Comparison of Intramedullary Nails in the Treatment of Trochanteric and Subtrochanteric Fractures

An Observational Study of 13,232 Fractures in the Norwegian Hip Fracture Register

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Background: Intramedullary nails are commonly used in the treatment of trochanteric and subtrochanteric fractures. We aimed to compare intramedullary nails in widespread use in Norway on the basis of reoperation risk.

Methods: We assessed data from 13,232 trochanteric or subtrochanteric fractures treated with an intramedullary nail and registered in the Norwegian Hip Fracture Register between 2007 and 2019. The primary outcome measure was the risk of reoperation for various types of short and long intramedullary nails. Secondly, we compared risk of reoperation for the selected nails with respect to fracture type (AO/OTA type A1, A2, A3, and subtrochanteric fractures). Cox regression analysis adjusted for sex, age, and American Society of Anesthesiologists class was used to estimate hazard rate ratios (HRRs) for reoperation.

Results: The mean patient age was 82.9 years, and 72.8% of the nails were used in the treatment of female patients. We included 8,283 short and 4,949 long nails. A1 fractures accounted for 29.8%, A2 for 40.6%, A3 for 7.2%, and subtrochanteric fractures for 22.4%. When comparing short nails regardless of fracture type, the TRIGEN INTERTAN had an increased risk of reoperation at 1 year (HRR, 1.31 [95% confidence interval (CI), 1.03 to 1.66]; p = 0.028) and 3 years (HRR, 1.31 [95% CI, 1.07 to 1.61]; p = 0.011) postoperatively compared with the Gamma3. For individual fracture types, we found no significant differences in reoperation risk between the various types of short nails. When comparing long nails, the TRIGEN TAN/FAN had an increased risk of reoperation at 1 year (HRR, 3.05 [95% CI, 2.10 to 4.42]; p < 0.001) and 3 years (HRR, 2.54 [95% CI, 1.82 to 3.54]; p < 0.001) postoperatively compared with the long Gamma3.

Conclusions: This study may indicate a slightly increased risk of reoperation for the short TRIGEN INTERTAN compared with other short nails in widespread use in Norway. In analyses of long nails, the TRIGEN TAN/FAN nail was associated with a higher risk of reoperation in the treatment of trochanteric and subtrochanteric fractures.

Level of Evidence: Therapeutic Level III. See Instructions for Authors for a complete description of levels of evidence.

Intramedullary nails have a long tradition in the treatment of trochanteric and subtrochanteric fractures but historically have been associated with a substantial risk of peri-implant fractures[1]. Modern generations of nails seem to have reduced this risk[1,2], and intramedullary nails are now recommended for unstable trochanteric and/or subtrochanteric fractures in national and international guidelines[3-5]. Previous studies that have compared the outcomes of various nail designs are small and rarely compared >2 different designs[6-10]. Few examples of systematic registration of implant performance for fracture-related implants exist[11]. The Norwegian Hip Fracture Register (NHFR) contains details regarding all intramedullary nails used in the treatment of hip fractures in Norway. In this study, we analyzed NHFR data from 2007 to 2019 and compared risk of reoperation between intramedullary nails used to treat trochanteric and subtrochanteric fractures. The secondary aim was to evaluate risk of reoperation for the various types of short and long nails with respect to fracture type (AO/OTA type A1, A2, A3, and subtrochanteric fractures).

Materials and Methods

Hip fractures have been prospectively registered on a national level in Norway using the NHFR since 2005. The completeness of the NHFR is currently 86% for primary osteosyntheses and 72% for reoperations after osteosyntheses[12]. Using a

Disclosure: The **Disclosure of Potential Conflicts of Interest** forms are provided with the online version of the article (http://links.lww.com/JBJS/H604).

