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Assessing the Necessity of Extra Reduction Aides in Intramedullary Nailing of Intertrochanteric Hip Fractures

John W. Yurek, DO, Nikki A. Doerr, MS, Alex Tang, MD, Adam S. Kohring, DO, Frank A. Liporace, MD, Richard S. Yoon, MD

Division of Orthopaedic Trauma and Adult Reconstruction, Department of Orthopaedic Surgery, Cooperman Barnabas Medical Center/Jersey City Medical Center – RWJBarnabas Health, Jersey City, NJ, USA

Purpose: This study aims to determine which intertrochanteric (IT) hip fracture and patient characteristics predict the necessity for adjunct reduction aides prior to prep and drape aiming for a more efficient surgery.

Materials and Methods: Institutional fracture registries from two academic medical centers from 2017-2022 were analyzed. Data on patient demographics, comorbidities, fracture patterns identified on radiographs including displacement of the lesser trochanter (LT), thin lateral wall (LW), reverse obliquity (RO), subtrochanteric extension (STE), and number of fracture parts were collected, and the need for additional aides following traction on fracture table were collected. Fractures were classified using the AO/OTA classification. Regression analyses identified significant risk factors for needing extra reduction aides.

Results: Of the 166 patients included, the average age was 80.84±12.7 years and BMI was 24.37±5.3 kg/m^2. Univariate regression revealed increased irreducibility risk associated with RO (odds ratio [OR] 27.917, $P \leq 0.001$), LW (OR 24.882, $P<0.001$), and STE (OR 5.255, $P=0.005$). Multivariate analysis significantly correlated RO (OR 120.74, $P<0.001$) and thin LW (OR 131.14, $P<0.001$) with increased risk. However, STE ($P=0.36$) and LT displacement ($P=0.77$) weren't significant. Fracture types 2.2, 3.2, and 3.3 displayed elevated risk ($P<0.001$), while no other factors increased risk.

Conclusion: Elderly patients with IT fractures with RO and/or thin LW are at higher risk of irreducibility, necessitating adjunct reduction aides. Other parameters showed no significant association, suggesting most fracture patterns can be achieved with traction manipulation alone.

Key Words: Intertrochanteric fractures, Irreducibility, Reverse obliquity, Closed fracture reduction, Fracture

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Address reprint request to
Richard S. Yoon, MD
(https://orcid.org/0000-0001-5240-6633)
Division of Orthopaedic Trauma and Adult Reconstruction, Department of Orthopaedic Surgery, Cooperman Barnabas Medical Center/Jersey City Medical Center — RWJBarnabas Health, 377 Jersey Avenue, Suite 550, Jersey City, NJ 07302, USA
TEL: +1-201-716 5850
E-mail: yoonrich@gmail.com

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INTRODUCTION

Although most intertrochanteric (IT) femur fractures are amenable to closed reduction with longitudinal traction and internal rotation of the fractured extremity, achievement of spontaneous reduction by closed manipulation alone can be difficult in approximately 3-17% of cases[1-3]. These fractures are designated as irreducible and various types of assistance such as intraoperative tools, percutaneous techniques, and open reduction may be required in order to achieve a stable reduction[1,4-6]. Some reduction techniques include traction on the distal fragment using a bone hook, clamping the fracture site with reduction forceps, and iliopsoas tenotomy[7]. While previous studies have recommended open reduction for irreducible fractures, other studies support the use of minimally invasive open techniques that offer potential benefits such as decreased complications including blood loss and risk of infection in elderly patients with concomitant medical comorbidities[8-11].

Despite improved surgical techniques and implant advances, fixation failure remains problematic in some cases of IT fracture, resulting in revision surgery, which is associated with increased morbidity and mortality[12]. The quality of reduction is the most crucial modifiable risk factor in the management of these fractures[2,13-15]. Difficulties in achieving reduction arise as a result of complex fracture pathoanatomy and mechanical deforming forces as well as limitations to achieving reduction on a fracture table[16]. In addition, reduction of IT femur fractures is particularly complicated in elderly patients secondary to poor bone quality, comorbidities, and unfavorable fracture patterns[11]. Expeditious treatment of these injuries while minimizing avoidable complications with adequate reduction may result in improvement of patient outcomes and a reduction of unnecessary costs[14]. However, although numerous studies comparing treatment modalities and reporting on management strategies have been published, data regarding risk factors associated with irreducibility is limited[1,4,8,15,17]. The aim of this study was to identify and report on risk factors associated with irreducibility of IT femur fracture. According to our hypothesis, the propensity for irreducibility as well as the need for reduction aides intraoperatively are increased by specific radiographic and clinical characteristics.

