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■ TRAUMA

Intramedullary nailing versus sliding hip screw for A1 and A2 trochanteric hip fractures

WHAT FACTORS INFLUENCE SURGEONS' CHOICE OF IMPLANT?

**J. J. Mellema,
S. Janssen,
T. Schouten,
D. Haverkamp,
M. P. J. van den
Bekerom,
D. Ring,
J. N. Doornberg,
Science of Variation
Group**

*From Department of
Orthopedic Surgery,
Academic Medical
Center, University of
Amsterdam, Amsterdam,
The Netherlands.*

Aims

This study evaluated variation in the surgical treatment of stable (A1) and unstable (A2) trochanteric hip fractures among an international group of orthopaedic surgeons, and determined the influence of patient, fracture, and surgeon characteristics on choice of implant (intramedullary nailing (IMN) versus sliding hip screw (SHS)).

Methods

A total of 128 orthopaedic surgeons in the Science of Variation Group evaluated radiographs of 30 patients with Type A1 and A2 trochanteric hip fractures and indicated their preferred treatment: IMN or SHS. The management of Type A3 (reverse obliquity) trochanteric fractures was not evaluated. Agreement between surgeons was calculated using multirater kappa. Multivariate logistic regression models were used to assess whether patient, fracture, and surgeon characteristics were independently associated with choice of implant.

Results

The overall agreement between surgeons on implant choice was fair (kappa = 0.27 (95% confidence interval (CI) 0.25 to 0.28)). Factors associated with preference for IMN included USA compared to Europe or the UK (Europe odds ratio (OR) 0.56 (95% CI 0.47 to 0.67); UK OR 0.16 (95% CI 0.12 to 0.22); $p < 0.001$); exposure to IMN only during training compared to surgeons that were exposed to both (only IMN during training OR 2.6 (95% CI 2.0 to 3.4); $p < 0.001$); and A2 compared to A1 fractures (Type A2 OR 10 (95% CI 8.4 to 12); $p < 0.001$).

Conclusion

In an international cohort of orthopaedic surgeons, there was a large variation in implant preference for patients with A1 and A2 trochanteric fractures. This is due to surgeon bias (country of practice and aspects of training). The observation that surgeons favoured the more expensive implant (IMN) in the absence of convincing evidence of its superiority suggests that surgeon de-biasing strategies may be a useful focus for optimizing patient outcomes and promoting value-based healthcare.

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Introduction

The intramedullary nail (IMN) and the sliding hip screw (SHS), an extramedullary device, are the two most commonly used implants for the treatment of trochanteric hip fractures in adults.¹ The evidence is compelling that reverse oblique and subtrochanteric fractures (AO/OTA 31-A3)² are best treated with an IMN.^{3–6} In contrast, the role of IMN for stable (AO/OTA 31-A1) fractures and unstable (AO/OTA 31-A2) trochanteric fractures is a subject of debate with large and arguably

unwarranted variation in treatment, despite equivocal (A2) or better (A1) outcomes of less expensive extramedullary devices and comparable operating times.^{7–9} In the absence of strong supportive evidence, the rates of IMN fixation increased from 3% in 1999 to 67% in 2006, and up to 90% in 2011 in the USA.¹⁰ Similar numbers have been published from Europe and the UK.^{11–13} This increase seems to be associated with hospital and surgeon factors, as the increased use of IMN is not correlated to clinical superiority of nailing

Correspondence should be sent to J. J. Mellema; email: josmellema@gmail.com

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Table I. Surgeon characteristics (n = 128).

Characteristic	Total
Sex, n (%)	
Male	122 (95)
Female	6 (5)
Area, n (%)	
USA	30 (23)
Europe	65 (51)
UK	12 (9)
Other	21 (16)
Yrs in independent practice, n (%)	
0 to 10	87 (68)
> 10	41 (32)
Specialization, n (%)	
Orthopaedic traumatology	92 (72)
Other	36 (28)
Involved in training other surgeons, n (%)	
Yes	114 (89)
No	14 (11)
Implant used during training, n (%)	
SHS	30 (23)
IMN	13 (10)
Both	85 (66)
Mean hip fractures operated last year, n (SD)	61 (70)
Knowledge of implant costs, n (%)	
Yes	86 (67)
No	42 (33)

IMN, intramedullary nail; SHS, sliding hip screw.

in recently published Level-I scientific evidence.^{1,14–26} SHS implants are considerably cheaper than IMN (€200 vs €1,200, respectively) so in the era of value-based healthcare, increased utilization of SHS for Type A1 and A2 fractures could improve cost-effectiveness.^{15,27}

