version 19 was used for statistical analysis.

RESULTS

The mean age of patients in our cohort was 68.2 years ± 10.6 (range : 38 to 86 years). There were 33 male (54.1%) and 28 female patients (45.9%) in the cohort. Right hip was injured in 27 cases (44.3%) and the left hip was injured in 34 cases (55.7%). Thirty two patients (52.5%) had 31A2.1 fracture, 15 patients (24.6%) had 31A2.2 fracture and 14 patients (23%) had 31A2.3 fracture. The demographic features of the patients are described in Table I. Both groups were comparable in terms of age, gender and fracture patterns according to AO/OTA classification. In the long PFN cohort, there were significantly higher cases with left side hip fracture.

The mean fluoroscopy exposure time in short PFN cohort was 189.5 seconds ± 26 (range : 150 to 250 seconds) and the mean fluoroscopy exposure time in long PFN cohort was 283.4 seconds ± 43.8 (range : 200 to 400 seconds). The mean fluoroscopy exposure time was 93.9 seconds shorter in the short PFN cohort and this difference was statistically significant ($p < 0.0001$; 95% CI : 75.4 to 112.3) (Figure 1).

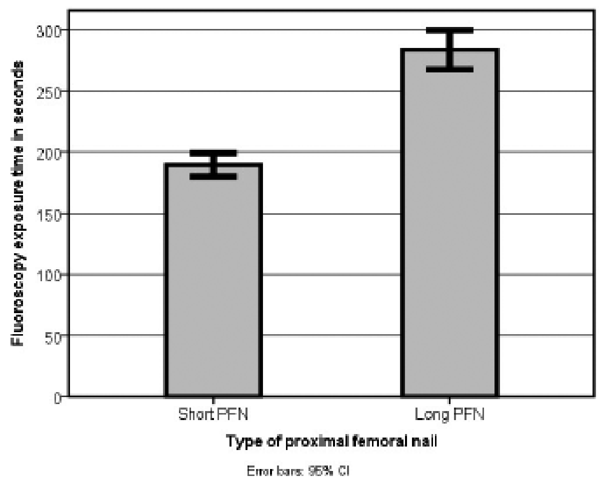

Fig. 1 — Shows significant difference in fluoroscopy exposure time because there is no overlapping of the 95% confidence intervals [short proximal femoral nail : short PFN ; long proximal femoral nail : long PFN].

Table I. — Shows comparative demographic features of Short and Long PFN groups

Demographic characteristics	Short PFN (n = 30)	Long PFN (n = 31)	p-value
Age in years (mean ± SD)	69.2 ± 10.3	67.3 ± 11.0	
Gender			0.49
Male (n[%])	14 [46.7]	19 [61.3]	0.25
female (n[%])	16 [53.3]	12 [38.7]	
Side of injury			
Right (n[%])	19 [63.3]	8 [25.8]	0.003*
Left (n[%])	11 [36.7]	23 [74.2]	
AO Classification			
A2.1 (n[%])	16 [53.3]	16 [51.6]	
A2.2 (n[%])	7 [23.3]	8 [25.8]	0.98
A2.3 (n[%])	7 [23.3]	7 [22.6]	

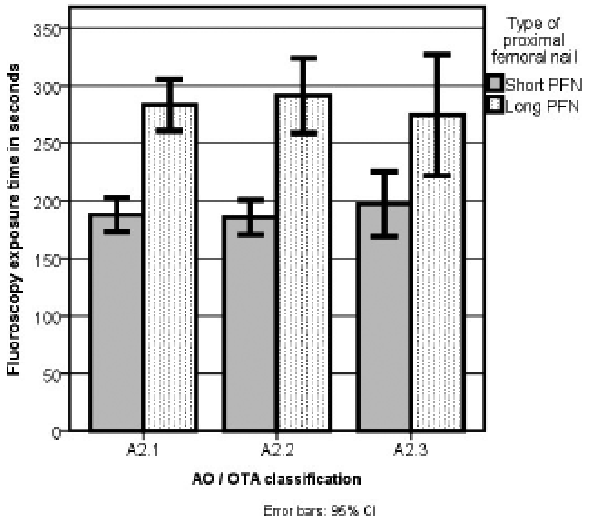

Fig. 2 — shows significantly lower fluoroscopy exposure time by the use of short PFN in A2.1, A2.2 and A2.3 fractures [short proximal femoral nail : short PFN].

