Original Article

Reliability and Usefulness of Radiographic Union Score (RUS) for Fracture Healing Assessment in Subtrochanteric Femoral Fractures

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Background: The fracture healing assessment in subtrochanteric femoral fracture (SFF) is essential due to a high rate of implant failure and non-union. It requires an effective diagnostic tool for determining fracture union status. However, significant disagreement exists among clinicians for SFF union diagnosis, and no standardized method is available. Previous studies showed that radiographic union score (RUS) is reliable and highly correlated with fracture healing status.

Objective: To evaluate the reliability and diagnostic accuracy of the RUS method for assessing the fracture healing status in the treatment of SFFs.

Materials and Methods: The present study was a retrospective review study conducted on 44 SFFs. A panel of seven reviewers, which included five orthopedic surgeons and two musculoskeletal radiologists, assessed the radiographic healing of SFF based on both the RUS method and the physician impression method. The interobserver and intraobserver reliabilities were calculated using the intraclass correlation coefficient (ICC) and Cohen's kappa coefficient. The correlation and diagnostic accuracy between RUS and the clinical union were also evaluated.

Results: The RUS method resulted in higher intraobserver and interobserver agreement compared to the physician impression method. Inter-rater agreements of the RUS method and physician impression method were moderate (ICC=0.60) and minimal (kappa=0.37), respectively. The RUS method had a higher correlation with clinical union outcome compared to the physician impression method in SFFs (AUC 0.908 versus 0.640). A RUS of 7 or more at 12 weeks had 88% sensitivity and 63% specificity for predicting clinical union outcome.

Conclusion: The application of the RUS method is reliable for determining the fracture healing status in SFFs and has better correlation with clinical union than the physician impression method. The RUS method may also be useful for predicting clinical union in SFFs. These results support the use of the radiographic scoring system for fracture healing assessment in SFFs.

Keywords: Hip fracture, Subtrochanteric fracture, Fracture healing assessment, Radiographic union, Clinical union, Physician impression

Received 11 December 2019 | Revised 3 March 2020 | Accepted 10 March 2020

J Med Assoc Thai 2020;103(11):1148-54
Website: http://www.jmatonline.com

Optimizing the treatment outcomes of subtrochanteric femoral fractures (SFFs) is challenging for trauma orthopedists. The subtrochanteric femur is an area of high stress resulting from high compressive forces medially and high tensile forces laterally(1) with surrounding strong hip muscles contributing to intense deforming forces after fracture, and decreased blood supply compared to other hip regions, causing a poor fracture healing response(2) and a relatively high rate of fixation failure and non-union (7% to 20%)(3). Therefore, the identification of fracture union status in SFF following surgical treatment is vital for determining a patient's clinical outcome and providing necessary postoperative intervention, especially in cases of non-union with stable implant fixation.

Generally, the fracture healing status of SFF is assessed by postoperative radiographs due to

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How to cite this article:

Thamyongkit S, Sa-ngasoongsong P, Kulachote N, Sirisreetreerux N, Chulsomlee K, Pengrung N, et al. Reliability and Usefulness of Radiographic Union Score (RUS) for Fracture Healing Assessment in Subtrochanteric Femoral Fractures. J Med Assoc Thai 2020;103:1148-54.

doi.org/10.35755/jmedassocthai.2020.11.10868

their ease of use and availability in daily clinical practice[4,5]. However, the radiographic evaluation of fracture union is mostly based on evidence of bone healing, such as the progression of callus formation and its size, cortical continuity, loss of fracture line, and the clinician's experiences with radiographic interpretation (physician impression). Although many advanced imaging techniques exist for fracture healing assessment such as computed tomography, ultrasound, and positron emission tomography[6], none of these methods are considered the gold standard due to a lack of consensus in the definition of fracture union in each technique. Furthermore, the diagnosis of fracture union remains a subjective issue with significant disagreement among clinicians regarding when a fracture is healed[4,5].