MATERIALS AND METHODS

This study was approved by Institutional Review Board of WCG IRB (No. WCG IRB 20171537) prior to initiation. The written informed consent was obtained from all patients. A retrospective analysis of consecutive patients who presented to the emergency departments at two level II trauma medical centers with IT fractures classified as AO/OTA 31-A1, A2, and A3 from March 2017 to April 2022 was conducted. Inclusion criteria were as follows: (1) patients presenting with acute low energy fractures, (2) patients undergoing surgical fixation, and (3) patients with adequate and available radiographic images (X-rays) for review on our institution's PACS (Picture Archiving and Communication System). Patients who did not meet the inclusion criteria, including those with IT fractures that were chronic (>48 hours) in nature, a result of high energy or gunshot wounds to the hip, and patients without adequate or available X-rays for review were excluded from the final analysis.

Variables collected manually from the electronic medical record included patient demographics, comorbidity data, fracture patterns, number of fracture parts, and fracture reduction. Demographic and comorbidity data included age, sex, race, body mass index (BMI), American Society of Anesthesiology (ASA) scores, Charlson comorbidity index (CCI), history of dementia, preoperative ambulatory status, and smoking status. Radiographic assessment of fracture patterns according to the AO/OTA classification was performed by a postgraduate year 5 senior resident using standard preoperative anteroposterior (AP) and lateral radiographs of the pelvis and hip. Individual assessment of fracture characteristics including displacement of the lesser trochanter (LT), thin lateral wall (LW), reverse obliqui-

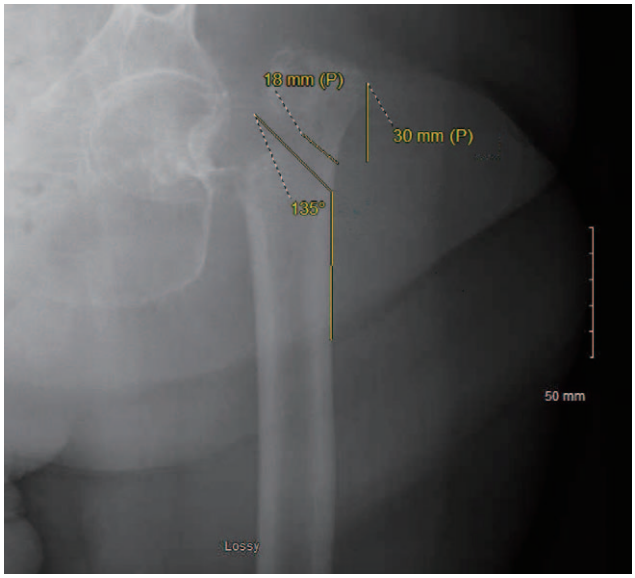

Fig. 1. Anteroposterior radiograph of the left hip demonstrating a thin lateral wall measured using a standard method.

ty (RO), and subtrochanteric extension (STE) was also performed. A standard method involving measurement of the distance from a reference point 3 cm distal to the innominate tubercle of the greater trochanter angled at 135° to the fracture site was used for assessment of the LW (Fig. 1). A distance less than 20.5 mm was considered a thin LW. Cases that lacked certainty with regard to classification were resolved by consultation with the senior authors, who are fellowship-trained trauma orthopedic surgeons. The number of fracture parts (i.e., two-part, three-part, or four-part fractures according to Evans[18], where one part is composed of either the greater trochanter, LT, femoral head, or femoral shaft) was also collected and identified on either plain radiography or computed tomography scan if available. In addition, evaluation of post-reduction AP and lateral intraoperative fluoroscopic images was performed in order to determine whether or not reduction of the fracture was achieved, necessitating the use of reduction tools (Fig. 2, 3).

