Injury, Int. J. Care Injured xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Injury

journal homepage: www.elsevier.com/locate/injury

Optimizing intraoperative imaging during proximal femoral fracture fixation – a performance improvement program for surgeons

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ARTICLE INFO

Article history:
Received 25 October 2017
Accepted 18 November 2017

Keywords:
Pertrochanteric fracture
Intramedullary nailing
Intraoperative imaging
Fluoroscopy
Quality improvement
Education
Proximal femoral fracture

ABSTRACT

Introduction: Formal training for surgeons regarding intraoperative imaging is lacking. This project investigated the effect of an educational intervention focusing on obtaining and assessing a standardized lateral view of the proximal femur during intramedullary nailing of a pertrochanteric fracture.
Materials and methods: Anatomical landmarks of the proximal femur that can be identified using intraoperative fluoroscopy and criteria for image quality, i.e. quality of projection were defined in a consensus process, followed by the development of educational materials and a 7-item checklist. Five surgeons from 5 Trauma Centers in 4 countries participated. Each surgeon a) assessed 5 of their own retrospective cases and 5 retrospective cases from 4 colleagues from their clinic, b) viewed an educational video and poster and re-assessed the same cases, and c) assessed the intraoperative images of 5 prospectively collected consecutive cases of their own and of colleagues afterwards.
Results: The percentage of positive ratings for image quality increased from 72% prior to educational intervention to 88% after intervention ($p < 0.001$), and number of "not assessable" images decreased significantly. Percentage agreement between surgeons on the assessments increased from 75% to 87%. The proportion of best possible ratings for fracture reduction and implant position increased from 58% to 72% and from 49% to 66%, respectively. Percentage agreement between surgeons on assessment of reduction and implant position increased.
Discussion and conclusions: A focused educational intervention can improve surgeons' ability to obtain and assess lateral view intraoperative images of the proximal femur and can improve the quality of reduction and implant positioning.

Introduction

Intraoperative fluoroscopy is universally used during fracture surgery to assess and document reduction of fracture fragments and correct placement of implants. Some specific procedures such as minimal invasive plating and closed nailing rely to a high degree on intraoperative fluoroscopy throughout the procedure. Intraoperative fluoroscopy differs from conventional x-ray in various aspects: First, the quality of the images obtained is inferior, and the area that can be exposed is limited [1,2]. Second, the surgeon can choose the exact view of the area of interest by directing the beam or changing the position of an extremity until the desired view is obtained. It is therefore critical for a surgeon to be able to obtain correct and standardized intraoperative views and to correctly interpret these images. However, systematic investigations on intraoperative imaging and structured teaching is lacking. In a survey among 98 surgeons with the question "have you had structured teaching on intraoperative imaging of the proximal

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https://doi.org/10.1016/j.injury.2017.11.024

femur?", the answer was "yes" by 0% of head of departments, 12% of practicing surgeons, and 27% of trainees [3].

Optimal reduction and correct intraoperative views are closely related [4]. If the desired view is not obtained in a standard projection, the probability for an insufficient reduction is high. Moreover, a correct reduction is a prerequisite for optimal implant placement, since the implants are designed to fit to an intact or reduced bony structure. Therefore, imaging, reduction and implant placement have a reciprocal influence on each other: improving imaging improves reduction.

In closed nailing for pertrochanteric fracture fixation there is a considerable incidence of malreduction with 40% of more than 15° internal rotation [5]. Malpositioning of implants due to residual malreduction leads to a higher number of mechanical failures [6–8].

Therefore, a performance improvement program has been designed to improve surgeons' ability to obtain a correct lateral view (also known as axial view) of the proximal femur and to correctly interpret this view during closed nailing. A set of criteria was established on how to obtain an optimal lateral view, and for the assessment of fracture reduction and implant positioning on this optimal lateral view. Specific teaching material was developed to perform a focused educational intervention. We hypothesized that such a focused educational intervention can improve the quality of lateral views as well as the quality of reduction and implant positioning.

Materials and methods

In the context of this study, image quality does not focus on physical or radiation-related information but on anatomical landmarks that help to obtain a good reduction and thus, a correct image. Therefore, anatomical landmarks of the proximal femur that can be identified using intraoperative fluoroscopy were defined in cadaver bones using lead markings, and criteria for the desired projection were defined in a consensus process among 5 surgeons. After review of 25 cases, a consensus meeting, and a second review of 50 additional cases, the criteria were finalized. A 21 min educational video and a poster were produced to explain how to achieve a good quality lateral image and good reduction and implant position: [https://www.aointeract.org/#/watch/video/L3YxL3ZpZGVvcy8xOTc=/intraoperative-imaging-of-femur]

