Acta Biomed 2020; Vol. 91, N. 2: 326-331 DOI: 10.23750/abm.v91i2.8709

Original article

The surgery outcomes of pediatric femoral shaft fractures and comparision of radiation risks

Seyhmus Yigit[1], *Azad Yıldırım*[2]

[1] Arthroscopy, trauma, pediatric orthopedics; [2] Trauma, Arthroscopy, Tumor and Infection Private Sultan Hospital, Department of Orthopaedics and Traumatology, Diyarbakir, Turkey

Summary. *Introduction:* To show midterm results and compare the two methods utilized in pediatric femoral diaphysis fractures fixation and the risks of radiation. *Methods:* We conducted retrospective studies of 60 children and adolescent between the age of 6 to 16 years who were exposed to traumatic femoral shaft fractures and treated with methods of fixation titanyum elastic nail (EN), submuscular bridge plating (SBP) Twenty eight (18 males and 10 females) were treated with SBP (group 1), and 32 patients (18 males and 14 females) were treated with EN (group 2). *Results:* The mean age of the patients was 10,3 years. Duration of follow-up was 29.8 months. Mean union time was 7,4 weeks (range, 6-10 weeks). Operative time was on average 60.6 minutes. Considering Flynn's criteria, the results of treatment was excellent in 50, good in 4 and poor in 6 cases. *Conclusions:* In the surgical treatment of pediatric femoral shaft fractures, fixation techniques such as submuscular bridge platingand elastic nails were found to have similar fracture healing and complication rates. An orthopaedic surgeon must protect himself, his personnel and the patient from radiation exposure. Open reduction internal plate fixation can be chosen as an alternative treatment for children who do not cause radiation exposure to the femoral fracture. (www.actabiomedica.it)

Key words: pediatric femoral fractures, radiation risk, canser risk

Introduction

Recently, the use of fluoroscopy has increased in orthopedic procedures (1). In general, orthopedic surgeons are less conscious about radiation exposure and health effects and are insensible to protection (2). Exposure to radiation from intra-operative imaging is a source of risk for patients, surgeons, and other staff (3). A slight radiation dose may cause local skin damage and systemic absorption by body organs, thereby causing DNA alterations, altered DNA damage response mechanisms, and ultimately cellular dysplasia and malignancy (4).

Femoral shaft fractures constitute approximately 2% of all pediatric fractures (5). Fractures occur with high-energy trauma such as falling or motor vehicle crash and surgical treatment is typically indicated (6). There are various methods for the treatment of femoral shaft fractures in children, but there are controversies about the treatment of children aged 6-16 years.The method to be selected should provide appropriate stability for early mobilization, should not disturb tissue blood supply and should prevent complications.Elastic nails (ENs) are generally used for stable shaft fractures of children less than 45 kg (100 pounds) (7). Elastic nails (ENs) are not a safe method for the treatment of fractures extending from the proximal or distal metaphyseal and for children over 45 kg (7). The method of submuscular bridge plating (SBP) provides minimal soft tissue invasion without compromising soft tissue blood supply and reliable stability allowing early movement (8).

The use of fluoroscopy during the operation is exposed to ionizing radiation to the patient, the surgeon and other operating room personnel. The duration of fluoroscopy usage may be increased according to the surgical technique and the experience of the surgeon. In general, during the use of fluoroscopy, the surgeon and surgical team become anxious about radiation and try to protect themselves from radiation. This study was performed to compare the results and complications of the three methods of fixation and primary goal of the study was to wish to emphasize radiation exposure and risks of diseases induced by radiation. We hypothesise that the dose of ionizing radiation has caused radiation damage to patients, surgeons and other operating room staff during the operation, and that three methods of fixation had similar fracture healing and complication rates at post-op 1st year.