In 2010, Whelan et al developed a new scoring system for tibial fracture union assessment and showed that this radiographic union score for tibial fractures (RUST) has improved reliability and reproducibility compared to the published method[7,8]. The RUST scoring method is a radiographic assessment tool for quantitatively evaluating fracture healing using a cortical scoring system. This tool is a reliable and repeatable outcome measurement for assessing tibial fracture healing[9]. The RUST method has also demonstrated a high correlation to the physical properties of healing and can predict the bone healing outcome after treatments[10,11]. However, a lack of information exists in the literature on the correlation and reliability of the cortical scoring method in SFFs. To the authors knowledge, no study has established a radiographic scoring system for SFF union assessment. Therefore, the purpose of the present study was to determine the reliability and usefulness of the RUS method for SFFs. The authors hypothesized that the RUS method has a high correlation with clinical outcomes and can improve the reliability of SFF healing assessments.

Materials and Methods

The present study was undertaken as a single-center retrospective study, and prior approval was obtained from the Institutional Review Board of the Faculty of Medicine, Ramathibodi Hospital, Mahidol University (ID10-58-52), based on the Declaration of Helsinki. An electronic hospital database was used to identify the patients who were treated between January 2005 and December 2014. The inclusion criteria were the patients 1) diagnosed with traumatic SFF and treated with intramedullary nail at the authors' institution, 2) aged between 18 and 60 years, and 3) had at least 12-month follow-up data and a complete set of postoperative anteroposterior (AP) and lateral radiographs (2 weeks, 12 weeks, and 24 weeks) available for analysis. The exclusion criteria were patients who 1) were diagnosed with infection after fracture fixation, 2) had reoperation or revision surgery, and 3) had a pathologic fracture other than trauma, such as a metastatic fracture.

Reviewers, data collection, and outcome measurement

A panel of seven reviewers was composed of five orthopedic trauma surgeons (Thamyongkit S, Sangasoongsong P, Kulachote N, Sirisreetreerux N, and Chulsomlee K) and two musculoskeletal radiologists (Chitrapazt N and Jaovisidha S) with more than five years of experience with the management of SFF. The present study included both specialized orthopedists and radiologists in the panel to determine interobserver and intraobserver reliability and applicability of the method in the two most common specialties involved in SFF treatment. Each case was reviewed for demographic data (age, gender, fracture classification according to AO or OTA classification, postoperative clinical examination, and fracture union status). The selection of radiographs was performed by a research assistant who did not participate in the review. All radiographs were then blinded of date and patient details (name, age, gender). Radiographic fracture healing evaluations were assessed by two methods. First, the reviewers determined the fracture healing status on each postoperative radiograph based on their general impressions on whether the fractures healed (physician impression). The purpose of this first method was to assess the individual ability for fracture healing assessment based on the reviewers' training and experience. Second, the reviewers randomly evaluated all postoperative radiographic images according to the RUS system. The RUS system is based on callus formation and visibility of the fracture line on four cortices observed on AP and lateral views. This system is modified from the original RUST system[7] (Figure 1). The total score, ranging from 4 to 12, provided the healing status of SFFs (Table 1). The same radiographic image was then re-evaluated by the same reviewer after a 4-week interval. The clinical union diagnosis was based on the clinical examination at 24 weeks postoperatively. Clinical union was defined as full weight-bearing by the patient through an injured limb, without an assistive device and without pain or tenderness at the fracture site[12].