1. The patient is placed on a fracture table in supine position. The patella of the fractures side should look upright in a neutral position. The fluoroscope is introduced from distal from the contralateral side at an angle of approximately 30° to the sagittal plane of the operated leg. For the lateral (=axial) view, the C-arm is swung around the leg of the patient until a position of around 20–25° to the horizontal plane to start with. The visible anatomical structures of the image must be centred on the circular screen, they should appear diagonally.
2. The following structures must be visible: the entire femoral head with the joint space, the femoral neck, both trochanters and the proximal portion of the shaft. A true lateral view is achieved if a straight diagonal line can be drawn from the middle of the head, parallel through the neck axis into the shaft ("head/neck and shaft in line"). For this purpose, the optimal position of the fluoroscope should possibly be adjusted; it is usually between 0 and 25° to the horizontal plane, depending on the femoral anteversion angle of the individual patient. Only with a correct positioning of the fluoroscope *and* a good reduction of the fracture a true lateral view can be obtained.
3. In a well reduced fracture on a true lateral view the so-called "anterior" and "posterior line" are continuous (=harmonic) without any opening/gap and/or step off. The "anterior line" is a virtual line anteriorly in the lateral view from the head to the neck to the shaft with an anterior curvature between the latter two corresponding to the crista intertrochanterica (a tuberosity where the anterior capsule attached at the transition between neck and shaft). The "posterior line" can be identified posteriorly from the head to the neck to the shaft (Fig. 1). Any ad latus deformity between the head/neck fragment and the shaft results in an anterior or posterior step off of these lines. Any angulation, opening or gap, either anterior or posterior is a sign of an external rotation/extension deformity or an internal rotation/flexion deformity respectively.
4. The ideal position of the guide wire for the sliding screw is in the center of the head/neck fragment ("center-center-position").

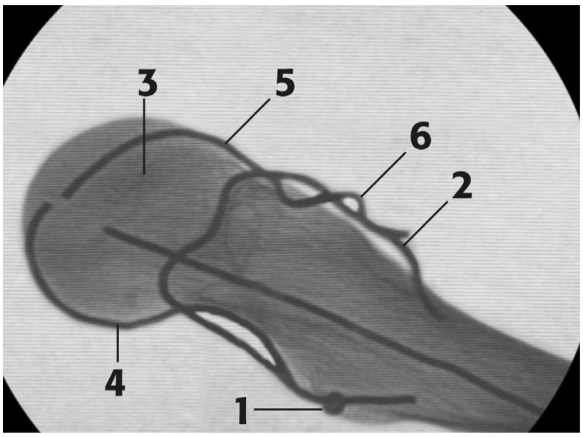

Fig. 1. The following structures must be visible in a good lateral image of a pertrochanteric fracture: the entire femoral head with the joint space, the femoral neck, both trochanters and the proximal portion of the shaft. If the fracture is correctly reduced, these anatomical landmarks can be identified on a lateral view image: 1. Lesser trochanter, 2. Greater trochanter, 3. Femoral head, 4. Posterior line (continuous), 5. Anterior line (continuous), 6. Capsule insertion (crista intertrochanterica).

Based on the criteria explained in the educational material, a 7-item questionnaire was developed to assess the intraoperatively obtained lateral images for the respective quality of the views (question [Q]1 and 2), for the landmarks (Q3–Q5), the reduction (Q6), and implant position (Q7) (Table 1).

The performance improvement study (NCT02272972) was conducted at five Trauma Centers in 4 countries (Austria, Slovenia, Switzerland, United States) between August 2014 and November 2016, after local ethics committee approval at each center. Five surgeons and a principal investigator (PI) were recruited at each clinic. Each surgeon a) assessed five own retrospective cases and five retrospective cases from the four colleagues per clinic (pre-educational assessment), b) viewed the educational video and the corresponding poster and re-assessed the same cases (post-educational assessment I). After the educational intervention, each surgeon treated 5 consecutive cases with a pertrochanteric fracture, and c) assessed the intraoperative post-implant images of the own cases and 5 of their colleagues' consecutive prospective cases at each clinic (post-educational assessment II) that were also treated after the educational intervention. Images were included of patients older than 18 years, diagnosed with a pertrochanteric fracture (AO 31-A1, A2, A3) and surgical treatment with either a Proximal Femoral Nail Antirotation (PFNA), a PFNA-II, a Dynamic Hip Screw (DHS), or a Titanium Trochanteric Fixation Nail System (TFN). All images were pseudonymized, and assessed by the individual surgeons using the same 7-item questionnaire at all three assessment time points. The video and poster was viewed and discussed by the surgeons in a 1 h group meeting at each site.

Please cite this article in press as: D. Rikli, et al., Optimizing intraoperative imaging during proximal femoral fracture fixation – a performance improvement program for surgeons, Injury (2017), https://doi.org/10.1016/j.injury.2017.11.024