The mean fluoroscopic exposure time (in seconds) in the short PFN cohort for 31A2.1, 31A2.2 and 31A2.3 fractures were 187.8 ± 28.2, 185.7 ± 16.2 and 197.1 ± 30.4 respectively. The mean fluoroscopic exposure time (in seconds) in the long PFN cohort for 31A2.1, 31A2.2 and 31A2.3 fractures were 283.4 ± 41.9, 291.3 ± 39.1 and 274.3 ± 56.8 respectively. Independent sample test demonstrated that the difference in fluoroscopy exposure time (in seconds) for 31A2.1 fracture by using short or long PFN was significantly lesser in the short PFN cohort (mean difference = 95.6 seconds ; p value < 0.0001 ; 95% CI : 69.7 to 121.6). The fluoroscopy exposure time for 31A2.2 fracture was also significant lower when the short PFN was used (mean difference = 105.5 seconds ; p value < 0.0001 ; 95% CI : 71.7 to 139.4). Even in 31A2.3 fractures, the fluoroscopy exposure time was significantly lower when the short PFN was inserted (mean difference = 77.1 seconds ; p value = 0.01 ; 95% CI : 22.2 to 132.1). Detailed analysis showed that the mean fluoroscopic exposure time was significantly shorter with the use of short PFN in A2.1, A2.2 and A2.3 fractures (Figure 2).

DISCUSSION

Fluoroscopy exposure time (FET) was used as primary outcome in the present study. Dose area product (DAP) and fluoroscopy exposure time are commonly reported instruments to quantify radiation exposure. Hardman et al *(17)* have suggested that fluoroscopy exposure time is a better instrument compared to dose area product because, the exposure time is completely under the surgeon's control whereas, the dose area product depends on factors outside the surgeon's control like the patient's habitus. Hardman et al [17] also opined that fluoroscopy exposure time was more reliable, reproducible and relevant measure of radiation exposure from the trauma surgeon's perspective. The radiation exposure to the patient and the surgeon is directly proportional to the fluoroscopy exposure time *(18)*. Also, there is a statistically significant correlation between the dose area product and fluoroscopy time *(19)*.

Our sample size of 61 participants was comparable to other previous studies which had sample size of 30 to 175 participants *(19,20,21,22,23)*. But ours was the only study to have a homogenous cohort consisting of only 31A2 fractures. In two studies *(20,22)* the pertrochanteric hip fractures were not classified as per AO/OTA classification. The cohort of Frisch et al *(23)* consisted of 31A2 and 31A3 fracture types, Kelly et al *(19)* reported fluoroscopy exposure time in a heterogeneous cohort consisting of 31A1, 31A2, 31A3, 31B1, 31B2 and and 31B3 fractures. Okcu et al *(21)* also reported radiation exposure in a homogenous cohort consisting of only 31A3 fractures. Our results were in accordance with previously published studies. Fluoroscopy exposure time was less in short cephalomedullary nail fixation compared to long cephalomedullary nail fixation in all studies *(20,21,22,23)* except the study by Kelly et al *(19)* wherein less fluoroscopy exposure time was seen in long cephalomedullary nail fixation. The authors did not give an explanation for this counter-intuitive observation. Three studies reported fluoroscopy exposure time but did not report statistical significance of the difference in the fluoroscopy exposure time *(19,20,22)*. One study demonstrated identical fluoroscopy exposure time for long and short cephalomedullary device and statistically there was no difference in the exposure time *(23)*. One probable explanation for observation of identical fluoroscopy time by Frisch et al *(23)* could be that fluoroscopy exposure time data was available only in 76% cases and this significantly high missing data proportion might have led to this conclusion. Only one study reported statistically significant lower fluoroscopy exposure time with short cephalomedullary device *(21)*.The mean fluoroscopy exposure time of 190 seconds in short cephalomedullary nail observed in the present study was higher than previously reported values which ranged from 32 seconds to 114 seconds *(19,20,21,22,23)*. The mean fluoroscopy exposure time of 283 seconds in long cephalomedullary nail observed in the present study was also higher than previously reported values which ranged from 65 seconds to 175 seconds *(19,20,21,22,23)*. There could be several reasons for longer fluoroscopy exposure time in long PFN including time taken for free hand distal locking, intra-operative change of plan from short to long PFN to accommodate the femoral curvature especially in short statured ladies and different nail designs used in various studies. The most commonly cited reason for longer fluoroscopy time in long proximal femoral nail is the longer time taken for distal locking of screws especially when using free hand perfect circle technique *(23)*. The Short PFN is a straight nail and has no anatomic curvature in the sagittal plane. Most of the Indian female patients are short statured with shorter radius of curvature. The sagittal femoral bowing in the Asian population is more pronounced as compared to the Western population *(24)*. Hence there is higher risk of anterior cortex perforation during short PFN insertion and surgeons would be taking due care to avoid cortical perforation. Because of this due diligence from the surgeon, there was not even a single case of anterior femoral cortical perforation in our study. The longer fluoroscopy time noted in our study could be due to different configuration of the proximal femoral nail used in our study compared to other previous studies. The nail used in our study had two proximal cephalomedullary screws and two distal locking screws. Three studies *(19,20,22)* used Gamma nail that had one cephalomedullary screw and one study *(21)* used PFNA that had one cephalomedullary helical blade. In three studies the short cephalomedullary nail *(19,20,22)* had only one distal locking screw whereas in our study we inserted two distal locking screw even in short PFN.