Methods

This retrospective study included 60 child and adolescent patients. Their age was between 6 to 16 years and were exposed to traumatic diaphyseal femoral fractures and surgically treated with TENs and SBP fixation. Patient data included age, gender, mechanism of injury and weight. Clinical variables included the presence of type of treatment modality TEN sor SBP, length of hospital stay, operative time, estimated blood loss (EBL) and fluoroscopy time. Radiographic fracture data included fracture pattern (transverse, oblique/spiral, or comminuted) and fracture location (proximal, mid or distal). Inclusion criteria: 1) femur shaft fracture, 2) patients aged between 6 to 16 years. 3), open femoral physes. The patients whose radiographs were not suitable, multiple injuries, open fractures and pathological fractures were excluded. All patients were operated in the supine position and under general anesthesia. In addition, the operations were completed by adhering to the rules of each method. Clinical and radiographic follow-up was performed routinely at 2nd, 4th, 6th, 8th and 12th weeks after surgery in all patients. Weight carry was allowed when sufficient callus occurs.

Outcomes were measured according to the Flynn scoring system (8). The excellent result is that the leg length inequality is less than 1 cm and that the malalignment is less than 5 degrees. There is no pain and complication. The good result is that the leg length inequality is less than 2 cm and that the malalignment is less than 10 degrees. There is no pain and there are minor complications. The poor result is that the leg length inequality is greater than 2 cm and the malalignment is more than 10 degrees. There is permanent pain and major or persistent complications.

Fluoroscopy was not used because the operation was performed in Group 2 but fluoroscopy was used in Group 1 and Group 3 according to surgical technique. According to the for each patient, the dose area product value (Dose area product (DAP) is an amount used to evaluate the radiation risk from diagnostic X-ray examinations and interventional procedures. DAP not only reflects the dose in the radiation field, but also reflects the irradiated tissue area) and the general fluoroscopic screening time (ET) (minutes) were recorded postoperatively. Moreover, we could not directly calculate the radiation concentration stored in the organs and organs with radiation reflecting the radiation type and the effective dose (E) (4) that measures the radiation hazard potential in organs. We accepted for every patient that the effective dose equals to the DAP value. $E=(\varepsilon_{AP}\times DAP)$. International Commission on Radiological Protection (ICRP) publication 103 (9), the risk for radiation induced cancers (R_C) and detrimental hereditary disorders (R_H) could be calculated by the following formulae: $R_C=0.055\times E(Sv)$, $R_H=0.002\times E\ (Sv)$.

In the historical system of dosimetry, exposure to 1 roentgen (R) of X-rays results in *absorption* of 1 rad [radiation-absorbed dose], which had the *effect* of 1 rem [roentgen-equivalent (in) man]. 1 mSv is the *dose* produced by *exposure* to 1 milligray (mGy) of radiation 1mSv $\approx$ 1 mGy (10). We did not investigate the early period results of ionizing radiation exposure since cancer formation is a time-consuming period. We did not screen for cancer in patients. We investigated the risk of cancer occurring with the increase in the dose of ionizing radiation.

We performed statistical analysis using standard statistical computer software, that is, Statistical Package for Social Sciences (SPSS, version 24). We used Kruskal Wallis test and chi-squared test exact to compare categorical data. Data were compared by using

P-value of <0.05 was considered to be statistically significant.

Results

A total number of 60 patients were studied. Twenty eight patients (18 males and 10 females) treated with SBP (group 1), and 32 patients (18 males and 14 females) treated with TENs (group 2), with an average age of 10,3 years (range, 6-16 years) (p = 0.399). The patients had a mean weight of 39,4 kg (range, 28 to 55 kg) (p = 0.596) (Table 1).

Fracture type was classified according to the OTA/AO classification (11). There were 32 (63,3%) Type A fractures, 20 (33,3%) Type B, and 8 (13,3%) Type C. Proximal diaphyseal fractures occurred in 16 (26,6%) patients, middle fractures in 32 (63.3%), and distal fractures in 12 (20,3%) (Table 2). The mechanisms of injury were 21 (35%) traffic accidents, 20 (33.3%) falling down from height, 12 (20%) fall of the bike, and 8 (13,3%) game injuries.

The mean duration of surgery was 60.6minutes (range, 40-90 minutes). The mean estimated blood loss was 102,3 mL (range, 50-200 mL). The hospital stay was on averenge 3,1 days. The mean follow-up period was 29.8 months (range 12 to 55 months). Average duration of union in all fractures was 7.4 weeks (6-10 weeks) and at this time full weight bearing was started. Majority of the patients achieved full range of knee motion in about 12 weeks. Patients were taught exercises to strengthen muscles and increase ROM in the perioperative period (Table 3).