A Cochrane systematic review of randomized controlled trials (RCTs) in 2010 concluded that the use of IMN may result in increased rates of intraoperative and subsequent fractures around or below the implant and higher rates of reoperation.²⁸ A study of 7,643 trochanteric fractures from the Norwegian Hip Fracture Register reported by Matre et al²⁹ also reported that IMN results in more reoperations than SHS in A1 trochanteric fractures. These data suggest that SHS is superior for stable trochanteric fractures.^{28,30} On the contrary, Parker^{1,14,21} found comparable results in a prospective RCT of 1,000 patients treated with the IMN (Targon Proximal Femoral Nail; B. Braun, Tuttlingen, Germany) versus SHS (Corin PLC, Cirencester, UK; Biomet, Bridgend, UK). Similarly, subsequent trials evaluating newer IMN devices have not reported an increased risk of perioperative femur fracture^{15,16} nor showed any significant difference in terms of pain and function at one year after surgery.^{17,24–26} It has therefore been suggested that with improved implant designs and surgeons' plateaued learning curves, the rate of complications for IMN is now equivalent to that of the SHS.³¹

In addition to presumed complication rate, the choice of implant has clear cost implications. In our (affiliated) teaching hospitals, IMN devices are four times more expensive (€800 to €1,200) as compared to Dynamic or Sliding Hip Screws (€200).¹⁵ Analysis of overall cost-effectiveness between the

Table II. Patient characteristics (n = 30).

Characteristic	Total
Sex, n (%)	
Male	10 (33)
Female	20 (67)
Mean age, yrs (SD)	84 (8.0)
AO/OTA fracture type, n (%)	
A1	8 (27)
A2	22 (73)
ASA classification, n (%)	
1	2 (7)
2	8 (27)
3	16 (53)
4	4 (13)
Side, n (%)	
Left	17 (57)
Right	13 (43)
Implant used, n (%)	
SHS	15 (50)
IMN	15 (50)

ASA, American Society of Anesthesiologists; IMN, intramedullary nail; SHS, sliding hip screw.

two implants showed that the use of SHS is likely more cost-effective for A1 and A2 trochanteric fractures, and IMN may be more cost-effective for A3 fractures. However, this analysis is highly sensitive to fixation failure rate.²⁷

Thus, summarizing studies on outcomes and cost-effectiveness, surgeons' preference for IMN over SHS for A1 and A2 fractures may be explained by professed surgical ease, or a perceived clinical and biomechanical superiority of IMN that is not evidence-based, and unswayed by the substantial difference in implant costs.³² There is currently limited understanding of this global variation in practice.

Therefore, the purpose of this study was to evaluate variation in treatment (i.e. inter-surgeon variability on implant choice) of stable (A1) and unstable (A2) trochanteric fractures among an international group of orthopaedic trauma surgeons, and to determine the influence of patient, fracture, and surgeon characteristics on decision-making (SHS vs IMN).

Methods

Orthopaedic surgeons who have expertise in managing general orthopaedic trauma—identified in both our Science of Variation Group (SOVG) (n = 340 of 800) and Ankleplatform Study Collaborative (n = 400 of 1,400)—were invited via email to evaluate radiographs of 30 preselected patients with stable trochanteric A1 and unstable A2 fractures. Both groups facilitate a collaborative effort to improve the study of variation in interpretation, classification, and treatment of injuries using a large number of fully trained practising orthopaedic surgeons from different countries around the world, predominantly the USA and Europe, to increase external validity. In addition, members of the European Federation of National Associations of Orthopaedics and Traumatology Task Force³³ were invited to participate via the SOVG weblink. The study was performed under a protocol approved by the institutional research board at the principal investigator's hospital (DH, JND).

Table III. Agreement between surgeons on implant choice.

Variable	Interobserver agreement		Proportion of agreement
	Agreement	Kappa (95% CI)	
Overall	Fair	0.27 (0.25 to 0.28)	0.75
Area			
USA	Fair	0.32 (0.27 to 0.38)	0.81
Europe	Fair	0.27 (0.26 to 0.29)	0.76
UK	Slight	0.16 (0.055 to 0.26)	0.74
Other	Fair	0.29 (0.26 to 0.32)	0.76
Yrs in independent practice			
0 to 10	Fair	0.25 (0.24 to 0.26)	0.74
> 10	Fair	0.29 (0.26 to 0.32)	0.77
Specialization			
Orthopaedic traumatology	Fair	0.29 (0.27 to 0.31)	0.77
Other	Fair	0.22 (0.20 to 0.23)	0.71
Involved in training other surgeons			
Yes	Fair	0.28 (0.26 to 0.29)	0.76
No	Slight	0.19 (0.15 to 0.23)	0.71
Implant used during training			
SHS	Fair	0.21 (0.19 to 0.23)	0.72
IMN	Fair	0.30 (0.18 to 0.42)	0.82
Both	Fair	0.28 (0.27 to 0.30)	0.75
Knowledge of implant costs			
Yes	Fair	0.29 (0.28 to 0.31)	0.77
No	Fair	0.22 (0.20 to 0.23)	0.72

CI, confidence interval; IMN, intramedullary nail; SHS, sliding hip screw.