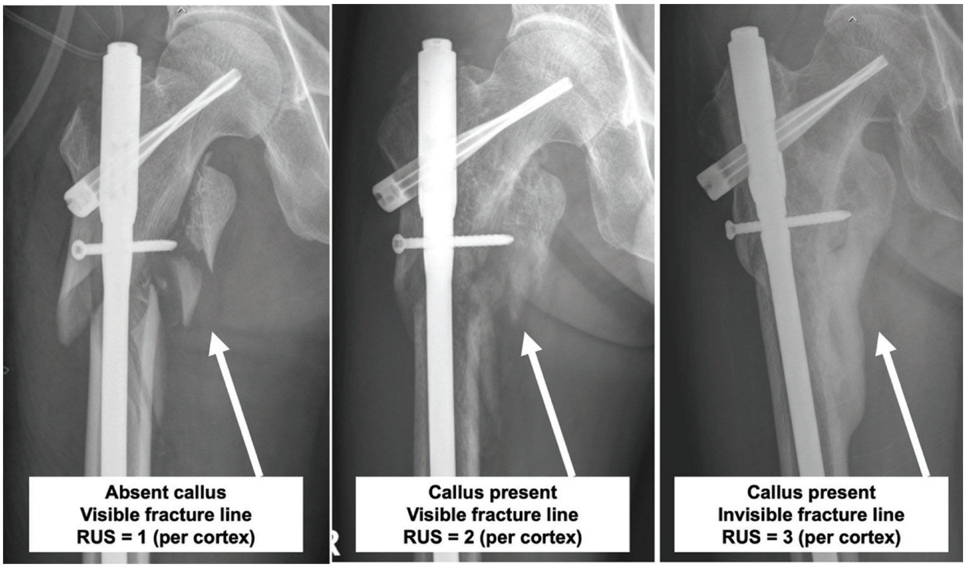

Figure 1. Example of medial cortex radiographic union score (RUS) modification in subtrochanteric fracture assessment in different stages of fracture healing (total scores should be performed and summed for each cortex: anterior, posterior, medial, and lateral).

Table 1. Radiographic union score (modified from Whelan, et al)[7]

Radiographic union score (RUS)						
Score	Description	Cortex				Total
		Anterior	Posterior	Lateral	Medial	
1	Fracture line, no callus					
2	Fracture line, visible callus					
3	No fracture line, visible callus					

Statistical analysis

SPSS Statistics for Windows, version 15.0 (SPSS Inc., Chicago, IL, USA) was used to perform statistical analysis. Continuous data was presented as mean with standard deviation, whereas categorical data was presented as number of cases with proportion. Agreements in the fracture healing assessments, meaning in the physician impression and RUS score, were determined using the Kappa statistics and intraclass coefficient correlation (ICC), respectively. Intraobserver and interobserver agreements were determined across the seven reviewers, and within the two groups of reviewers (five surgeons and two radiologists). Kappa values, for discrete data, were interpreted as follows: 0.0 to 0.2 as poor agreement, 0.21 to 0.40 as fair agreement, 0.41 to 0.60 as moderate agreement, 0.61 to 0.80 as good agreement, and 0.8 to 1.0 as very good agreement[13]. ICC values, for continuous data, were interpreted as follows: 0.75 to 1.00 as excellent, 0.40 to 0.75 as fair to good, and less than 0.40 as poor[14]. The receiver operating characteristic (ROC) curve and area under curve (AUC) were used to assess the diagnostic accuracy of the physician impression and the RUS score at 12 and 24 weeks for predicting the union SFF.

Results

Nighty-four patients who had SFFs in 2005 to 2014 were identified from the hospital patient database. After screening for exclusion criteria, 44 patients were included in the present study (Figure 2). The mean age was 66±15 years. Twelve patients were male (27.3%), and 32 were female (72.7%). According to the AO classification, 32 patients (72.7%) were classified as type A, seven patients (15.9%) as type B, and five patients (11.4%) as type C. Thirty-six patients (81.8%) achieved clinical union with the average fracture healing time as 20.2±12.7 weeks. However, eight patients (18.2%) were classified as delayed union or non-union and