IBM SPSS Statistics software (ver. 25.0; IBM) was used in performance of all statistical analyses. Univariate and backward stepwise multivariate binary logistic regressions were used for identification of risk factors, including demographic data and fracture characteristics, associated with irreducibility. These findings were reported as an odds ratio (OR) with an associated 95% confidence interval (CI). A $P \leq 0.05$ was considered statistically significant. In addition, a logistic regression equation was used to predict the probability or odds of reducibility without the use of a reduction tool based on the sum product of the regression coefficients for each fracture pattern from the backward stepwise multivariate analysis (Fig. 4).

RESULTS

A total of 166 patients were identified and met the inclusion criteria. Patient demographic data included a mean age

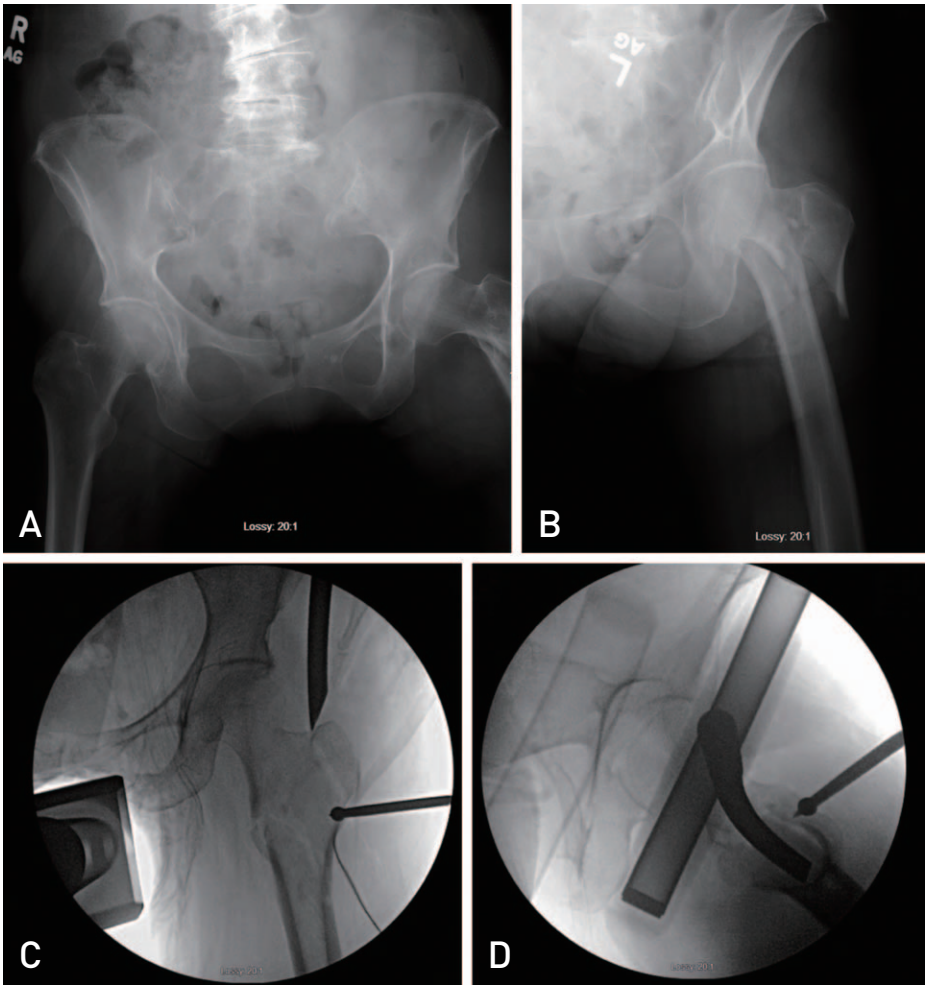

Fig. 2. Anteroposterior radiograph of the pelvis (**A**) and left hip (**B**) demonstrating an intertrochanteric fracture with a reverse obliquity pattern. Anteroposterior (**C**) and lateral (**D**) intraoperative fluoroscopic imaging showing the use of a reduction tool.

