Heliyon 10 (2024) e25389

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Accuracy of detecting burst of the lateral wall in intertrochanteric hip fractures with plain radiographs: Is postoperative CT necessary?

Xiaoyang Jia[a,1], Minfei Qiang[a,1], Kun Zhang[b,1], Qinghui Han[c], Gengxin Jia[a], Tianhao Shi[a], Ying Wu[d], Yanxi Chen[a,*]

[a] *Department of Orthopedic Surgery, Zhongshan Hospital, Fudan University, 180 Fenglin Rd, Shanghai, 200032, China*
[b] *Research and Development Department, Yangfeng (Shanghai) Science and Technology CO., LTD, Shanghai, 200439, China*
[c] *Department of Orthopedic Trauma, East Hospital, Tongji University School of Medicine, 150 Jimo Rd, Shanghai, 200120, China*
[d] *Department of Biostatistics, Guangdong Provincial Key Laboratory of Tropical Disease Research, School of Public Health, Southern Medical University, Guangdong, Guangzhou, 510515, China*

A R T I C L E I N F O

Keywords:
Hip fracture
Intertrochanteric fracture
Lateral femoral wall
Computed tomography
Radiographs

A B S T R A C T

Background: Postoperative burst of the lateral femoral wall is thought to be the main predictor of reoperation for intertrochanteric fractures, which is routinely evaluated using plain radiographs. We retrospectively compared computed tomography (CT) scans and radiographs regarding the ability to detect burst of the lateral wall. We also investigated whether intramedullary nails may cause iatrogenic burst of the lateral wall.

Methods: From January 2010 to December 2021, patients aged 65 years and older who undergone intertrochanteric fractures treated with the proximal femoral nail antirotation 2 (PFNA-II) were included. The incidence of burst of the lateral wall was evaluated with two different imaging modalities by two observers. Two rounds of evaluation were performed: (1) with plain radiographs alone; and (2) with CT scans combined with radiographs. Interobserver and intraobserver agreement (κ value) for evaluation of the lateral wall burst was assessed.

Results: A total of 1507 patients were included (362 males and 1145 females). Compared with radiographs alone (12.0 %, 181/1507 patients), a higher rate of lateral wall burst was found by CT scans combined with radiographs (72.9 %, 1098/1507 patients) for observer 1 at first reading ($P < 0.001$). Similar results were seen in other evaluations. Interobserver and intraobserver agreement was substantial for radiographs alone (κ, 0.659–0.727) and almost perfect for CT scans combined with radiographs (κ, 0.847–0.926).

Conclusions: Computed tomography combined with radiographs is superior to radiographs alone for detecting burst of the lateral wall after intertrochanteric fracture fixation. Additionally, PFNA-II could cause iatrogenic burst of the lateral wall for intertrochanteric fractures in the elderly.

* Corresponding author.
E-mail address: cyxtongji@126.com (Y. Chen).

[1] These authors contributed equally to this work.

https://doi.org/10.1016/j.heliyon.2024.e25389
Received 4 October 2023; Received in revised form 15 January 2024; Accepted 25 January 2024
Available online 2 February 2024

1. Introduction

Hip fractures represent the most common form of fractures among the geriatric population, incapacitating 4.5 million people worldwide each year [1–3]. Nearly half of these fractures are intertrochanteric fractures. With an aging population, the incidence of such fractures is observing a concomitant rise [1,4]. The outcome of intertrochanteric fractures remains poor if left untreated. Consequently, surgical intervention remains the mainstay treatment [1]. Intramedullary implants, considering the advantages of biomechanics, have been widely used for these fractures and achieved well-clinical outcomes [5–7]. However, postoperative burst of the lateral femoral wall is the serious complication that is thought to be the main predictor of reoperation [8,9]. It is because that the lateral femoral wall is crucial for maintaining the stability of intertrochanteric fractures [10]. Therefore, early and accurate detection of lateral wall burst is important. It can provide a valuable reference for formulating postoperative rehabilitation plans, which may reduce postoperative complications such as internal fixation failure.

Traditionally, the quality of fracture reduction was evaluated on pelvic radiographs. However, some patients with intact lateral wall on radiographs have the poor outcomes that may be related to factors such as lateral wall burst and internal fixation. And they are ultimately found to have a burst of the lateral wall during revision surgery. This apparent discrepancy may be the result of the limited ability of radiographs to detect burst of the lateral wall following intertrochanteric fracture surgery [11,12]. Over recent years, computed tomography (CT) has increasingly become an indispensable tool in orthopedic and trauma practice, with its benefits now widely recognized by multiple scientific disciplines [12–14]. Preoperative CT has been found to be significant more accurate in evaluating injury details of intertrochanteric fractures [12]. Despite this, its value in detecting burst of the lateral wall has not been evaluated.

Therefore, the aim of this study was to compare the ability of CT scans with plain radiography to that of plain radiography in detecting burst of the lateral femoral wall following intertrochanteric fracture surgery. In addition, the purpose was to evaluate whether intramedullary nails may cause iatrogenic burst of the lateral wall.

2. Materials and methods

2.1. Data sources

The current study received approval from the Institutional Review Board and was exempted from the requirement of informed consent, owing to the utilization of deidentified patient data. The study was conducted using the hospital information and imaging systems to access both inpatient and outpatient data, inclusive of patient demographics and imaging details.