Hou et al observed that there was no difference in the clinical outcome, complication and reoperation rate after treating 31A2 fractures with either short or long PFN *(25)*. A systematic review by Dunn et al *(26)* concluded that the use of short PFN is safe and associated with shorter operative duration, lower re-operation rate and cost effective compared to the use of long PFN in all types of intertrochanteric hip fractures and also in 31A2 variant of intertrochanteric hip fractures.

It is estimated that the fluoroscopic exposure time of 60 seconds leads to deep whole body radiation exposure of 0.2 mSv to the unprotected operating surgeon *(27)* and the average fluoroscopic exposure time of 283 and 190 seconds for long and short PFN would be associated with radiation exposure of 9.4 mSv and 6.3 mSv respectively to the surgeon per operated patient. As per the recommendations of the International Council on Radiation Protection (IRCP) the maximum allowable limit for radiation exposure to the operating surgeon annually is 50 mSv *(28,29)*. Though debatable, we feel that the difference of fluoroscopy exposure time of 94 seconds would be clinically significant because the radiation exposure would be reduced by 0.31 mSv per patient.

It is worth noting that very often the high exposure of healthcare professionals and patients with ionizing radiation allows a better reduction of fracture, better internal fixation and consequently better outcomes. Moreover, studies have shown that not performing distal locking in cephalomedullary nails in stable intertrochanteric fractures yields good clinical outcomes without compromising fracture union. Also additional benefits of not performing distal locking in cephalomedullary nails include reduce operative time and reduced fluoroscopy exposure time *(30,31)*.

There are many factors that affect the nail selection in pertrochanteric fractures like extension to subtrochanteric area, sagittal bow of the femur, canal diameter, purchase of the PFN in the bone and

Dorr index. But there was no formal evaluation of the justification of the reason for using the long PFN and this is potentially a limitation of the study. Future studies evaluating the reasons for choice of implant would be useful and this could help us understand the decision making process of various surgeons and determined as to whether it is a single factor or combination of factors that makes a surgeon choose one particular type of implant.

We prospectively studied a homogenous cohort consisting of 31A2 fractures because surgeons prefer to treat the above fracture pattern with either short or long PFN depending on the hold of the intramedullary device in the bone, severity of osteoporosis and possibility of recurrent falls, curvature of the femoral shaft etc. 31A1 fractures can be treated with the sliding hip screw whereas 31A3 fractures (reverse oblique types) are usually treated with the long PFN although it has been shown *(21)* that there is no additional benefit of using long PFN in 31A3 fractures.

We would like to acknowledge the following shortcomings of the study. Cumulative radiation dose was not used as outcome in the present study. Measurement could be more precise by using a dosimeter. The Image intensifier C-Arm used in the present study did not have the facility for in-built measurement of dose area product (DAP) or cumulative radiation dose. Radiographers with varying levels of experience participated in this study but, the years of experience of the radiographers was not evaluated in the present study. It is probable that radiographers with more experience might have shorter fluoroscopy time as compared to junior radiographers. All procedures were performed by consultant orthopaedic surgeons or postgraduate trainee doctors under the direct supervision of the consultant orthopaedic surgeons. We did not stratify our results based on the years of experience of the operating surgeon, the number of previous procedures performed by the operating surgeon and the grade of the operating surgeon (trainer / trainee). We did not evaluate the impact of learning curve on fluoroscopy exposure time in our study.

But despite all the above limitations, it is worth noting that there exist few prospective studies comparing radiation exposure in short and long cephalomedullary nailing devices. As we had excluded cases with 31A1 and 31A3 fracture patterns, the generalizability of the results are limited only to 31A2 fractures.

We also would recommend that the total fluoroscopy time be recorded in the hospital operating theatre record book for future audit of radiation exposure. Presently, there exists no formal course/workshop on reduction of radiation exposure for orthopaedic surgeons, orthopaedic trainees and radiographers. There is a need to start radiation protection awareness courses for orthopaedic doctors, orthopaedic trainee doctors and radiographers. Further evaluation needs to be done to determine which steps of the cephalomedullary nail take longer time-making of entry point, insertion of cephalocervical lag screw or insertion of the distal interlocking screws.

CONCLUSION

It can be concluded from the present study that the radiation exposure is significantly lower with the use of the short proximal femoral nail in 31A2 intertrochanteric fractures. Radiation exposure depends not only on the length of the cephalomedullary nail but also on other important factors like variance among the fracture types, use of reduction manoeuvres, expertise of the surgeon and expertise of the radiology technician. The aim of the study was to bring awareness about fluoroscopy time and consequent radiation exposure amongst the orthopaedic surgeons with the use of short and long proximal femoral nails.

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