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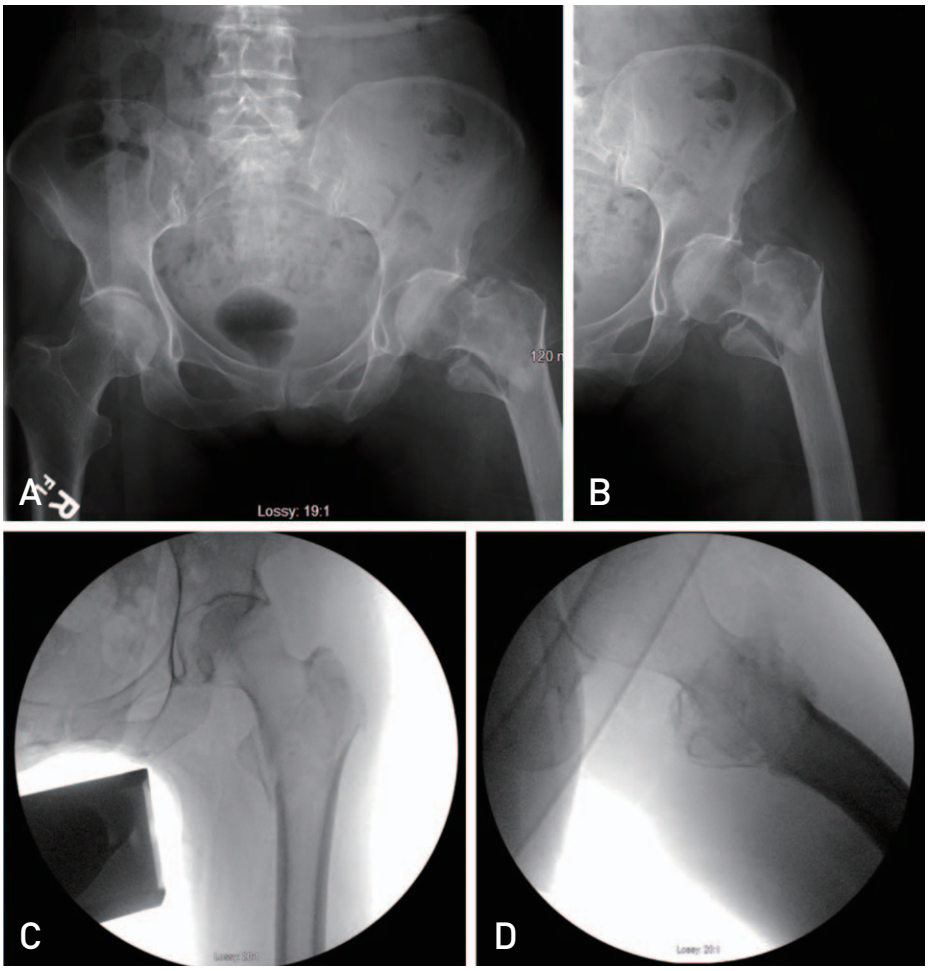

Fig. 3. Anteroposterior view of the pelvis (**A**) and left hip (**B**) demonstrating an intertrochanteric fracture with displacement of the lesser trochanter. Anteroposterior (**C**) and lateral (**D**) intraoperative imaging following successful closed reduction without reduction tools.

of 80.84±12.7 years, BMI of 24.37±5.3 kg/m², and CCI of 5.78±2.7. Females represented 77.1% of our study population (Table 1). Twenty-three fractures (13.9%) were irreducible. There were 105 patients with a two-part fracture, 45 with a three-part fracture, and 16 with a four-part fracture. According to the AO/OTA classification, 64 IT fractures were 1.2, 69 fractures were 1.3, five fractures were 2.2, three fractures were 2.3, one fracture was 3.1, six fractures were 3.2, and 18 fractures were 3.3 (Table 2).

In univariate regression analysis, out of all of the fracture patterns studied, the risk of irreducibility on the fracture table was significantly increased by RO (OR 27.917, $P<0.001$) as well as thin LW (OR 24.882, $P<0.001$) and STE (OR 5.255, $P=0.005$) (Table 3). There was no statistical difference in risk with LT involvement ($P=0.08$). In backward stepwise multivariate analysis, the risk of irreducibility was significantly increased for RO (OR 120.74, $P<0.001$) and thin LW (OR 131.14, $P<0.001$) fracture patterns while STE ($P=0.36$) and LT displacement ($P=0.77$) were not (Table 4). According to the AO/OTA classification, the risk of irreducibility was significant for fracture types 2.2, 3.2, and 3.3 ($P\leq0.001$) (Table 3). No other risk factors, including age, sex, race, BMI, ASA scores, CCI, dementia, preoperative ambulatory status, or number of fracture parts were found to increase the risk of irreducibility.