2.2. Study population

From January 1, 2010 to December 31, 2021, a cohort of patients aged 65 years or above, who sustained an intertrochanteric fracture and undergone treatment via the proximal femoral nail antirotation 2 (PFNA-II) technique, were reviewed. The cohort

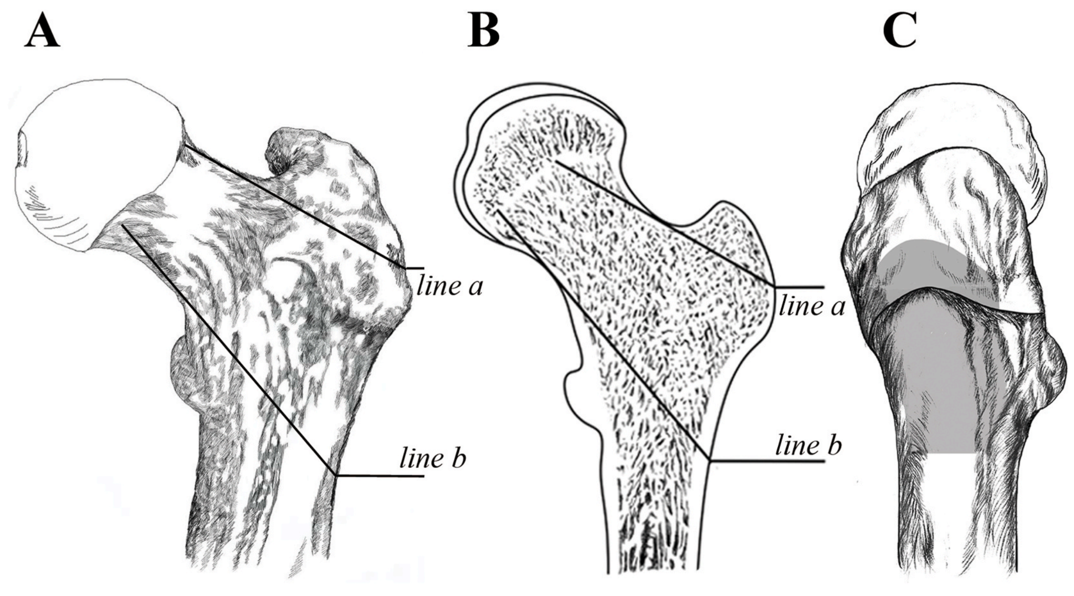

Fig. 1. Anatomy of the lateral trochanteric wall. Line a is the tangent to the superior femoral neck, and line b is the tangent to the inferior femoral neck. The part of the lateral femoral cortex which lies between line a and line b is the lateral femoral wall. The anteroposterior (**A** and **B**) and lateral views (gray-filled area) (**C**).

comprised 1710 patients, of which 429 were male and 1281 were female. Patients with pathological fractures, open fractures, previous hip surgery femoral deformities, or without necessary imaging data (radiographs and CT scans of injured hip before and after operation) were excluded. One experienced orthopedic surgeon reviewed clinical and imaging data to confirm that each patient met the criteria. Importantly, this surgeon had no role in the subsequent radiographic analyses.

2.3. Radiological technique

Patients at our trauma center routinely undergo both radiography (DigitalDiagnost, Philips Healthcare) and CT scans of pelvic following hip fracture surgery. Axial thin-slice CT images of the hip were acquired utilizing a spiral CT scanner, either with a 16-detector or 32-detector configuration (GE LightSpeed; GE Medical Systems). The principal scanning parameters incorporated a section thickness of 0.625 mm, a tube voltage set at 120 kVp, a pitch value of 1.375, and a matrix resolution of 512×512. The CT images were imported into a computer-assisted orthopedic clinical research platform (SuperImage system, orthopedic edition 1.1; Cybermed) [12, 15]. A three-dimensional (3D) image of hip joint was generated through the utilization of a surface-shaded display algorithm. In these 3D surface-shaded display images, individual osseous components were discerned via an interactive, automatic segmentation protocol. Subsequently, the proximal end of the femur was generated by excising extraneous bony structures.

2.4. Image evaluation

The assessment of whether the lateral femoral wall (Fig. 1A–C) had burst was based on images (DICOM 3.0 format) that were displayed utilizing a computer workstation (SuperImage orthopedic edition 1.1; Cybermed Ltd). This analysis was conducted by two independent orthopedic surgeons with varying levels of experience: one junior orthopedic resident and one senior orthopedic surgeon. Two observers performed assessments in a double-blind, randomized methodology to eliminate biases. The assessments were carried out in two separate rounds to ascertain the reliability and reproducibility of the results. In the first round, evaluations were restricted to plain radiographs (anteroposterior and lateral views). A second round was conducted four weeks later, incorporating both plain radiographs and CT scans (including multiplanar reconstruction mode [axial, sagittal, and coronal planes] and volume-render mode). To establish intraobserver reliability, the round was repeated after an additional four-week interval using a newly randomized sequence.

2.5. Postoperative outcomes

The surgeries were performed or closely supervised by a senior surgeon (Y.C., with more than 25 years in performing operations for intertrochanteric fractures). All surgical procedures were performed in accordance with the standard process.