Table 1. Demography of patients

	Group 1	Group 2
Weigt	41±1,7	38,1±2
Age	11±0,7	9,7±0,7
Sex	18m -10f	18m - 14f

Table 2. Types of fractures and anatomical locations

	TipA/ Proximal	TipB/ Middle	Tip C/ Distal
Group 1	16/6	10/18	2/4
Group 2	16/10	10/14	6/8

Table 3. Operative data

	Group 1	Group 2
Hospital stay	2,9±0,2 days	3,1±0,2 days
Operative time	65,5±2,55 min	59±3,3 min
Union	7±0,3 weeks	7,8±0,2 weeks
EBL	112,1±13,7 ml	93,7±13,7 ml

Table 4. Results according to Flynn's criteria

Flynn's criteria	Excellent	Good	Poor
Group 1	24	2	2
Group 2	16	2	4

Table 5. Fluoroscopy time and radiation risks

	Group 1	Group 2
Fluoroscopy time	34.7 ±2,6 sn	40,8±3 sn
DAP	60,4±4,65 cGy×cm^2	70,87±5,2 cGy×cm^2
Rc	3,32±0,25 Sv	3,897±0,28 Sv
R_H	0,114±0,12 Sv	0,151±0,14 Sv

Our treatment outcome according to Flynn's criteria were excellent in 50 (83.3%) patients, good in 4 (6.6%) patients and poor in 6 (10%) cases. (Table 4). We did not have any complications such as compartment syndrome, union, infection, fracture, or knee ankylosis.

The mean fluoroscopy time was 29.6 seconds (range, 2-70 seconds) (p<0,001). DAP was on average 51,55 cGy×cm^2 (3,43-121,8 cGy×cm^2) R_C was on average 2,834 Sv (0,188-6,699 Sv). R_H was on average 1,048 Sv (0,068-2,436 Sv. (Table 5).

Discussion

Femoral shaft fractures constitute approximately 2% of all pediatric fractures (5). There are various methods for the treatment of femoral shaft fractures in children, but there are controversies about the treatment of children aged 6-16 years. External fixation, rigid intramedullary nailing, submuscular plating, open reduction internal plate fixation and elastic nails are methods of treatment of fractures of femoral shaft in children. Each method has advantages and disanvantages. In the literature, there are studies on the results of surgery of children's femoral shaft fractures. As far as we know, this study is the first study to compare radiation risk for SBP and TEN techniques in treatment of femoral shaft fractures in children aged between 6 to 16 years. A slight radiation dose may cause local skin damage and systemic absorption by body organs, thereby causing DNA alterations, altered DNA damage response mechanisms, and ultimately cellular dysplasia and malignancy (4). As the child's organs and tissues continue to mature, radiation exposures are of concern, and, can also increase the risk of cancer throughout life (12). Our outcomes is paralel to our hypothesise. The results of two methods of fixation was same in 1st year. Repeated fluoroscopic scanning is essential for femoral shaft fracture in children treated with the methods such as ENs and SBP, which increased the radiation exposure in patients. When surgeons choose the surgical method, they should not forget the damage resulted of radiation.

In experimental studies, 1% of the population is predicted to develop cancer or leukemia associated with low-level exposure to radiation (<100 mGy) (13). Mastrangelo presented that a significant increase in the incidence of cancer in orthopedic staff (14). Alonso (15) showed that the distribution radiation in a 2 meter region of a C-arm unit was greater than 1 mSv. Therefore within 2 meters of the C Arm unit, all personnel should wear protective equipment. Thyroid guards reduce exposure by a factor of 2.5.The lead gown should contain at least 0,5 mm equivalent lead and the glasses should be at least 0,15 mm lead equivalent thick (16). In general, during the use of fluoroscopy, the surgeon and surgical team become anxious about radiation and try to protect themselves from radiation. The patient can not escape the harmful effects of radiation. Some studies have shown that the risk of developing malignancy in children is 3-4 times higher than in adults for the same radiation dose (17, 18). Some studies have shown that children have a high relative risk of cancer, even within the first 10 years following exposure (18). Thyroid gland, breasts, bone marrow, brain and skin are the most sensitive organs against radiation in children. Minimally invasive surgical techniques are not harmless techniques (19). The linear dose of carcinogenic effect of radiation in children is 0.1 Gy for thyroid gland, 0.3 Gy for breast, 0.3 Gy for bone marrow, 1.5 Gy for brain, 4.3 Gy for skin (12). In our study, the mean DAP was0. 51Gy and was higher than the thyroid and breast linear dose. Fluoroscopy time, DAP, R_C and R_H notably less for the ORPF technique compared with SBP and EN. Dose area product (DAP) increases as more fluoroscopy is taken. Increased dose area product (DAP) increases the risk of radiation-induced cancers (RC) and harmful hereditary disorders (RH) in ENs and SBP method. The closed reduction procedure has been associated with a higher exposure time compared to open procedures because fluoroscopy is more widely used. Open reduction internal plate fixation (ORPF) can be chosen as an alternative treatment for children which do not cause radiation exposure to the femoral fracture.