Finally, a predictive model using a logistic regression equation based on the multivariate analysis revealed that the chance of reduction is lower for patients with an isolated thin LW fracture compared to other fracture patterns in isolation (33% odds of reduction for thin LW vs. 35% for RO vs. 96% for STE vs. 98% for LT displacement) (Fig. 3). The results demonstrated that the odds of successful reduction without the use of an intraoperative reduction tool on the fracture table was 0.19% for patients who presented with all fracture

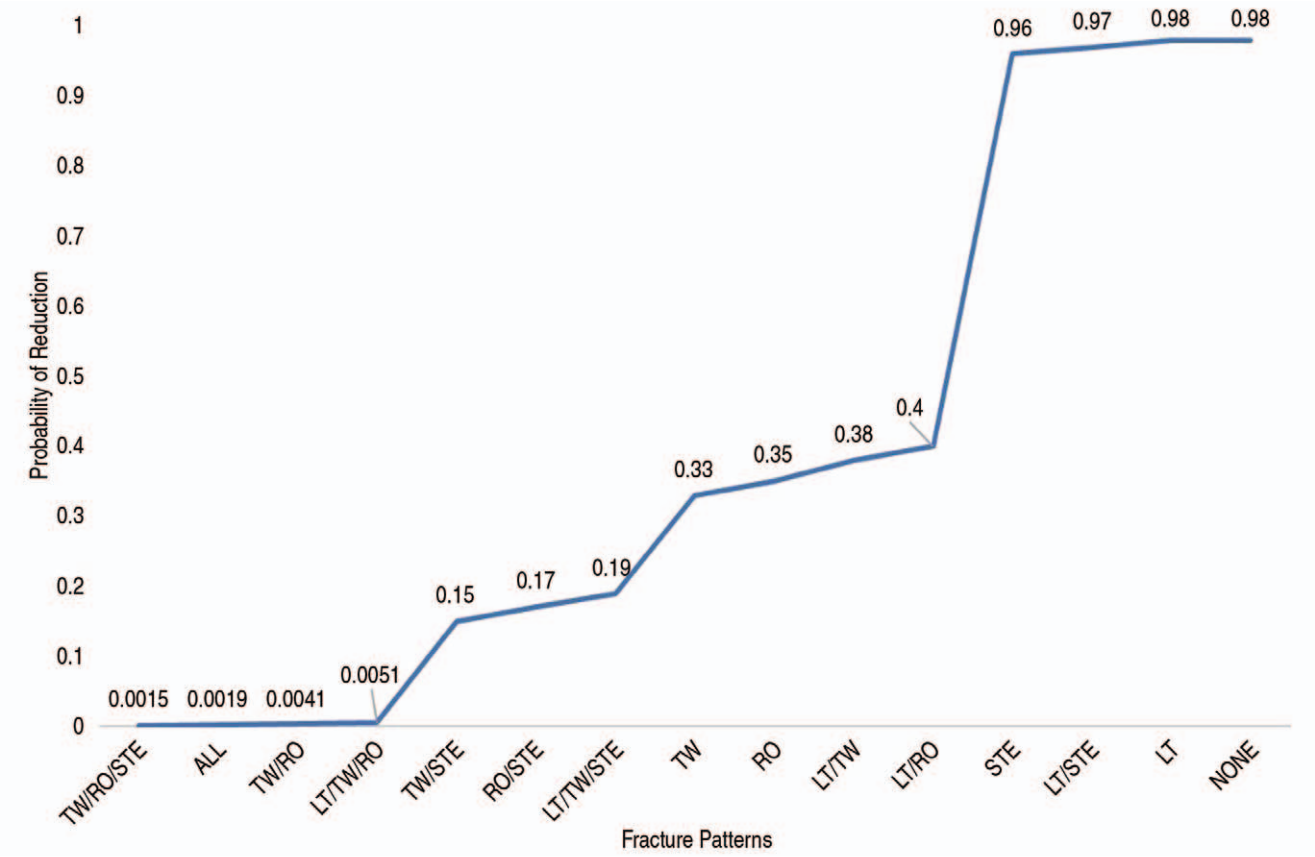

Fig. 4. Reduction probabilities derived from the logistic regression equation based on the multivariate analysis for fracture characteristics.
TW: thin lateral wall, RO: reverse obliquity, STE: subtrochanteric extension, LT: lesser trochanter displacement.

patterns, while the odds of reduction for patients with none of the fracture patterns was 98%. Out of all possible combinations of fracture patterns, the lowest odds of reduction (0.15%) were observed for patients who presented with RO, thin LW, and STE.