Differences in postoperative outcomes were compared between patients with and without burst of the lateral wall, based on CT scans combined with radiographs data from consistent results of two evaluations by two observers. At the 12-month follow-up, functional outcomes were assessed using the Harris hip score [16] and the visual analog scale (VAS) for pain quantification. The Harris hip score serves as a quantifiable metric for evaluating hip functionality post-surgery, employing a numerical range of 0–100 points, where segments of 0–69, 70–79, 80–89, and 90–100 respectively signify poor, fair, good, and excellent functional outcomes. Concurrently, the VAS furnishes an ordinal scale to quantify pain intensity, ranging from 0 to 10 points, with 0 denoting an absence of pain and 10 representing maximum pain severity. Postoperative rate of revision surgery within 12 months after operation were also compared.

2.6. Statistical analysis

Data normality was ascertained through the application of the Kolmogorov-Smirnov test. Quantitative variables were expressed as means with standard deviation (SD) or medians and interquartile ranges. Categorical variables were delineated by frequencies and percentages.

The difference between two imaging modalities in the evaluation of the incidence of burst of the lateral wall was determined by the McNemar χ^2 test with the four-grid table. To quantify interobserver and intraobserver reliability concerning the incidence of lateral wall burst, multireader kappa (κ) statistics were employed. The kappa values were categorized as follows: 0.01–0.20 indicated slight agreement, 0.21–0.40 indicated fair agreement, 0.41–0.60 indicated moderate agreement, 0.61–0.80 indicated substantial agreement, and 0.81–0.99 indicated almost perfect agreement. Furthermore, a value of zero represented complete discordance, -1.00 denoted absolute disagreement, and $+1.00$ corresponded to full agreement [17].

To evaluate the impact of baseline patient characteristics on postoperative outcomes, multivariable linear regression analyses were conducted to compare differences in Harris and VAS scores between patients with and without lateral wall burst, and a logistic regression analysis was performed for the rate of revision surgery. Covariates (including age, sex, time from injury to operation, and AO/OTA classification) for inclusion in the regression model were either clinically pertinent or exhibited a univariate P-value of less than 0.10 [1,18]. In consideration of the number of available incidents, covariate selection was judiciously performed to maintain model parsimony. All statistical tests were two-sided and paired, with a significance level set at $P < 0.05$. All statistical analyses were executed utilizing Stata software, version 14.1 (StataCorp LLC).

3. Results

3.1. Patient characteristic

Of the 1710 patients, 203 (11.9 %) were excluded based on one or more of the exclusion criteria: pathological fractures (11 patients), open fractures (5 patients), previous hip surgery femoral deformities (8 patients), and/or without necessary imaging data (179 patients). The final study of 1507 patients included 362 (24.0 %) male (mean age, 75.6 ± 5.9 years; range, 65–89 years) and 1145 (76.0 %) female (mean age, 74.2 ± 5.6 years; range, 65–90 years).

3.2. Incidence of burst of the lateral wall

In evaluating burst of the lateral wall for observer 1 at first reading, there was a significant difference between plain radiographs (12.0 % [181/1507 patients]) and CT scans combined with radiographs (72.9 % [1098/1507 patients]) ($P < 0.001$) (Table 1). Similar results were observed in the first reading by observer 2 (radiographs, 12.6 % [190/1507 patients]; CT scans, 75.0 % [1130/507 patients]; $P < 0.001$) and the second reading by observer1 (radiographs, 10.7 % [162/1507 patients]; CT scans, 73.1 % [1102/507 patients]; $P < 0.001$) and observer 2 (radiographs, 11.5 % [174/1507 patients]; CT scans, 72.8 % [1097/507 patients]; $P < 0.001$) (Table 1).

3.3. Interobserver and intraobserver reliability

For interobserver agreement at first reading, substantial agreement was achieved for plain radiographs ($\kappa = 0.727$) (Table 2a). It improved to almost perfect for CT scans combined with radiographs ($\kappa = 0.869$) (Table 3a). Similar data were seen at second reading (Tables 2b and 3b). For intraobserver reliability, the agreement was substantial using plain radiographs ($\kappa = 0.661$ for observer 1; $\kappa = 0.669$ for observer 2) (Tables 4a and 4b). The increase was obtained ($\kappa = 0.926$ for observer 1; $\kappa = 0.868$ for observer 2) when CT scans in combined with radiographs were utilized (Tables 5a and 5b).

3.4. Postoperative outcomes for patients with and without lateral wall burst

Based on CT scans and radiographs, there were 1097 patients with burst of the lateral wall and 377 patients without burst of the lateral wall. Of the 1474 total patients, 295 patients (214 patients with burst of the lateral wall and 81 patients without burst of the lateral wall) lost follow-up within 12 months after surgery. The characteristics of remaining patients (883 patients with burst of the lateral wall and 296 patients without burst of the lateral wall) were seen Table 6. Variables that differed between patients with burst of the lateral wall and without burst of the lateral wall included time from injury to operation ($P = 0.03$) and fracture classification ($P = 0.01$). There was no significant difference between patients with lateral wall burst and without lateral wall burst in Harris score (with, 73.2 ± 7.2 points; without, 73.4 ± 7.8 points; $P = 0.18$), VAS score (with, 2.5 ± 1.2 points; without, 2.4 ± 1.1 points; $P = 0.21$), and rate of revision surgery (with, 3.7 % [33/883 patients]; without, 2.7 % [8/296 patients]; $P = 0.40$).