In this series, the average duration of surgery was 60.6 minutes, which was almost similar to other studies (20, 21). The most important factor affecting time is the failure of closed reduction, which in some cases leads to open reduction. Median hospital stay in our study was 3,1 days. This was much lower than the ones reported in other studies (20, 22). In our study, full weight bearing was an average of 7,4 weeks in all methods respectively. These are comparable to other studies (23). Earlier mobilization resulted in benefits like shorter hospital stay, less school days loss, less joint stiffness and muscle atrophy. Majority of the patients achieved full range of knee motion upto 12 weeks. As reported by Flynn (8), Cramer (24) and Galpin (25), in our study too there was no case of delayed and non-union. Moroz reported a 5 fold poor outcome in patients weighing more than 49 kg (26). In our study, there was no difference between weight of children on complication rate and recovery time. Also, there was no difference between different fracture locations to complication and fracture union. However, for older and more severe patients in general, doctors tend to prefer SBP instead of TEN. In addition, for proximal or distal fractures, doctors tend to prefer SBP, over middle fractures, and doctors should tend to choose TEN as first choice.

All our groups were almost the same or similar in terms of number and complications. In our study, the results of three fixation methods have similar results in terms of fracture healing and complication as well. We did not have any complications such as compartment syndrome, union, infection, fracture, or knee ankylosis.

There were several limitations in our study. This is a small group study of 78 patients due to the problem of finding data in most of the retrospective studies. Another limitation was that we did not investigate the early results of ionizing radiation exposure since cancer formation is a time-consuming period. Finally, this study ignored many personal and environmental factors such as age, BMI, weight, lead gown, C arm brand etc. that could affect the radiation effect dose.

Conclusions

TheT ENs and SBP methods were found to be safe to maintain fracture healing and to protect against complications in femoral shaft fractures. If the fractures are made according to the surgical technique, if it is not a pathological fracture, if not loaded early, fractures in children usually heal. An orthopaedic surgeon must protect himself, his personnel and the patient from radiation exposure. Open reduction internal plate fixation can be chosen as an alternative treatment for children who do not cause radiation exposure to the femoral fracture.