DISCUSSION

In our retrospective study of 166 IT fractures treated between March 2017 and April 2022, it was determined that 13.9% of cases were irreducible by closed reduction alone, requiring the use of an intraoperative tool for assistance. Our results are consistent with findings from several studies demonstrating that closed reduction of IT fractures on a fracture table is unsuccessful in approximately 5.8-17.6% of cases[19]. The fracture prognosis, including the postoperative outcomes, is largely defined by the quality of reduction[2,19]. Reestablishing bone contact with the medial anatomy is important in order to enable adequate and early weight bearing[19]. IT fractures typically occur along a line between the greater and LTs, enabling a successful closed reduction with longitudinal traction, slight abduction, and slight internal or external rotation[8].

Haidukewych et al.[20] reported that while the incidence of RO patterns among all hip fractures is low, approximately 2%, the risk of complications associated with fracture healing is 32% for patients with these types of fractures, which may be attributed to a poor intraoperative reduction. Based on multiple preoperative radiographic images, RO was identified as a strong predictor of intraoperative irreducibility, which was previously studied as a potential risk factor by Hao et al.[4]. In their review of 1,174 trochanteric fractures, 67% of irreducible fractures showed an association with RO and not being amenable to closed reduction.

Our data also demonstrates that the risk of irreducibility is significantly increased by the presence of a thin LW (OR 24.882, $P<0.001$). Gotfried[21], who conducted an assessment of 24 patients, reported that the LW was a key factor in reconstruction of an unstable IT fracture and should guide decision-making when selecting the optimal internal fixa-

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Table 1. Baseline Characteristics of Patients Requiring Surgical Intervention for Low-Energy Intertrochanteric Fractures (n=166)

Variable		Value
Age (yr)		80.84±12.7
Sex		
	Female	128 (77.1)
	Male	38 (22.9)
Race		
	White	117 (70.5)
	African American	19 (11.4)
	Asian	5 (3.0)
	Hispanic	4 (2.4)
	Asian Indian	2 (1.2)
	Other	18 (10.8)
BMI (kg/m^2)		24.37±5.3
ASA score		
	1	1 (0.6)
	2	42 (25.3)
	3	103 (62.0)
	4	20 (12.0)
CCI		5.78±2.7
Smoking status		
	Never	147 (88.6)
	Current	11 (6.6)
	Former	8 (4.8)
Laterality		
	Left	89 (53.6)
	Right	77 (46.4)
Fracture parts		
	2	105 (63.3)
	3	45 (27.1)
	4	16 (9.6)
AO/OTA classification		
	1.2	64 (38.6)
	1.3	69 (41.6)
	2.2	5 (3.0)
	2.3	3 (1.8)
	3.1	1 (0.6)
	3.2	6 (3.6)
	3.3	18 (10.8)
Preoperative ambulatory status		
	Ambulatory	134 (80.7)
	Non-ambulatory	32 (19.3)
Displacement of lesser trochanter		
	No	73 (44.0)
	Yes	93 (56.0)
Reducibility		
	No	23 (13.9)
	Yes	143 (86.1)

Values are presented as mean±standard deviation or number (%).
BMI: body mass index, ASA: American Society of Anesthesiology, CCI: Charlson comorbidity index.

tion. Similarly, Hsu et al.[22], who studied 208 patients who underwent surgical treatment for IT fractures, reported that LW thickness was a reliable predictor of postoperative fracture that increased the risk of re-operation and further complications.