1-page form, the surgeon provides details regarding the individual patient, fracture, operation, and—since 2011—surgeon experience. Surgeon experience is quantified as ≥3 or <3 years of experience in the surgical treatment of hip fractures; further detail regarding training is not specified. Trochanteric fractures are classified as type A1, A2, A3, or subtrochanteric, as described by the AO/OTA classification system[13]. Intraoperative complications, including technical problems and notable hemorrhage, are also registered.

In this study, all trochanteric or subtrochanteric fractures treated with a short or long intramedullary nail and reported to the NHFR between January 1, 2007, and December 31, 2019, were eligible for inclusion (Fig. 1). Fractures in patients <60 years of age, pathological fractures (other than from osteoporosis), registry records missing data (American Society of Anesthesiologists [ASA] classification, fracture classification, type of implant), and fractures treated with a nail not in widespread use during the study period (n < 150) were excluded. Ultimately, 8,283 short nails and 4,949 long nails were included (Fig. 1).

The number of and reasons for reoperation were reported in the registry. In the NHFR, >1 cause of reoperation may be reported. The following hierarchy was chosen to identify the more severe cause in each case and to ensure that each reoperation was only counted once: infection, peri-implant fracture, hardware failure, cut-out, nonunion, unspecified sequelae (treated with total hip arthroplasty [THA] and registered in the Norwegian Arthroplasty Register), pain alone, and other. Reoperations were reported by the operating surgeon on a 1-page form similar to that used for the primary operations. Time of death is collected from the Norwegian National Population Register.

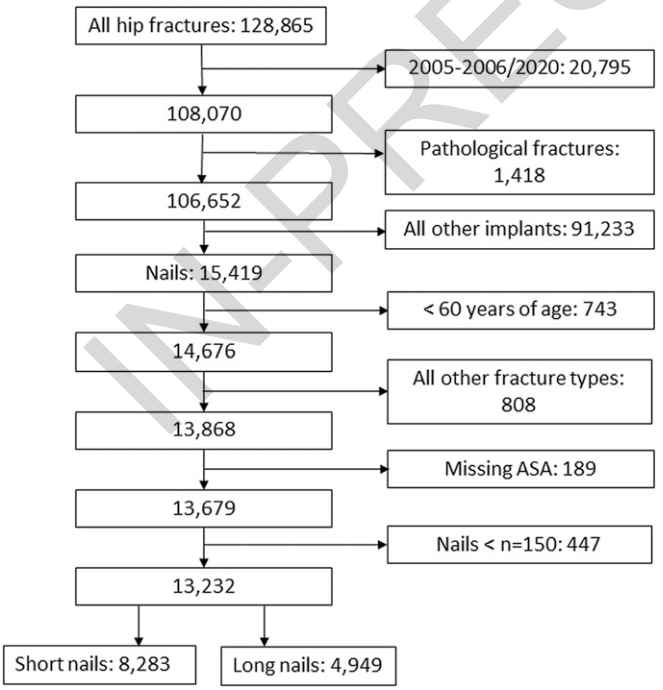

Fig. 1
Flowchart showing inclusions and exclusions.