Conflict of interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article

References

1. O'Rourke PJ, Crerand S, Harrington P, Casey M, Quinlan W. Risks of radiation exposure to orthopaedic surgeons. J R Coll Surg Edinb. 1996;(41):40-3.
2. JK Jain, RK Sen, SC Bansal, ON Nagi. Image intensifier and the orthopedic surgeon. Ind J Orthop. 2001;35(2):13-9.
3. Bindal RK, Glaze S, Ognoskie M, Tunner V, Malone R, Ghosh S. Surgeon and patient radiation exposure in minimally invasive transforaminal lumbar interbody fusion. J Neurosurg Spine. 2008;(9):570-573.
4. Le Heron JC. Estimation of effective dose to the patient during medical x-ray examinations from measurements of the dose-area product. Phys Med Biol 1992;(37):2117-26.
5. Sahlin Y. Occurrence of fractures in a defined population: a 1-year study. Injury. 1990;21(3):158-160.
6. Loder RT, O'Donnell PW, Feinberg JR. Epidemiology and mechanisms of femur fractures in children. J Pediatr Orthop. 2006;(26):561-566.
7. Flynn JM, Luedtke L, Ganley TJ, Pill SG. Titanium elastic nails for pediatric femur fractures: lessons from the learning curve. Am J Orthop. 2002;(31):71-74.
8. Flynn JM, Hresko T, Reynolds RA, Blasier RD, Davidson R, Kasser J. Titanium elastic nails for pediatric femur fractures: a multicenter study of early results with analysis of complications. J Pediatr Orthop. 2001;(21):4-8.
9. The recommendations of the International Commission on Radiological Protection. Ann ICRP 2007; 37:1-332. Editor J. VALENTIN. ICRP publication 103.
10. An Evaluation of Radiation Exposure Guidance for Military Operations: Interim Report. 1997. J. Christopher Johnson and Susan Thaul, Editors. National Academy of Sciences. ISBN 0-309-05895-3.
11. Huda W, Greene-Donnelly K. *RT x-ray physics review*. 2011. Madison, WI: Medical Physics Publishing.
12. Kleinerman RA. Cancer risks following diagnostic and therapeutic radiation exposure in children. Pediatr Radiol. 2006;36:121-125.
13. Huda W. Kerma-area product in diagnostic radiology. 2014. AJR, 203:[web]W565-W569.
14. Mastrangelo G, Fedeli U, Fadda E, Giovanazzi A, Scoizzato L, Saia B. Increased cancer risk among surgeons in an orthopaedic hospital. Occup Med (Lond) 2005;(55):498-500.
15. Alonso JA, DL Shaw, A Maxwell, McGill GP, Hart GC. Scattered radiation during fixation of hip fractures. Is distance alone enough protection? J Bone Joint Surg Br. 2001;83(6):815-18.
16. Theocharopoulos N, Perisinakis K, Damilakis J, Papadokostakis G, Hadjipavlou A, Gourtsoyiannis N. Occupational exposure from common fluoroscopic projections used in orthopaedic surgery. J Bone Joint Surg Am. 2003;(85):1698-703.
17. Andreassi MG, Ait-Ali L, Botto N, Manfredi S, Mottola G, Picano E. Cardiac catheterization and long-term chromosomal damage in children with congenital heart disease. Eur Heart J. 2006;27:2703-2708.
18. Committee to Assess Health Risks from Exposure to Low Levels of Ionizing Radiation. Nuclear and Radiation Studies Board, Division on Earth and Life Studies. National Research Council of the National Academies. Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII Phase 2. The National Academies Press; Washington, DC: 2006.
19. UNSCEAR (2000) UNSCEAR 2000. The United Nations Scientific Committee on the Effects of Atomic Radiation. Health Phys 79:314 [PubMed].

20. Saikia KC, Bhuyan SK, Bhattacharya TD, SP Saikia. Titanium elastic nailing in femoral diaphyseal fractures of children in 6-16 years of age. Indian J Orthop 2007;41(4):381-5.
21. Mann DC, Weddington J, Davenport K. Closed Ender nailing of femoral shaft fractures in adolescents. J Paediatr Orthop 1986;6(6):651-5.
22. Ho CA, Skaggs DL, Tang CW, Kay RM. Use of flexible intramedullary nails in paediatric femur fractures. J Paediatr Orthop 2006;26(4):497-504.
23. Mazda K, Khairouni A, Pennecot GF, et al. Closed flexible intramedullary nailing of the femoral shaft fractures in children. J Paediatr Orthop B 1997;6(3):198-202.
24. Cramer KE, Tornetta P 3rd, Spero CR, Alter S, Miraliakbar H, Teefey J. Ender rod fixation of femoral shaft fractures in children. Clin Orthop Relat Res 2000;(376):119-23.
25. Galpin RD, Willis RB, Sabano N. Intramedullary nailingof paediatric femoral fractures. J Paediar Orthop 1994;14(2):184-9.
26. Moroz LA, Launay F, Kocher MS, Newton PO, Frick SL, Sponseller PD, et al. Titanium elastic nailing of the femur in children: predictors of complications and poor outcomes. J Bone Joint Surg Br. 2006;(88):1361-1366.

Received: 23 June 2019
Accepted: 24 November 2019
Correspondence:
Seyhmus Yigit
Private Sultan Hospital Diyarbakır
Department of Orthopaedics and Traumatology
Diyarbakir, Turkey
Tel.+905325158123
Fax +904122374958
E-mail: seyhmusygt@gmail.com