Surgeon characteristics. In all, 128 orthopaedic surgeons logged onto our website and all completed the online evaluation. Surgeons were predominantly men (95%), in independent practice for less than ten years (68%), and specialized in orthopaedic trauma (92%). Most participating surgeons used both SHS and IMN devices during residency (66%). A total of 86 (67%) surgeons had knowledge of implant costs. Half of participating surgeons were from Europe (51%, $n = 65$) (Table I). **Patients.** Patients with traumatic trochanteric hip fractures treated with either a SHS or IMN between 2008 and 2013 were identified in our surgery database. A total of 30 patients were selected by two senior authors (TS, JND). Inclusion criteria were: isolated trochanteric AO/OTA 31-A1 or AO/OTA 31-A2 fracture treated with either SHS or IMN, anteroposterior (AP) and lateral fracture radiographs of adequate quality, and patients aged 18 years and older. Patients who were previously treated with an implant on the contralateral hip were excluded from this study.

Of these patients, 15 were in reality treated with a SHS and 15 with an IMN based on treating surgeons' preference, though respondents were not privy to these data. Distribution of fracture characteristics (A1 and A2) was evenly distributed between these two subgroups of 15 cases. The ratio for fracture characteristics was selected to correspond to the epidemiology of trochanteric fractures as in the randomized controlled trial conducted by Parker et al.¹⁴

Table IV. Surgeon characteristics associated with implant choice.

Characteristic	Recommending IMN, OR (95% CI)	p-value*
Sex		
Male	0.79 (0.57 to 1.10)	0.168
Female	Reference	
Area		
USA	Reference	
Europe	0.56 (0.47 to 0.67)	< 0.001
UK	0.16 (0.12 to 0.22)	< 0.001
Other	0.59 (0.47 to 0.73)	< 0.001
Yrs in independent practice		
0 to 10	Reference	
> 10	0.93 (0.78 to 1.11)	0.435
Specialization		
Orthopaedic traumatology	1.14 (0.95 to 1.37)	0.160
Other	Reference	
Involved in training other surgeons		
Yes	1.19 (0.94 to 1.51)	0.143
No	Reference	
Implant used during own training		
SHS	0.72 (0.60 to 0.87)	0.001
IMN	2.58 (1.99 to 3.35)	< 0.001
Both	Reference	
Number of hip fractures operated last year, per 20-unit increase	1.05 (1.03 to 1.07)	< 0.001
Knowledge of implant costs		
Yes	1.09 (0.93 to 1.27)	0.281
No	Reference group	

*Multivariate logistic regression analysis.

CI, confidence interval; IMN, intramedullary nail; OR, odds ratio; SHS, sliding hip screw.

There were four (27%) A1 fractures and 11 (73%) A2 cases in both groups. Most patients were women (67%), with a mean age of 84 years (SD 8; 62 to 99). In total, 16 (53%) were classified according to the ASA classification as patients with severe systemic disease that is not life-threatening (ASA 3) (Table II).³⁴

In addition, the number of subjects was determined based on an adequate balance between the number of subjects and the expected number of observations.³⁵

Online evaluation. All radiographs were anonymized for use in this study. The radiographs were uploaded to the online Digital Imaging and Communication in Medicine (DICOM) viewer of the Science of Variation Group (<https://www.traumaplatform.org>). Upon login to the website, observers were asked to evaluate 30 pairs of anonymized AP and lateral view radiographs of the trochanteric fractures in a random order. A short description of the patient's age, sex, side of injury, and ASA classification³⁴ accompanied each set of radiographs. Observers were asked to select their preferred treatment: SHS or IMN. Observers could open a short descriptive summary of the definition of the A1 and A2 trochanteric fracture classifications with corresponding images. Subsequently, observers were asked to provide the following information: sex; country of practice; years in independent practice; specialization (general orthopaedics, orthopaedic trauma, or other); caseload (number of hip fractures operated last year); type of implants used for trochanteric fractures during orthopaedic training; and costs of SHS and IMN in surgeon's hospital. Observers completed the survey in their own time, at

Table V. Patient characteristics (including fracture characteristics) associated with implant choice.