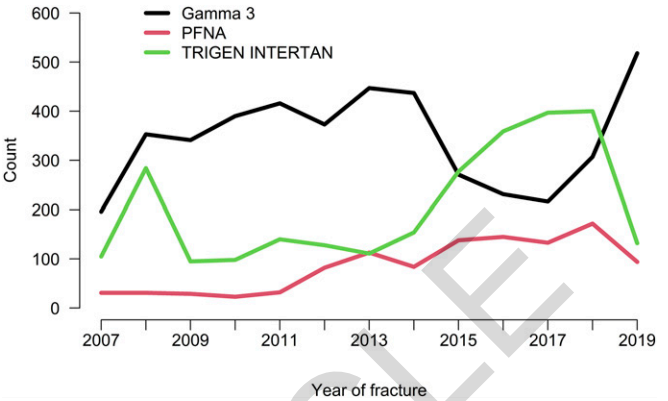

Fig. 2-A

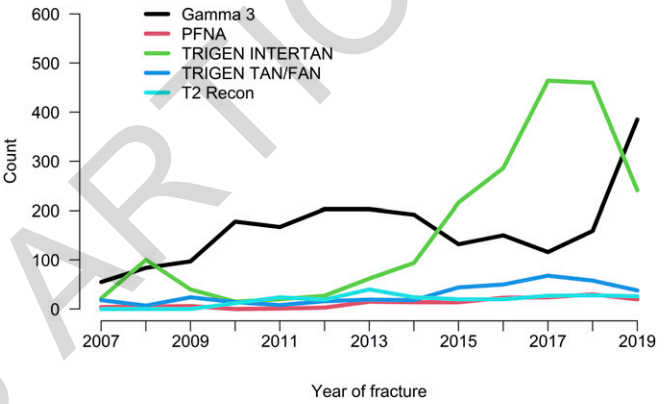

Fig. 2-B

Figs. 2-A and 2-B Annual volume of selected short nails (**Fig. 2-A**) and long nails (**Fig. 2-B**).

Statistical Analysis

Short and long nails were analyzed separately. Baseline data were analyzed using the Pearson chi-square test for categorical variables and analysis of variance (ANOVA) for continuous variables. The median and interquartile range (IQR) were chosen to describe the duration of surgery because of the extreme outliers, which may represent errors in the registry reporting process. For reoperation risk, hazard rate ratios (HRRs) with 95% confidence intervals (CIs) were calculated using Cox regression analysis, adjusted for age, sex, and ASA classification. Separate analyses of reoperation risk were conducted for short and long nails as well as for the different fracture types. The Gamma3 (Stryker) was the most common nail in the analyses of both short and long nails and was used as the reference. The proportional hazard assumption was tested visually using log minus log plots and was not met when comparing all short or long nails. Accordingly, separate analyses were performed comparing only short Gamma3 (reference) with short TRIGEN INTERTAN (Smith & Nephew) nails and only long Gamma3 (reference) with TRIGEN TAN/FAN (Smith & Nephew) nails. For these analyses, the proportional hazard assumption was fulfilled.

Patients were followed from the primary operation to reoperation, death, or the end of the study. The end of the study

was set at December 31, 2019, to allow minimum 1-year follow-up for all patients. The significance level was set at 0.05. Statistical analyses were performed using IBM SPSS Statistics (version 26; IBM) and the R statistical package (R Foundation for Statistical Computing).

The STROBE (STrengthening the Reporting of OBservational studies in Epidemiology) guidelines were followed[14].

Source of Funding

The Norwegian Hip Fracture Register is funded by the Western Norway Regional Health Authority.

Results

The mean patient age was 82.9 years, and 72.8% of the nails were used in the treatment of female patients. We identified 3 brands of short nails and 5 brands of long nails (n ≥150) in widespread use in Norway during the study period (Figs. 2-A and 2-B). Short and long versions of each brand were considered separate entities, as fracture-type distribution varied between short and long nails.

Short Nails

Of the 8,283 short nails, 4,496 were Gamma3 (Stryker), 1,107 were PFNA (Proximal Femoral Nail Antirotation; DePuy Synthes), and 2,680 were TRIGEN INTERTAN (Intertrochanteric Antegrade Nail; Smith & Nephew) (Fig. 2-A).

Baseline Data

Baseline data are presented in Table I. The mean patient age was 83.2 years. Of the 8,283 short nails, 71.9% were used in female patients and 91.2% were in patients classified as ASA 2 or 3. With respect to fracture type, 43.9% of the nails were used for A1 fractures, 46.9% for A2 fractures, 4.4% for A3 fractures, and 4.9% for subtrochanteric fractures.