4. Discussion

The results of this study showed that, compared with plain radiographs alone, postoperative CT images combined with radiographs may be a superior tool for detecting burst of the lateral femoral wall following intertrochanteric fracture surgery. Meanwhile, PFNA-II can cause iatrogenic burst of the lateral wall for intertrochanteric fractures in the elderly.

The data of this study showed that PFNA-II could cause iatrogenic burst of the lateral femoral wall. We found that intramedullary nail may cause iatrogenic lateral wall burst in the early stage. Therefore, measures such as inwardly shifting the needle entry point, careful operation when expanding the medullary cavity, proper fixation of the lateral wall with bone forceps during reaming and main nail insertion were tried during the operation. However, it was still difficult to avoid iatrogenic burst of the lateral wall. This might be due to the design of PFNA-II itself. As we know, the design of PFNA-II was predicated on the anatomical parameters derived from

Table 1
The difference between plain radiographs alone and CT scans combined with radiographs on incidence of burst of the lateral femoral wall.

Plain radiographs	CT scans + Radiographs, Observer 1			CT scans + Radiographs, Observer 2		
	Burst of lateral wall	Non-burst of lateral wall	Total	Burst of lateral wall	Non-burst of lateral wall	Total
First reading						
Burst of lateral wall	163	18	181	174	16	190
Non-burst of lateral wall	935	391	1326	956	361	1317
Total	1098	409	1507	1130	377	1507
Second reading						
Burst of lateral wall	151	11	162	161	13	174
Non-burst of lateral wall	951	394	1345	936	397	1333
Total	1102	405	1507	1097	410	1507

Table 2a
Interobserver agreement on incidence of burst of the lateral wall based on plain radiographs at first reading.

Observer 1	Observer 2	
	Burst of lateral wall	Non-burst of lateral wall
Burst of lateral wall	141*	40
Non-burst of lateral wall	49	1277*

* Data are number of agreements.

Table 2b
Interobserver agreement on incidence of burst of the lateral wall based on plain radiographs at second reading.

Observer 1	Observer 2	
	Burst of lateral wall	Non-burst of lateral wall
Burst of lateral wall	117*	45
Non-burst of lateral wall	57	1288*

* Data are number of agreements.

Table 3a
Interobserver agreement on incidence of burst of the lateral wall based on CT scans combined with radiographs at first reading.

Observer 1	Observer 2	
	Burst of lateral wall	Non-burst of lateral wall
Burst of lateral wall	1076*	22
Non-burst of lateral wall	54	355*

* Data are number of agreements.

Table 3b
Interobserver agreement on incidence of burst of the lateral wall based on CT scans combined with radiographs at second reading.

Observer 1	Observer 2	
	Burst of lateral wall	Non-burst of lateral wall
Burst of lateral wall	1054*	48
Non-burst of lateral wall	43	362*

* Data are number of agreements.

Table 4a
Intraobserver agreement on incidence of burst of the lateral wall based on plain radiographs for observer 1.

First reading	Second reading	
	Burst of lateral wall	Non-burst of lateral wall
Burst of lateral wall	120*	61
Non-burst of lateral wall	42	1284*

* Data are number of agreements.

Table 4b
Intraobserver agreement on incidence of burst of the lateral wall based on plain radiographs for observer 2.

First reading	Second reading	
	Burst of lateral wall	Non-burst of lateral wall
Burst of lateral wall	129*	61
Non-burst of lateral wall	45	1272*

* Data are number of agreements.

Table 5a
Intraobserver agreement on incidence of burst of the lateral wall based on CT scans combined with radiographs for observer 1.

First reading	Second reading	
	Burst of lateral wall	Non-burst of lateral wall
Burst of lateral wall	1078*	20
Non-burst of lateral wall	24	385*

* Data are number of agreements.

Table 5b
Intraobserver agreement on incidence of burst of the lateral wall based on CT scans combined with radiographs for observer 2.

First reading	Second reading	
	Burst of lateral wall	Non-burst of lateral wall
Burst of lateral wall	1075*	55
Non-burst of lateral wall	22	355*

* Data are number of agreements.

Table 6
Baseline demographics of patients and fracture characteristics[a].

Demographics	Total (1179)	Burst of lateral wall (n = 883)	Non-burst of lateral wall (n = 296)	*P* value
Age, y				0.42
65–74	373 (31.6)	285 (32.3)	88 (29.7)	
≥75	806 (68.4)	598 (67.7)	208 (70.3)	
Sex				0.31
Male	304 (25.8)	221 (25.0)	83 (28.0)	
Female	875 (74.2)	662 (75.0)	213 (72.0)	
Education level				0.24
Primary school	601 (51.0)	440 (49.8)	161 (54.4)	
Junior high school	166 (14.1)	132 (14.9)	34 (11.5)	
Senior high school or above	412 (34.9)	311 (35.2)	101 (34.1)	
ASA classification[b]				0.08
1-2	642 (54.5)	465 (52.7)	177 (59.8)	
3	340 (28.8)	261 (29.6)	79 (26.7)	
4	197 (16.7)	157 (17.8)	40 (13.5)	
Time from injury to operation, h				0.03
≤48	503 (42.7)	361 (40.9)	142 (48.0)	
>48	676 (57.3)	522 (59.1)	154 (52.0)	
AO/OTA classification[c]				0.01
A1	635 (53.9)	468 (53.0)	167 (56.4)	
A2	387 (32.8)	282 (31.9)	105 (35.5)	
A3	157 (13.3)	133 (15.1)	24 (8.1)	
Preoperative lateral wall fracture				0.26
Yes	387 (32.8)	282 (31.9)	105 (35.5)	
No	792 (67.2)	601 (68.1)	191 (64.5)	