Characteristic	Recommending IMN, OR (95% CI)	p-value*
Sex		
Male	0.94 (0.80 to 1.11)	0.456
Female	Reference	
Age, per 1 yr increase	0.99 (0.98 to 1.01)	0.341
Fracture type (AO/OTA)		
A1	Reference	< 0.001
A2	10.18 (8.44 to 12.26)	
ASA classification		
1	Reference	0.174
2	0.79 (0.57 to 1.11)	
3	1.26 (0.92 to 1.73)	
4	0.99 (0.67 to 1.46)	
Side		
Left	Reference	0.933
Right	1.01 (0.86 to 1.18)	

*Multivariate logistic regression analysis.

ASA, American Society of Anesthesiologists; CI, confidence interval; IMN, intramedullary nail; OR, odds ratio; SHS, sliding hip screw.

their own pace, and had the possibility to use different computers at various points in time.

Statistical analysis. Patient and surgeon characteristics were summarized with frequencies and percentages for categorical variables and with mean and SD for continuous variables. Agreement between surgeons was calculated using the multi-rater kappa as described by Siegel and Castellan.³⁶ The kappa statistic is a frequently used measure of chance-corrected agreement between observers and interpreted according to the guidelines of Landis and Koch:³⁷ a value of 0.01 to 0.20 indicates slight agreement; 0.21 to 0.40, fair agreement; 0.41 to 0.60, moderate agreement; 0.61 to 0.80, substantial agreement; and 0.81 to 0.99, almost perfect agreement. In addition, the proportion of agreement was calculated and defined as the proportion of observers agreeing with the most provided answer.

Multivariate logistic regression models were used to identify predictors (patient, fracture, and surgeon characteristics) associated with the outcome (implant choice). The sample size was sufficient based on "events per variable" for logistic regression models, resulting in stable models without overfitting.³⁸ We constructed separate models to assess the effect of surgeon characteristics and patient characteristics, including fracture characteristics, on implant choice, while controlling for other factors (i.e. covariate adjustment). Analyses were performed using STATA v. 13.0 (StataCorp, College Station, Texas, USA) and SPSS v. 22 (IBM, Armonk, New York, USA).

Results

Agreement between surgeons on implant choice. The overall agreement between surgeons on implant choice when treating A1 and A2 trochanteric fractures was fair (kappa = 0.27 (95% confidence interval (CI) 0.25 to 0.28)). Subgroup analysis (area, years in independent practice, specialization, training other surgeons, implant used during training, and knowledge of implant costs) showed that interobserver reliability ranged from slight agreement (kappa = 0.16 (95% CI 0.06 to 0.26)) to

fair agreement (kappa = 0.32 (95% CI 0.27 to 0.38)). The mean proportion of agreement was 0.75 (Table III).

Association of patient, fracture, and surgeon characteristics with implant choice. Surgeon characteristics that were independently associated with choice of implant included country of practice, implant used during residency, and caseload.

The odds of recommending an IMN for their patients were 44% lower for surgeons practising in Europe and 84% lower for those in the UK, compared to surgeons from the USA (odds ratio (OR) 0.56 (95% CI 0.47 to 0.67) and OR 0.16 (95% CI 0.12 to 0.22); $p < 0.001$, respectively). Furthermore, the odds of using an IMN for surgeons that used only IMN devices during residency was 2.6 times higher compared to surgeons who used both implants during their training (OR 2.6 (95% CI 2.0 to 3.4); $p < 0.001$); whereas the odds of choosing an IMN was 28% lower for surgeons that only used SHS during their training (OR 0.72 (95% CI 0.60 to 0.87); $p = 0.001$). Surgeons with higher caseload had a higher probability of using an IMN (OR 1.1 (95% CI 1.0 to 1.1); $p < 0.001$) (Table IV).

Finally, fracture characteristics were independently associated with implant choice, while other patient characteristics were not. The odds of a surgeon recommending an IMN device was ten times higher for treatment of trochanteric A2 fractures compared to A1 fractures (OR 10 (95% CI 8.4 to 12); $p < 0.001$) (Table V).

Discussion

There is variation in choice of implant for the surgical treatment of AO/OTA 31-A1 and 31-A2 fractures, despite similar results of SHS versus IMN in recently published Level-I evidence.^{1,14–17,21,24–26} In this study, we evaluated inter-surgeon agreement on implant choice as well as factors that influence decision-making for SHS versus IMN among an international group of fully trained orthopaedic surgeons. We found that the overall agreement between orthopaedic surgeons on implant choice was only fair according to the categorical rating by Landis and Koch³⁷ which does reflect a large variation in treatment. When subsequently evaluating which factors influence decision-making, we found that surgeons from the USA were more likely to opt for IMN compared to surgeons based in Europe or the UK, and that surgeons exposed to IMN only during their training were more likely to opt for IMN compared to surgeons that had been exposed to both. While two-thirds of surgeons had knowledge of the implant costs, this had no bearing on their choice of implant. The odds of recommending an IMN for A2 fractures was higher compared to A1 fractures, and no further patient characteristics, other than fracture type, were associated with implant choice.