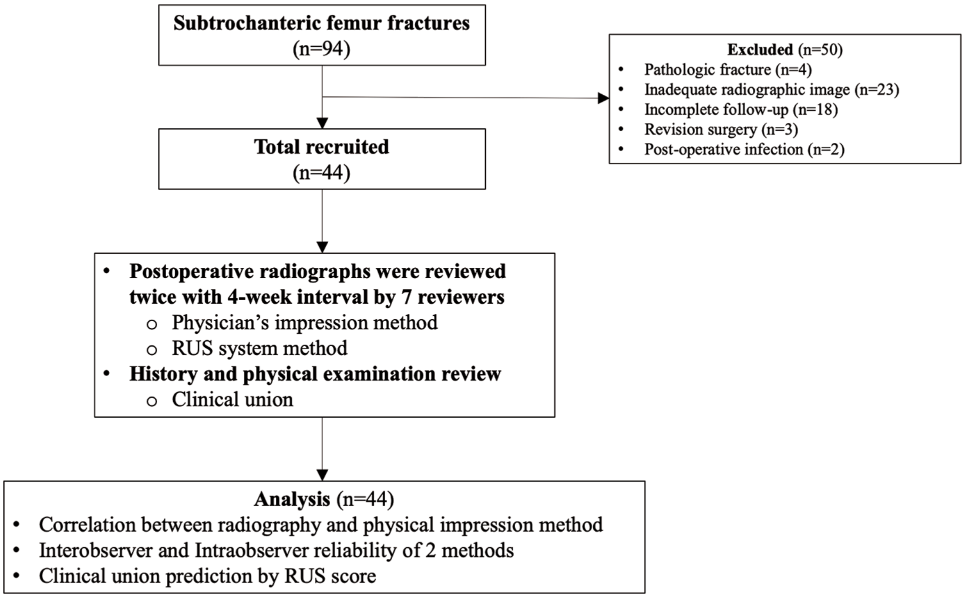

Figure 2. Outcome measurement and data analysis.

Table 2. Interobserver and intraobserver agreement of physician impression and RUS score

Agreement	Radiologists Median (range)	Orthopedic surgeons Median (range)	Overall Median (range)
Physician impression			
Intraobserver	0.63 (0.34 to 0.92)	0.63 (0.30 to 0.93)	0.63 (0.34 to 0.92)
Interobserver	0.53 (0.24 to 0.82)	0.35 (0.05 to 0.65)	0.37 (0.08 to 0.66)
RUS score			
Intraobserver	0.80 (0.66 to 0.89)	0.76 (0.60 to 0.86)	0.78 (0.64 to 0.92)
Interobserver	0.62 (0.48 to 0.72)	0.61 (0.48 to 0.73)	0.60 (0.48 to 0.72)

RUS=radiographic union score

received additional operations, including autologous bone graft, dynamization, or revision surgery.

Overall, the interobserver reliability of physician impression and RUS from the seven reviewers were fair and moderate (kappa=0.37 and ICC=0.60, respectively). The overall intraobserver reliability for physician impression and RUS were good and excellent (kappa=0.63 and ICC=0.78, respectively). In subgroup analysis, there was no significant difference in the agreement between orthopedic surgeons and radiologists for both physician impression and RUS methods ($p>0.05$, data not shown) (Table 2).

Figure 3 demonstrates the ROC curve analysis for using physician impression or RUS score at 24 weeks postoperatively in predicting SFF union. At 24 weeks postoperatively, RUS application resulted in an AUC of 0.908 (95% confidence interval [CI] 0.771 to 0.972, $p<0.0001$), whereas the AUC for the physician impression method was 0.640 (95% CI 0.481 to 0.785, $p=0.058$) (Figure 3). Table 3 shows the diagnostic accuracy of using the RUS score with different cut-off points at 12 and 24 weeks postoperatively for predicting the SFF healing status. The present study result showed that a higher score in the RUS method had good correlation with the SFF union. A RUS score of 7 or higher, at 12 weeks postoperatively, had a sensitivity of 88% and a specificity of 63% for predicting SFF union, whereas this same cut-off point had 100% sensitivity and 50% specificity at 24 weeks (Table 3).

Discussion

Despite advances in fracture management and diagnostic tools for fracture healing assessment,

Table 3. Diagnostic accuracy of RUS score at 12 and 24 weeks for predicting SFF union

RUS score	At 12 weeks (%)		At 24 weeks (%)	
	Sensitivity (95% CI)	Specificity (95% CI)	Sensitivity (95% CI)	Specificity (95% CI)
≥5	100 (90 to 100)	0 (0 to 37)	100 (90 to 100)	0 (0 to 37)
≥6	97 (85 to 100)	13 (0 to 53)	100 (90 to 100)	13 (0 to 53)
≥7	88 (73 to 97)	63 (25 to 92)	100 (90 to 100)	50 (16 to 84)
≥8	65 (47 to 80)	75 (35 to 97)	82 (67 to 93)	75 (35 to 97)
≥9	15 (5 to 31)	88 (47 to 100)	38 (22 to 56)	88 (47 to 100)
≥10	3 (0 to 10)	100 (63 to 100)	3 (0 to 10)	100 (63 to 100)