Based on our prediction model, the probability of reduction was 0.19% for fractures with all four fracture characteristics, and 98% for those with none. Of particular interest, the probability of reduction was also 98% for LT displacement alone. The combination of characteristics showing the worst chance of reduction at 0.15% were those with thin LW, RO, and STE without LT involvement. However, in a review of 141 trochanteric fractures, Ikuta et al.[19] reported that successful closed reduction was achieved when no displacement of the LT was observed, whereas proximal displacement of the LT showed an association with irreducibility. Based on our data, we observed a trend indicating better reduction probability for every combination of fracture characteristic with LT involvement when compared to those without LT involvement. While this has no statistical or clinical significance and is therefore a moot point, these findings could potentially be explained by the tendinous insertion of the iliopsoas onto the LT. Philippon et al.[23], who examined 53 specimens, reported that the insertion points of the iliopsoas were a single tendon, double tendon, and triple tendon with a double tendon occurrence rate of 64.2%. Gómez-Hoyos et al.[24]. who also studied the tendinous footprint, reported a longitudinally oval shape distributed in the anteromedial region. In addition, Moehring et al.[1] described a distinct irreducible IT fracture pattern where the LT was bisected, and the iliopsoas remained attached to the proximal fragment necessitating an open reduction. The variance in tendinous insertion sites and fracture location in relation to the LT could explain the inconsistencies reported in the literature regarding IT irreducibility based on LT involvement. According to our findings, the probability of reducibility was increased by LT involvement, which we theorize was caused by the deforming forces displacing the LT fragment into flexion preventing it from being a hindrance to reduction.

Previous studies have demonstrated that the quality of reduction is an intraoperative factor that is essentially under the control of the orthopaedic surgeon, and that a poor reduction can result in development of complications such as varus deformity, fixation failure, and refracture[2]. These complications occur more commonly in irreducible fractures. Because achieving the restoration of length, rotation, and alignment should be the objective in treatment of all fractures, includ-

Table 2. Total Fracture Pattern Characteristics within Each AO/OTA Classification

AO/OTA	TW	RO	STE	LT displacement	*P*-value
1.2	0	0	1	0	<0.0001
1.3	0	0	6	69	<0.0001
2.2	5	0	3	3	<0.0001
2.3	3	0	2	3	<0.0001
3.1	0	1	0	0	<0.0001
3.2	0	5	2	1	<0.0001
3.3	0	18	1	18	<0.0001

Values are presented as number only.
TW: thin lateral wall, RO: reverse obliquity, STE: subtrochanteric extension, LT: lesser trochanter.

ing those defined as irreducible, recently published studies have reported on useful techniques in an effort to provide assistance in achieving the perfect reduction[3]. One such study, published in 2014 by Kim et al.[3], describes the hook leverage technique, which involves insertion of a bone hook through an incision along the anterior cortex of the proximal femur into the fracture site between the proximal and distal fragments. The tip of the hook should engage with the proximal fragment as the reduction is carried out with a rotational movement around a longitudinal axis, disimpacting the proximal fragment[3]. In 2021, Fang et al.[2] proposed that the postoperative immobilization period is directly determined by the reduction quality. They also reported on minimally invasive techniques designed to minimize damage to soft tissue, resulting in shorter healing time, less intraoperative blood loss, and decreased pain for use in treatment of irreducible fractures. To the best of the author's knowledge, few studies that provide radiographic and clinical predictors of irreducibility that can be useful in preoperative planning while minimizing complications associated with a poor reduction and increased operative time have been reported.

This study is not without limitations. First, due to the retrospective nature of this study, our data is inherently more susceptible to selection biases; this study only includes low energy IT fractures and other confounding factors that may not have been accounted for during the study period are introduced. Using stringent inclusion criteria, we attempted to mitigate this limitation by including a consecutive cohort of patients with an IT fracture who presented at our institution over a relatively long study period spanning over five years. In addition, univariate and multivariate regression analyses were performed in order to account for any demographic variable that might influence the results of the study, and the results showed no differences in reduction. Second, this study includes a relatively small sample size of only low-energy IT fractures, which likely explains how the results of regression analysis indicated that the risks of irreducibility were significantly higher for certain AO/OTA fracture types[6]. Despite the relatively small sample size, a breakdown of each AO/OTA fracture class for each fracture pattern revealed that the fractures included in our study are heterogenous, which may be more representative of the general population presenting to the emergency department with an IT fracture.

Perhaps the most important limitation of our study can be attributed to its observational nature. Interpretation of our results is limited by the accuracy of the observer who reviewed and interpreted the radiographs. A single reviewer was utilized for radiographic interpretation of all fracture patterns, thus there is potential for poor intraobserver reliability. However, we believe that a postgraduate year 5 resident with several years of training can be regarded as an appropriate and qualified reviewer capable of providing an accurate and reliable assessment of the fracture patterns on initial X-rays. In addition, fellowship-trained orthopedic trauma surgeons were consulted during the initial review, which further minimizes this limitation.