This study has several limitations. First, surgeons evaluated actual cases based on provided descriptions including clinical information and radiographs presented online; however, this was only a simulation of a true clinical patient encounter. Second, for practical purposes we limited the number of predetermined factors in our analyses; therefore, we may not have included all factors that influence decision-making. Third, our study, as well as current Level-I evidence, does not address specific AO/OTA subgroups (e.g. A2.3). The strengths of this study include the use of a representative sample of patients

and fracture types treated with both SHS and IMN as seen in routine practice,¹⁴ and high generalizability of results owing to the participation of a large global cohort of fully trained, practising orthopaedic surgeons. However, interpretation and treatment recommendation of our participating international group of surgeons may not reflect practice in specific regions due to geographical differences.

The overall agreement between orthopaedic surgeons on implant choice when treating trochanteric fractures was only 'fair'. This reflects a large, potentially undesirable, variation in treatment among surgeons for a very common fracture. This variation cannot be explained due to misdiagnosis—there is substantial agreement between orthopaedic surgeons for the classification of trochanteric fractures.³⁹ Our study found that surgeons were ten times more likely to select an IMN rather than SHS for A2 trochanteric hip fractures compared to A1 trochanteric hip fractures. This is despite similar results of SHS versus IMN in recently published Level-I evidence studies for A2 fractures,^{1,14,15,21,25,26} including for functional outcome, reoperation rate, or quality of life. When considering A1 and A2 fractures together, our results suggest that a surgeon's country of practice and their familiarity with an implant gained during training are the main drivers of variability in decision-making. In general, variation in clinical decision-making is affected by multiple factors, such as available technology, training, supply of specialists, and financial incentives.⁴⁰

According to our findings, surgeon characteristics were independently associated with implant choice for treatment of A1 and A2 trochanteric hip fractures. Surgeons from the USA were more likely to recommend an IMN compared to surgeons based in Europe or the UK. The geographical variation in treatment, especially the difference in practice between USA and non-USA based surgeons, may be explained by attributed superiority of nailing devices on the basis of factors other than clinical outcome (e.g. biomechanical properties, perceived surgical ease, and payment models).^{10,18,19,32,41} In addition, training of orthopaedic surgeons influenced implant choice. Surgeons who only used IMN devices during orthopaedic training were more likely to recommend an IMN, whereas surgeons who were only taught to use a SHS were less likely to prefer an IMN, compared to surgeons who used both devices during training. Our results are consistent with other studies reporting that training (e.g. fellowship, speciality) of orthopaedic surgeons is associated with treatment and other clinical practice patterns.^{40,42–45} Along those lines, we speculate that industrial suppliers may play a role in the training of orthopaedic surgeons and promote the use of IMN for A1 and A2 trochanteric fractures despite limited evidence of their superiority over SHS.⁴⁶ Additionally, USA-based surgeons may be more receptive of IMN marketing, compared to surgeons in Europe and the UK: among members of the American Academy of Orthopaedic Surgeons, a survey reveals that implant costs do not seem an important factor in decision-making,³² while UK surgeons in the NHS may be more cognizant of the societal burden of healthcare and according to this study seem to be more likely to use the cost-effective SHS.

There is conflicting advice globally. Guidelines from the American Association of Orthopedic Surgeons support the use of an IMN over a SHS to treat A2 and A3 trochanteric fractures

and give equal recommendation to both treatments for A1 fractures.⁴⁷ Current guidance from the National Institute for Health and Care Excellence (NICE) in the UK states that a SHS should be used in preference to an IMN for A1 and A2 trochanteric fractures.⁴⁸ This lack of consensus is likely to explain some of the variation in decision making for A2 fractures. Such differences between regional guidelines may further explain some of the variation in decision-making for A2 trochanteric fractures.

Finally, patient characteristics were not associated with implant choice in our study, although some Level-I studies reported significant increased blood loss when using a SHS compared to IMN,^{16,17} and suggest that in high-risk elderly patients requiring less blood loss a nail should be considered.²² The RCTs by Parker et al^{1,14,21} did not show difference in blood loss and units blood transfused. On the other hand, Whitehouse et al⁴⁹ performed a case-mix adjusted analysis of registry data of patients in England, Wales, and Northern Ireland with trochanteric fractures (including Type A3) and found higher 30-day mortality with the use of IMN. They suggest that SHS should be the preferred choice of implant. The authors discuss that the incidence of thromboembolic events in this frail patient group may be higher when IMN is used and suggest this as the cause of increased mortality.