RUS=radiographic union score; CI=confidence interval

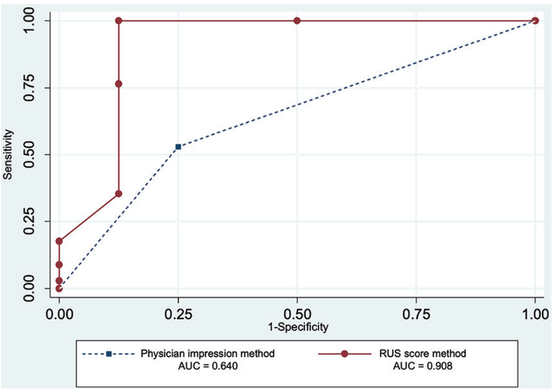

Figure 3. ROC curve of predicting fracture union at 24 weeks postoperatively by RUS methods.

the determination of when a fracture being healed remains a subjective issue and constitutes a dilemma for orthopedic surgeons[5,6,15,16]. Among the long bone fracture treatments, SFF is one of the most challenging problems due to the intense concentration of deforming forces and the decreased vascularity of this region, resulting in a high rate of delayed union and nonunion[2] and requiring a reliable diagnostic tool for evaluating the fracture union. The present study aimed to demonstrate the reliability and usefulness of a simple radiographic assessment, the RUS method, on the fracture healing assessment in SFF patients who underwent intramedullary nail fixation, and compared it with the general assessment in orthopedic practice, the physician impression method.

The present study demonstrated that the RUS method resulted in higher intraobserver and interobserver agreements for determining SFF healing status among all specialists (radiologist, orthopedic surgeon, and overall group) when compared to the physician impression method (Table 2). The application of the RUS method also had a higher correlation with clinical union outcome compared to the individual physician impression method (AUC 0.908 versus 0.640, respectively) (Figure 3). These results are comparable to the previous studies using the RUS method for fracture healing assessment in tibia fractures and femoral shaft fractures[7,9,17,18]. The present study also showed that the physician impression method, even with experienced specialists such as orthopedic surgeons or musculoskeletal radiologists, had lower agreement and correlation with clinical outcomes, compared to the RUS method.

The present study revealed a higher RUS score and a good predictive factor for SFF union. The sensitivities of a RUS score of 7 or higher for predicting SFF union at 12 and 24 weeks postoperatively were 88% and 100%, respectively. With a RUS score of 9 or higher, the specificities at 12 and 24 weeks postoperatively were both 88% (Table 3). These results are comparable with the previous study by Perlepe et al that found the RUS method can contribute to detecting the delayed union of tibia and femoral shaft fractures at three months after injury[18]. Moreover, the present study findings also supported that determination of fracture healing assessment based on the presence of any bridging callus or cortical continuity on the simple radiograph is reliable and has a high correlation with the final healing outcome for tibial and femoral shaft fractures treated by intramedullary nail fixations[12,19,20].

The present study still had some limitations. First, due to the lack of a gold standard for fracture union diagnosis and the limitation of using postoperative CT scan for fracture healing assessment[6], this study was designed to use clinical union based on the clinical examination at 24 weeks postoperatively. Second, there was a relatively small sample size because the authors only recruited the SFF patients who had appropriate data for analysis (treatment with proximal femoral nail fixation, a complete set of radiographs, and a complete postoperative follow-up at one year). However, the present study showed that, despite the limited sample size, a high correlation still existed between RUS and clinical union outcomes, as shown previously. Therefore, the authors recommend the application of the RUS method as a useful SFF treatment with the ability, as part of the complete clinical picture, to help practitioners set proper patient expectations and guide patient treatment.

Conclusion

The application of the RUS method in SFFs treated with intramedullary nail fixation has improved reliability for fracture healing assessment with good agreement between orthopedic surgeons and musculoskeletal radiologists. Moreover, this method also has high correlation with clinical union outcomes and is useful for predicting clinical union in SFFs. Therefore, the authors recommend using postoperative radiographic evaluation with the RUS method in SFF treatment.

What is already known on this topic?

SFF requires a good diagnostic tool for determining fracture union status. Many advanced imaging techniques exist for fracture healing assessment such as computed tomography, ultrasound, and positron emission tomography However, significant disagreement exists among clinicians for SFF union diagnosis, and no standardized method is available.

What this study adds?

This study demonstrates high correlation between RUS score and SFF clinical union status. The RUS method also improves reliability and agreement on fracture healing assessment in SFFs treated with intramedullary nail fixation. Thus, the RUS method is a useful evaluation tool for accessing postoperative fracture healing status in SFF treatment.

Conflicts of interest

The authors declare no conflict of interest.

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