SD, standard deviation; ASA, American Society of Anesthesiologists; AO/OTA, AO Foundation/Orthopaedic Trauma Association.
[a] Data are expressed as number (percentage) of patients unless otherwise indicated; Percentages may not total 100 because of rounding.
[b] Range, 1 to 6; higher level indicates greater risk during anesthesia. Classifications include 1 (a healthy patient with no disease), 2 (a patient with mild systemic disease), 3 (a patient with severe systemic disease), 4 (a patient with severe systemic disease that is life-threatening), 5 (a patient who is not expected to survive with surgery), and 6 (a patient in whom brain death has occurred).
[c] Range, A1 to A3; different classification indicates different type of fracture. A1 (simple fracture), A2 (comminuted fracture involving the lateral cortex), and A3 (reverse oblique fracture).

Western populations [19,20]. There were differences in skeletal anatomical parameters between Asian and Western population groups [20–22]. Therefore, the key to solving the problem was to design an intramedullary nail that conformed to the Chinese morphological parameters. However, this solution cannot be realized in the short term. Thus, accurate detection of lateral wall burst was particularly important.

To our knowledge, the routine assessment after surgery was plain radiographs. The results of this study showed that the accuracy of plain radiography alone was lower in evaluation of burst of the lateral wall compared with the CT scans combined with radiographs (Figs. 2A–D and 3A–D). The limitations of plain radiography, such as inaccurate projection angles, patient non-compliance, and image superimposition, may contribute to the observed deficiencies. Computed tomography images in combination with radiographs found

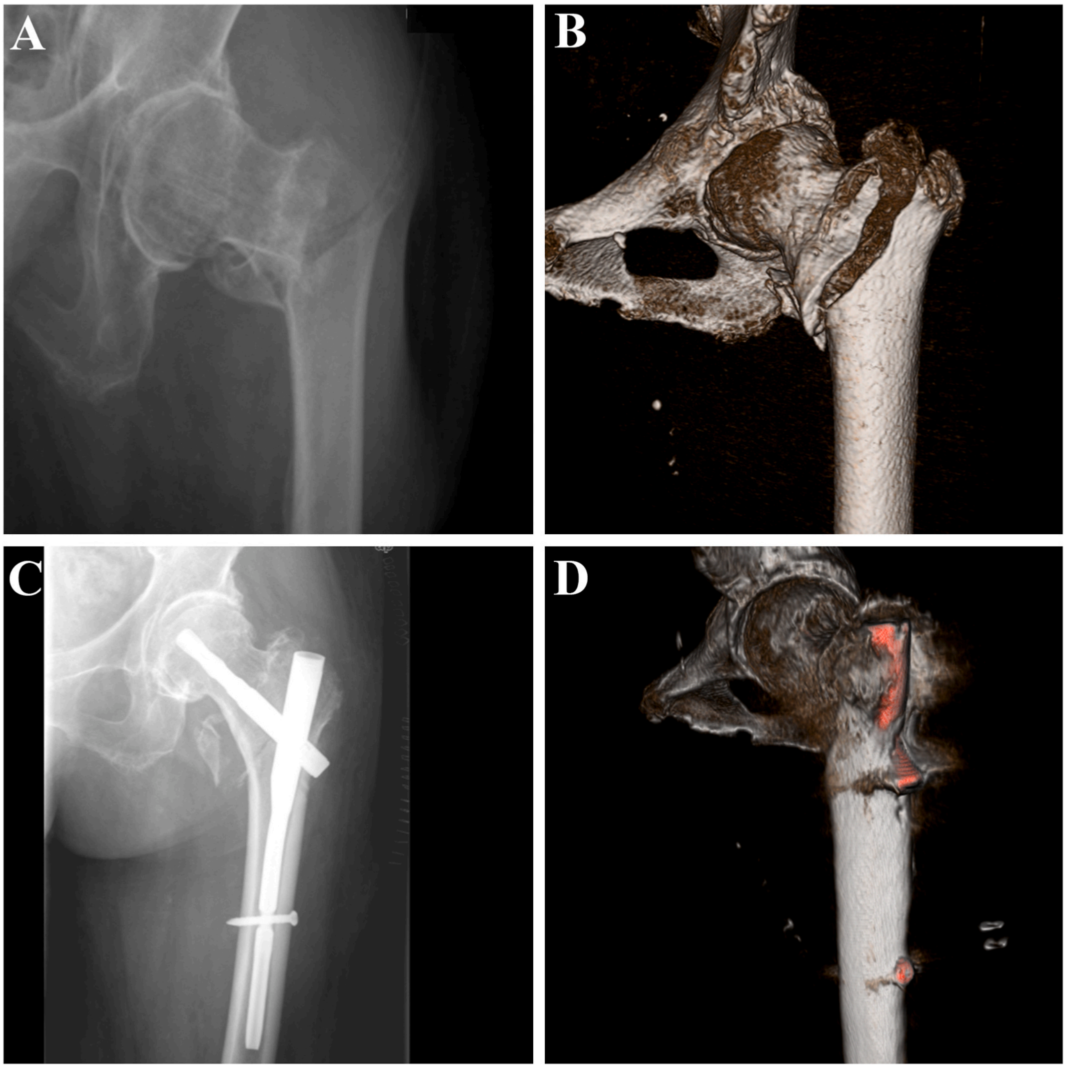

Fig. 2. An 86-year-old woman with intertrochanteric hip fracture (AO/OTA type 31-A1.3) treated with PFNA-II. The lateral wall is intact in the preoperative anteroposterior radiograph (**A**) and 3D CT image (**B**). Postoperative anteroposterior radiograph shows that the fracture reduction is well, and the lateral femoral wall is intact (**C**). However, burst of the lateral wall was seen in the postoperative 3D images, and the main nail is exposed (**D**).