In conclusion, we found that the overall agreement between orthopaedic surgeons on implant choice for treatment of A1 and A2 trochanteric fractures was fair, reflecting a large variation in treatment of trochanteric hip fractures among orthopaedic surgeons for these relatively common fracture types. According to our findings the choice for the most expensive, but not clinically superior, implant is influenced by surgeon bias (country of practice and training) and fracture characteristics (non-evidence-based attributed superiority of IMN for A2 trochanteric hip fractures). Surgeons' variation on implant choice could be reduced if it was driven by the cost-effectiveness of SHS. In other words, treatment preferences based on current value-based healthcare principles could reduce healthcare costs as well as unwarranted variation in treatment of trochanteric fractures.

Take home message

- There is a large variation in treatment among orthopaedic surgeons for a very common fracture.
- Implant choice is influenced by surgeon bias (country of practice and training) and fracture characteristics (non-evidence-based attributed superiority of intramedullary nailing for A2 trochanteric hip fractures).
- Surgeons' variation on implant choice could be reduced if it was driven by the cost-effectiveness of sliding hip screw.

References

1. Parker MJ. Sliding hip screw versus intramedullary nail for trochanteric hip fractures; a randomised trial of 1000 patients with presentation of results related to fracture stability. *Injury*. 2017;48(12):2762–2767.
2. Marsh JL, Slongo TF, Agel J, et al. Fracture and dislocation classification compendium - 2007: Orthopaedic Trauma Association classification, database and outcomes committee. *J Orthop Trauma*. 2007;21(10 Suppl):1–133.
3. Kregor PJ, Obrebsky WT, Kreder HJ, Swiontkowski MF, Evidence-Based Orthopaedic Trauma Working Group. Unstable pertrochanteric femoral fractures. *J Orthop Trauma*. 2005;19(1):63–66.
4. Haidukewych GJ, Israel TA, Berry DJ. Reverse obliquity fractures of the intertrochanteric region of the femur. *J Bone Joint Surg Am*. 2001;83-A(5):643–650.