CONCLUSION

Our results suggest that the risk of irreducibility on the fracture table is higher for elderly patients with low energy IT fractures with RO and/or thin LW compared with STE and displacement of the LT. Other parameters including age, sex, race, BMI, ASA scores, CCI, dementia, preoperative ambulatory status, and number of fracture parts showed no significant association. Reduction of most fracture patterns can be achieved with traction manipulation alone. Nevertheless, these data provide useful information that can be utilized in predicting irreducibility in order to assist in preoperative planning with the potential benefit of

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Table 3. Univariate Logistic Regression Analyses Determining the Risk Factors Associated with Intertrochanteric Fracture Irreducibility

Univariate	OR	95% CI		*P*-value
		Lower limit	Upper limit	
Thin lateral wall	24.882	4.649	133.181	<0.001
Reverse obliquity	27.917	9.37	83.172	<0.001
Subtrochanteric extension	5.255	1.864	16.59	0.005
Lesser trochanteric involvement	2.429	0.905	6.517	0.08
AO/OTA				
1.2 (ref.)	-	-	-	-
1.3	0	0	-	0.99
2.2	94.5	6.575	1,358.134	<0.001
2.3	1.02×10^{11}	0	-	0.99
3.1	1.02×10^{11}	0	-	0.99
3.2	63	4.957	800.677	0.001
3.3	126	13.889	1,143.052	<0.001
Age (yr)	1.02	0.988	1.053	0.22
Sex				
Female (ref.)	-	-	-	-
Male	1.08	0.373	3.131	0.89
Race				
White (ref.)	-	-	-	-
African American	1.0	0	-	-
Asian	0	0	-	1.0
Hispanic	1.0	0	-	1.0
Asian Indian	1.0	0	-	1.0
Other	1.62×10^{9}	0	-	1.0
BMI (kg/m^2)	0.985	0.908	1.068	0.71
ASA score	-	-	-	-
1 (ref.)	0	0	-	1.0
2	0	0	-	1.0
3	0	0	-	1.0
4	-	-	-	-
CCI	0.997	0.844	1.178	0.97
Dementia	1.909	0.612	5.955	0.27
Preoperative ambulatory status				
Ambulatory (ref.)	-	-	-	-
Non-ambulatory	0.838	0.286	2.457	0.75
No. of fracture parts				
2 (ref.)	-	-	-	-
3	0.41	0.16	1.049	0.06
4	0.819	0.164	4.089	0.81

OR: odds ratio, CI: confidence interval, ref.: reference, BMI: body mass index, ASA: American Society of Anesthesiology, CCI: Charlson comorbidity index.

Table 4. Multivariate Logistic Regression Analyses for Irreducibility Based on Fracture Characteristic

Multivariate	OR	95% CI		*P*-value
		Lower limit	Upper limit	
Thin lateral wall	131.14	12.71	1,353.11	<0.001
Reverse obliquity	120.74	21.72	671.36	<0.001
Subtrochanteric extension	2.68	0.33	22.01	0.36
Lesser trochanteric involvement	0.79	0.17	3.73	0.77

OR: odds ratio, CI: confidence interval.

minimizing complications while improving overall patient care.

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CONFLICT OF INTEREST

Author F.A.L. reports no direct disclosures related to the submitted work, however, reports the following disclosures that could be perceived as a real or apparent conflict of interest in the context of the subject of this manuscript. AAOS: Board or committee member, AO: Unpaid consultant, Biomet: IP royalties; Paid consultant; Paid presenter or speaker; Research support, DePuy, A Johnson & Johnson Company: IP royalties; Research support, Orthopedic Trauma Association: Board or committee member, Stryker: IP royalties, Synthes: Paid consultant; Paid presenter or speaker.

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ORCID

John W. Yurek (https://orcid.org/0000-0001-7501-9548)
Nikki A. Doerr (https://orcid.org/0000-0003-0335-3859)
Alex Tang (https://orcid.org/0000-0001-7086-4355)
Adam S. Kohring (https://orcid.org/0009-0002-6471-9332)
Frank A. Liporace (https://orcid.org/0000-0002-7082-5329)
Richard S. Yoon (https://orcid.org/0000-0001-5240-6633)

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