more burst of the lateral wall compared to radiographs alone, which was due to the superiority of CT scans. Multiplanar reconstruction facilitates the visualization of coronal, sagittal, and axial planes of the proximal femur and the internal fixation apparatus, thereby enriching the data available for surgical decision-making. Surface-shaded display modes clearly demarcate the individual bones comprising the hip joint, thus simplifying the elimination of extraneous bony structures from the analysis. Consequently, attention can be focused solely on relevant bones and internal fixation components, unobscured by irrelevant anatomical elements. Volume-rendering techniques further offer semi-transparent and comprehensive perspectives of both osseous and metallic structures, revealing intricate details of the bone surface and internal fixation mechanisms. The above factors were also the reasons for the almost perfect interobserver and intraobserver reliability of CT scans.

Some researchers may argue why we cannot detect burst of the lateral wall intraoperatively. It was known that the lateral wall burst may not be accurately detected using intraoperative C-arm fluoroscopy for the same limitations of plain radiographs. In addition, multiple intraoperative fluoroscopies increased the radiation for surgeons and patients and blood loss. Burst of the lateral wall may be accurately detected using intraoperative 3D CT imaging. However, operating room CT machines were not standard equipment in most hospitals, while intraoperative CT also had the disadvantage of intraoperative C-arm fluoroscopy. Even if the lateral wall burst was detected during the operation, this fact cannot be changed through remedial measures such as wire cerclage. Therefore, it was important to accurately detect the lateral wall burst after surgery, so that these patients could be given reasonable postoperative rehabilitation guidance. Data of this study showed that there was not significant difference in functional outcomes and rate of revision surgery between patients with and without burst of the lateral wall, which was also verified the above viewpoint.