5. **Matre K, Havelin LI, Gjertsen J-E, Vinje T, Espehaug B, Fevang JM.** Sliding hip screw versus IM nail in reverse oblique trochanteric and subtrochanteric fractures. A study of 2716 patients in the Norwegian hip fracture register. *Injury*. 2013;44(6):735–742.
6. **Kregor PJ, Obremsky WT, Kreder HJ, Swiontkowski MF.** Unstable pertrochanteric femoral fractures. *J Orthop Trauma*. 2014;28(Suppl 8):S25–S28.
7. **Kaplan K, Miyamoto R, Levine BR, Egol KA, Zuckerman JD.** Surgical management of hip fractures: an evidence-based review of the literature. II: intertrochanteric fractures. *J Am Acad Orthop Surg*. 2008;16(11):665–673.
8. **Schipper IB, Marti RK, van der Werken C.** Unstable trochanteric femoral fractures: extramedullary or intramedullary fixation. review of literature. *Injury*. 2004;35(2):142–151.
9. **Lorich DG, Geller DS, Nielson JH.** Osteoporotic pertrochanteric hip fractures: management and current controversies. *Instr Course Lect*. 2004;53:441–454.
10. **Anglen JO, Weinstein JN, American Board of Orthopaedic Surgery Research Committee.** Nail or plate fixation of intertrochanteric hip fractures: changing pattern of practice. A review of the American Board of orthopaedic surgery database. *J Bone Joint Surg Am*. 2008;90-A(4):700–707.
11. **Rogmark C, Spetz C-L, Garellick G.** More intramedullary nails and arthroplasties for treatment of hip fractures in Sweden. *Acta Orthop*. 2010;81(5):588–592.
12. **Knobe M, Gradl G, Ladenburger A, Tarkin IS, Pape H-C.** Unstable intertrochanteric femur fractures: is there a consensus on definition and treatment in Germany? *Clin Orthop Relat Res*. 2013;471(9):2831–2840.
13. **Murray DJ, Foley G, Chougale A.** Current practice in the treatment of AO type 31-A2 hip fractures: does sub-specialty and experience of surgeon determine type of fixation? *Surgeon*. 2014;12(4):206–209.
14. **Parker MJ, Bowers TR, Pryor GA.** Sliding hip screw versus the Targon PF nail in the treatment of trochanteric fractures of the hip: a randomised trial of 600 fractures. *J Bone Joint Surg Br*. 2012;94-B(3):391–397.
15. **Barton TM, Gleeson R, Topliss C, Greenwood R, Harries WJ, Chessier TJS.** A comparison of the long gamma nail with the sliding hip screw for the treatment of AO/OTA 31-A2 fractures of the proximal part of the femur: a prospective randomized trial. *J Bone Joint Surg Am*. 2010;92-A(4):792–798.
16. **Little NJ, Verma V, Fernando C, Elliott DS, Khaleel A.** A prospective trial comparing the Holland nail with the dynamic hip screw in the treatment of intertrochanteric fractures of the hip. *J Bone Joint Surg Br*. 2008;90-B(8):1073–1078.
17. **Matre K, Vinje T, Havelin LI, et al.** TRIGEN INTERTAN intramedullary nail versus sliding hip screw: a prospective, randomized multicenter study on pain, function, and complications in 684 patients with an intertrochanteric or subtrochanteric fracture and one year of follow-up. *J Bone Joint Surg Am*. 2013;95-A(3):200–208.
18. **Forte ML, Virnig BA, Kane RL, et al.** Geographic variation in device use for intertrochanteric hip fractures. *J Bone Joint Surg Am*. 2008;90-A(4):691–699.
19. **Forte ML, Virnig BA, Eberly LE, et al.** Provider factors associated with intramedullary nail use for intertrochanteric hip fractures. *J Bone Joint Surg Am*. 2010;92-A(5):1105–1114.
20. **Bernstein J, Ahn J.** Provider factors associated with intramedullary nail use for intertrochanteric hip fractures. *J Bone Joint Surg Am*. 2010;92-A(15).
21. **Parker MJ, Cawley S.** Sliding hip screw versus the Targon PFT nail for trochanteric hip fractures: a randomised trial of 400 patients. *Bone Joint J*. 2017;99-B(9):1210–1215.
22. **Singh NK, Sharma V, Trikha V, et al.** Is PFNA-II a better implant for stable intertrochanteric fractures in elderly population? A prospective randomized study. *J Clin Orthop Trauma*. 2019;10(Suppl 1):S71–S76.
23. **Kouvidis G, Sakellariou VI, Mavrogenis AF, et al.** Dual lag screw cephalomedullary nail versus the classic sliding hip screw for the stabilization of intertrochanteric fractures. A prospective randomized study. *Strategies Trauma Limb Reconstr*. 2012;7(3):155–162.
24. **Guerra MTE, Pasqualin S, Souza MP, Lenz R.** Functional recovery of elderly patients with surgically-treated intertrochanteric fractures: preliminary results of a randomised trial comparing the dynamic hip screw and proximal femoral nail techniques. *Injury*. 2014;45(Suppl 5):S26–S31.
25. **Reindl R, Harvey EJ, Berry GK, Rahme E, Canadian Orthopaedic Trauma Society (COTS).** Intramedullary versus extramedullary fixation for unstable Intertrochanteric fractures: a prospective randomized controlled trial. *J Bone Joint Surg Am*. 2015;97-A(23):1905–1912.
26. **Sanders D, Bryant D, Tieszer C, 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*. 2017;31(1):1–8.
27. **Swart E, Makhni EC, Macaulay W, Rosenwasser MP, Bozic KJ.** Cost-Effectiveness analysis of fixation options for intertrochanteric hip fractures. *J Bone Joint Surg Am*. 2014;96-A(19):1612–1620.
28. **Parker MJ, Handoll HH.** Gamma and other cephalocondylic intramedullary nails versus extramedullary implants for extracapsular hip fractures in adults. *Cochrane Database Syst Rev*. 2010;9:CD000093.
29. **Matre K, Havelin LI, Gjertsen J-E, Espehaug B, Fevang JM.** Intramedullary nails result in more reoperations than sliding hip screws in two-part intertrochanteric fractures. *Clin Orthop Relat Res*. 2013;471(4):1379–1386.
30. **Norris R, Bhattacharjee D, Parker MJ.** Occurrence of secondary fracture around intramedullary nails used for trochanteric hip fractures: a systematic review of 13,568 patients. *Injury*. 2012;43(6):706–711.
31. **Bhandari M, Schemitsch E, Jönsson A, Zlowodzki M, Haidukewych GJ.** Gamma nails revisited: gamma nails versus compression hip screws in the management of intertrochanteric fractures of the hip: a meta-analysis. *J Orthop Trauma*. 2009;23(6):460–464.
32. **Niu E, Yang A, Harris AHS, Bishop J.** Which fixation device is preferred for surgical treatment of Intertrochanteric hip fractures in the United States? A survey of orthopaedic surgeons. *Clin Orthop Relat Res*. 2015;473(11):3647–3655.
33. **Gebhard F.** What implant for fixation of proximal femoral fractures? *A European Survey of Surgeons' Preferred Choice*. 15th European Federation of National Associations of Orthopaedics and Traumatology. 2014.
34. **Saklad M.** Grading of patients for surgical procedures. *Anesthesiology*. 1941;2(3):281–284.
35. **Walter SD, Eliasziw M, Donner A.** Sample size and optimal designs for reliability studies. *Stat Med*. 1998;17(1):101–110.
36. **Siegel S, Castellan JN.** *Nonparametric statistics for the behavioral sciences*. New York, New York, USA: McGraw-Hill, 1988.
37. **Landis JR, Koch GG.** An application of hierarchical kappa-type statistics in the assessment of majority agreement among multiple observers. *Biometrics*. 1977;33(2):363–374.
38. **Harrell FE.** *Regression modeling strategies*. New York, New York, USA: Springer, 2001.
39. **Crijns TJ, Janssen SJ, Davis JT, Ring D, Sanchez HB, Science of Variation Group.** Reliability of the classification of proximal femur fractures: does clinical experience matter? *Injury*. 2018;49(4):819–823.
40. **Birkmeyer JD, Reames BN, McCulloch P, Carr AJ, Campbell WB, Wennberg JE.** Understanding of regional variation in the use of surgery. *Lancet*. 2013;382(9898):1121–1129.
41. **Court-Brown C, McQueen M, Swiontkowski MF, Ring D, Friedman SM, Duckworth AD.** *Musculoskeletal trauma in the elderly*. Boca Raton, Florida, USA: CRC Press, 2016.
42. **Lubelski D, Williams SK, O'Rourke C, et al.** Differences in the surgical treatment of lower back pain among spine surgeons in the United States. *Spine*. 2016;41(11):978–986.
43. **Lubelski D, Alentado VJ, Williams SK, et al.** Variability in surgical treatment of spondylolisthesis among spine surgeons. *World Neurosurg*. 2018;111:e564–e572.
44. **Irwin ZN, Hilibrand A, Gustavel M, et al.** Variation in surgical decision making for degenerative spinal disorders. Part I: lumbar spine. *Spine*. 2005;30(19):2208–2213.
45. **Bederman SS, Kreder HJ, Weller I, Finkelstein JA, Ford MH, Yee AJM.** The who, what and when of surgery for the degenerative lumbar spine: a population-based study of surgeon factors, surgical procedures, recent trends and reoperation rates. *Can J Surg*. 2009;52(4):283–290.
46. **Leopold SS.** Editorial: is it time to end Surgeon-Industry consulting? *Clin Orthop Relat Res*. 2015;473(9):2727–2730.
47. **No authors listed.** Guidelines. management of hip fractures in the elderly. American Academy of Orthopaedic Surgeons. 2014. <https://www.aaos.org/CustomTemplates/Content.aspx?id=6395&ssopc=1> (date last accessed 3 February 2021).
48. **No authors listed.** Quality statement 4: trochanteric fracture. 2016. National Institute for Health and Care Excellence (NICE). <https://www.nice.org.uk/guidance/qs16/chapter/Quality-statement-4-Trochanteric-fracture> (date last accessed 3 February 2021).
49. **Whitehouse MR, Berstock JR, Kelly MB, et al.** Higher 30-day mortality associated with the use of intramedullary nails compared with sliding hip screws for the treatment of trochanteric hip fractures: a prospective national registry study. *Bone Joint J*. 2019;101-B(1):83–91.