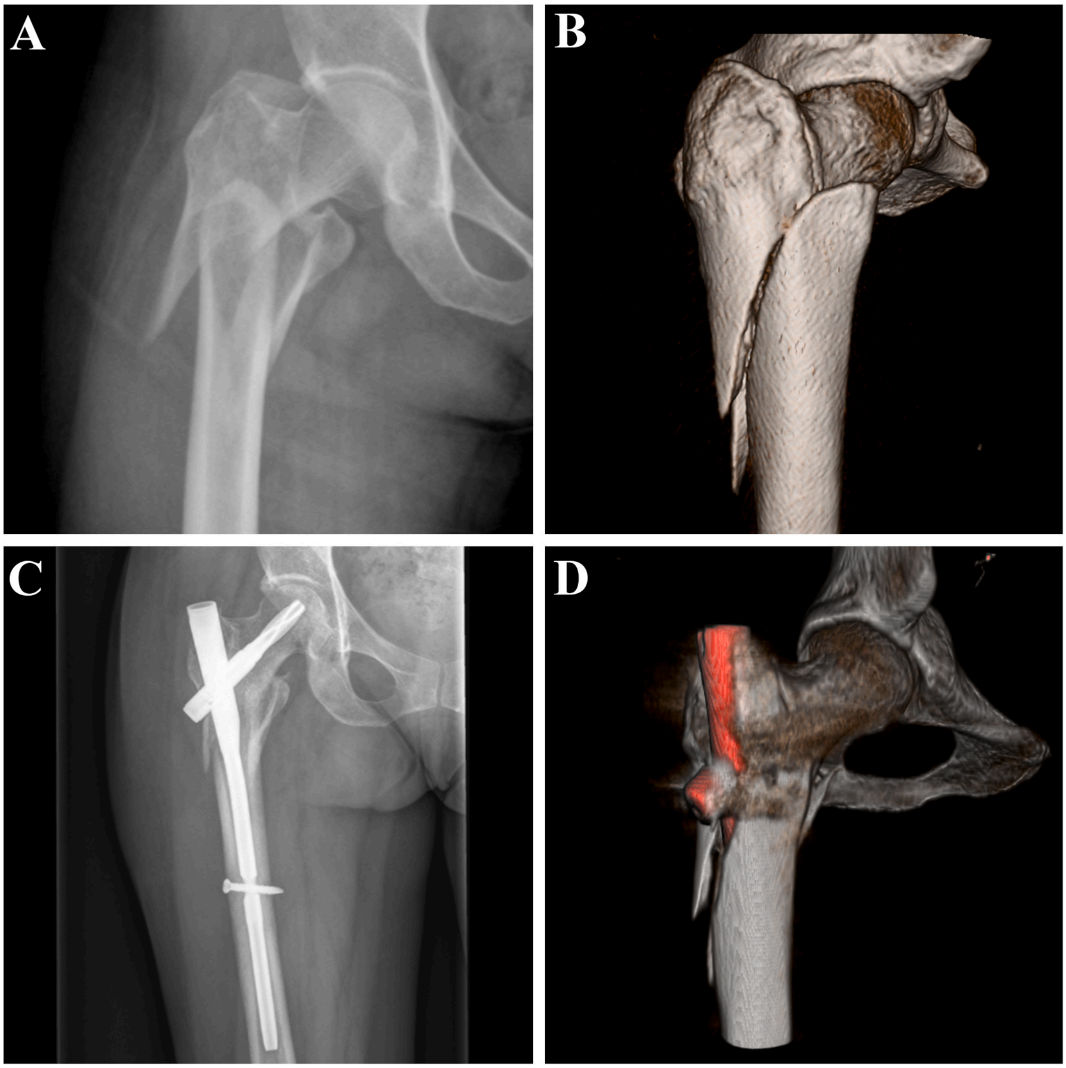

Fig. 3. A 62-year-old male with intertrochanteric hip fracture (AO/OTA type 31-A2.2) treated with PFNA-II. Fracture of the lateral wall is seen in the anteroposterior radiograph (**A**) and 3D CT image (**B**). Burst of the lateral femoral wall is not found in the postoperative plain radiograph (**C**). However, postoperative burst of the lateral wall and exposed main nail are seen in the 3D CT image (**D**).

This study had some limitations. First, there was no gold standard to calculate diagnostic value when plain radiographs are compared to CT images to detect the incidence of lateral wall burst. Intraoperative direct visualization of the lateral wall should be considered the gold standard. However, intertrochanteric fractures were treated with closed reduction and internal fixation. It was not advisable to enlarge the surgical incision just to observe the integrity of the lateral wall. Meanwhile, the accuracy of evaluating internal fixation after fracture surgery based on CT images has also been confirmed to a certain extent. Subsequent experimental investigations are necessitated to validate these findings. Second, concerns regarding augmented radiation exposure warrant further scrutiny. Previous studies reported that specific protocols in combination with filters and image postprocessing software may solve the radiation dose problem [23,24]. Additionally, this study was a retrospective, single-center research with a low level of evidence, so further study must be done in a larger randomized prospective study.

In conclusion, our data showed that CT scans combined with plain radiographs appears to be superior to radiographs alone for detecting burst of the lateral wall after intertrochanteric fracture fixation, and they had the greater interobserver and intraobserver agreement. A substantial number of patients without burst of the lateral wall on plain radiographs had lateral wall burst according to CT scans in combination with radiographs. In addition, PFNA-II could cause iatrogenic burst of the lateral wall for intertrochanteric fractures in the elderly. Therefore, we suggest that postoperative CT scans should be performed routinely to evaluate the integrity of the lateral wall when PFNA-II is used for the treatment of intertrochanteric hip fractures. This procedure is helpful for surgeons to take steps to early intervention and adjust rehabilitation program for patients with burst of the lateral femoral wall.

Ethics statement

The study was approved by our Institutional Review Board of East Hospital, Tongji University School of Medicine (2016-048) and was in compliance with the Declaration of Helsinki. Additionally, it was exempted from the requirement of informed consent, owing to the utilization of deidentified patient data.

Funding statement

Yanxi Chen was supported by the National Natural Science Foundation of China (grant no. 82272479), and Xiaoyang Jia was the National Postdoctoral Fellowship Program of China (grant no. GZB20230155).

Data availability statement

Data will be made available on request.

Additional information

No additional information is available for this paper.

CRediT authorship contribution statement

Xiaoyang Jia: Writing – original draft, Visualization, Supervision, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Minfei Qiang:** Writing – original draft, Software, Resources, Methodology, Investigation, Data curation, Conceptualization. **Kun Zhang:** Writing – original draft, Visualization, Software, Resources, Project administration, Methodology, Data curation, Conceptualization. **Qinghui Han:** Software, Methodology, Investigation, Data curation. **Gengxin Jia:** Software, Formal analysis, Data curation, Conceptualization. **Tianhao Shi:** Software, Methodology, Data curation, Conceptualization. **Ying Wu:** Writing – original draft, Supervision, Software, Resources, Methodology, Data curation, Conceptualization. **Yanxi Chen:** Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:Yanxi Chen reports was provided by the National Natural Science Foundation of China (No. 82272479).