Author information:

J. J. Mellema, MD, Orthopaedic Surgery Resident
 S. Janssen, MD, PhD, Orthopaedic Surgery Resident
 Department of Orthopaedic Surgery, Academic Medical Center, University of Amsterdam, Amsterdam, The Netherlands.

T. Schouten, MD, Orthopaedic Surgery Resident, Department of Orthopaedic Surgery, HagaZiekenhuis, The Hague, The Netherlands.

D. Haverkamp, MD PhD, Orthopaedic Surgeon, Xpert Orthopedie, Amsterdam, The Netherlands.

M. P. J. van den Bekerom, MD, PhD, Orthopaedic Surgeon, Professor of Orthopaedic Surgery, Department of Orthopaedic Surgery, Onze Lieve Vrouwe Gasthuis, Amsterdam, The Netherlands.

D. Ring, MD PhD, Orthopaedic Surgeon, Professor of Surgery and Psychiatry, Department of Surgery and Perioperative Care, Dell Medical School, The University of Texas at Austin, Austin, Texas, USA.

J. N. Doornberg, MD PhD, Orthopaedic Surgeon, Professor of Orthopaedic Surgery, Department of Orthopaedic Surgery, Groningen University Medical Centre, Groningen, The Netherlands.

Author contributions:

J. J. Mellema: Designed the study, Analyzed the data, Wrote the draft.

S. Janssen: Analyzed the data, Wrote the draft.

T. Schouten: Assembled the data, Wrote the draft.

D. Haverkamp: Designed the study, Wrote the draft.

M. P. J. van den Bekerom: Designed the study, Wrote the draft.

D. Ring: Designed the study, Wrote the draft.

J. N. Doornberg: Designed the study, Assembled the data, Analyzed the data, Wrote the draft.

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