References

[1] M. Bhandari, M. Swiontkowski, Management of acute hip fracture, N. Engl. J. Med. 377 (21) (2017) 2053–2062.
[2] R. Burge, B. Dawson-Hughes, D.H. Solomon, J.B. Wong, A. King, A. Tosteson, Incidence and economic burden of osteoporosis-related fractures in the United States, J. Bone Miner. Res. 22 (3) (2007) 465–475.
[3] D.K. Dhanwal, E.M. Dennison, N.C. Harvey, C. Cooper, Epidemiology of hip fracture: worldwide geographic variation, Indian J. Orthop. 45 (1) (2011) 15–22.
[4] G. Yang, Y. Wang, Y. Zeng, G.F. Gao, X. Liang, M. Zhou, et al., Rapid health transition in China, 1990-2010: findings from the global burden of disease study 2010, Lancet 381 (9882) (2013) 1987–2015.
[5] D.D. Bohl, B.A. Basques, N.S. Golinvaux, C.P. Miller, M.R. Baumgaertner, J.N. Grauer, Extramedullary compared with intramedullary implants for intertrochanteric hip fractures: thirty-day outcomes of 4432 procedures from the ACS NSQIP database, J. Bone Joint Surg. Am. 96 (22) (2014) 1871–1877.
[6] K. De Bruijn, D. den Hartog, W. Tuinebreijer, G. Roukema, Reliability of predictors for screw cutout in intertrochanteric hip fractures, J. Bone Joint Surg. Am. 94 (14) (2012) 1266–1272.
[7] D. Sanders, D. Bryant, C. Tieszer, A.R. Lawendy, M. MacLeod, S. Papp, et al., A multicenter randomized control trial comparing a novel intramedullary device (InterTAN) versus conventional treatment (sliding hip screw) of geriatric hip fractures, J. Orthop. Trauma 31 (1) (2017) 1–8.
[8] H. Palm, S. Jacobsen, S. Sonne-Holm, P. Gebuhr, Hip Fracture Study Group, Integrity of the lateral femoral wall in intertrochanteric hip fractures: an important predictor of a reoperation, J. Bone Joint Surg. Am. 89 (3) (2007) 470–475.
[9] C.E. Hsu, C.M. Shih, C.C. Wang, K.C. Huang, Lateral femoral wall thickness. A reliable predictor of post-operative lateral wall fracture in intertrochanteric fractures, Bone Joint Lett. J 95-B (8) (2013) 1134–1138.
[10] G. Hecht, A.M. Saiz Jr., T.J. Shelton, M.R. Haffner, C. Delman, A. Shieh, et al., CT scans better assess lateral wall morphology of "stable appearing" intertrochanteric (IT) femur fractures and predict early failure of sliding hip screw (SHS) fixation, OTA Int. 4 (3) (2021) e140.
[11] X. Jia, Y. Chen, M. Qiang, K. Zhang, H. Li, Y. Jiang, et al., Detection of intra-articular screw penetration of proximal humerus fractures: is postoperative computed tomography the necessary imaging modality? Acad. Radiol. 26 (2) (2019) 257–263.
[12] X. Jia, K. Zhang, M. Qiang, Y. Wu, Y. Chen, Association of computer-assisted virtual preoperative planning with postoperative mortality and complications in older patients with intertrochanteric hip fracture, JAMA Netw. Open 3 (8) (2020) e205830.
[13] B.S. Kuszyk, D.G. Heath, D.F. Bliss, E.K. Fishman, Skeletal 3-D CT: advantages of volume rendering over surface rendering, Skeletal Radiol. 25 (3) (1996) 207–214.
[14] X. Jia, K. Zhang, M. Qiang, Y. Chen, The accuracy of intra-operative fluoroscopy in evaluating the reduction quality of intertrochanteric hip fractures, Int. Orthop. 44 (6) (2020) 1201–1208.
[15] X. Jia, K. Zhang, M. Qiang, Q. Han, G. Zhao, Y. Wu, et al., Design of well-matched end-structure of anatomical proximal femoral locking plate based on computer-assisted imaging combined with 3D printing technology: a quality improvement study, Int. J. Surg. 109 (5) (2023) 1169–1179.
[16] W.H. Harris, Traumatic arthritis of the hip after dislocation and acetabular fractures: treatment by mold arthroplasty. An end-result study using a new method of result evaluation, J. Bone Joint Surg. Am. 51 (4) (1969) 737–755.
[17] J.R. Landis, G.G. Koch, The measurement of observer agreement for categorical data, Biometrics 33 (1) (1977) 159–174.

[18] J.D. Zuckerman, Hip fracture, N. Engl. J. Med. 334 (23) (1996) 1519–1525.
[19] J.H. Ji, J.Y. Jeong, H.S. Song, J.H. Ok, S.J. Yang, B.K. Jeon, et al., Early clinical results of reverse total shoulder arthroplasty in the Korean population, J. Shoulder Elbow Surg. 22 (8) (2013) 1102–1107.
[20] Q. Tang, Y. Zhou, D. Yang, H. Xu, Q. Liu, The offset of the tibial shaft from the tibial plateau in Chinese people, the offset of the tibial shaft from the tibial plateau in Chinese people, J. Bone Joint Surg. Am. 92 (10) (2010) 1981–1987.
[21] M.C. Kendall, L.J.C. Alves, Letter to the Editor concerning pain catastrophizing as a predictor for postoperative pain and opiate consumption in total joint arthroplasty patients, Arch. Orthop. Trauma Surg. 138 (5) (2018) 743.
[22] Q. Zhang, L.L. Shi, K.C. Ravella, J.L. Koh, S. Wang, C. Liu, et al., Distinct proximal humeral geometry in Chinese population and clinical relevance, J. Bone Joint Surg. Am. 98 (24) (2016) 2071–2081.
[23] J.M. Boone, W.R. Hendee, M.F. McNitt-Gray, S.E. Seltzer, Radiation exposure from CT scans: how to close our knowledge gaps, monitor and safeguard exposure–proceedings and recommendations of the Radiation Dose Summit, sponsored by NIBIB, February 24-25, 2011, Radiology 265 (2) (2012) 544–554.
[24] J. Henckel, R. Richards, K. Lozhkin, S. Harris, F.M. Rodriguez y Baena, A.R. Barrett, et al., Very low-dose computed tomography for planning and outcome measurement in knee replacement. The imperial knee protocol, J. Bone Joint Surg. Br. 88 (11) (2006) 1513–1518.