Perioperative Data

Perioperative data are presented in Table II. Most patients had spinal anesthesia (86.2%). The median duration of surgery was 46 minutes (IQR, 35 to 60 minutes), with no significant difference between the nail brands. Technical problems and hemorrhage were the 2 most prevalent

TABLE I Baseline Data: Short Nails

	Total	Gamma3	PFNA	TRIGEN INTERTAN
Total no. of nails	8,283	4,496	1,107	2,680
Female *(no. [%])*	5,953 (71.9)	3,242 (72.1)	816 (73.7)	1,895 (70.7)
Age* *(yr)*	83.2 ± 8.5	83.2 ± 8.4	83.1 ± 8.3	83.3 ± 8.6
Age group *(no. [%])*				
60-74 yr	1,351 (16.3)	719 (16.0)	184 (16.6)	448 (16.7)
75-79 yr	1,044 (12.6)	571 (12.7)	129 (11.7)	344 (12.8)
80-84 yr	1,705 (20.6)	949 (21.1)	240 (21.7)	516 (19.3)
85-89 yr	2,158 (26.1)	1,176 (26.2)	285 (25.7)	697 (26.0)
≥90 yr	2,025 (24.4)	1,081 (24.0)	269 (24.3)	675 (25.2)
ASA class *(no. [%])*				
1	173 (2.1)	82 (1.8)	23 (2.1)	68 (2.5)
2	2,685 (32.4)	1,397 (31.1)	352 (31.8)	936 (34.9)
3	4,867 (58.8)	2,688 (59.8)	662 (59.8)	1,517 (56.6)
4	558 (6.7)	329 (7.3)	70 (6.3)	159 (5.9)
Cognitive impairment *(no. [%])*				
Yes	2,130 (25.7)	1,142 (25.4)	275 (24.8)	713 (26.6)
No	5,135 (62.0)	2,789 (62.0)	694 (62.7)	1,652 (61.6)
Uncertain	853 (10.3)	475 (10.6)	107 (9.7)	271 (10.1)
Missing	165 (2.0)	90 (2.0)	31 (2.8)	44 (1.6)
Fracture type *(no. [%])*				
AO/OTA A1	3,633 (43.9)	2,053 (45.7)	322 (29.1)	1,258 (46.9)
AO/OTA A2	3,882 (46.9)	2,126 (47.3)	549 (49.6)	1,207 (45.0)
AO/OTA A3	361 (4.4)	146 (3.2)	90 (8.1)	125 (4.7)
Subtrochanteric	407 (4.9)	171 (3.8)	146 (13.2)	90 (3.4)
No. of hospitals used in	42	32	13	26

*The values are given as the mean and standard deviation.

TABLE II Perioperative Data: Short Nails

	Total	Gamma 3	PFNA	TRIGEN INTERTAN
Total no. of nails	8,283	4,496	1,107	2,680
Anesthesia method *(no. [%])*				
General	841 (10.2)	424 (9.4)	100 (9.0)	317 (11.8)
Spinal	7,138 (86.2)	3,910 (87.0)	966 (87.3)	2,262 (84.4)
Other	208 (2.5)	109 (2.4)	32 (2.9)	67 (2.5)
Missing	96 (1.2)	53 (1.2)	9 (0.8)	34(1.3)
Duration of surgery* *(min)*	46 [35-60]	45 [33-60]	46 [31-70]	50 [39-67]
Surgeon experience† *(no. [%])*				
<3 years	1,041 (17.2)	637 (21.0)	93 (9.5)	311 (15.4)
≥3 years	4,739 (78.5)	2,240 (73.7)	856 (87.4)	1,643 (81.4)
Missing	258 (4.3)	163 (5.4)	30 (3.1)	65 (3.2)
Intraoperative complications *(no. [%])*				
Yes	250 (3.0)	115 (2.6)	30 (2.7)	105 (3.9)
No	7,734 (93.4)	4,233 (94.2)	1,027 (92.8)	2,474 (92.3)
Missing	299 (3.6)	148 (3.3)	50 (4.5)	101 (3.8)
Prophylactic antibiotics *(no. [%])*				
Yes	7,878 (95.1)	4,370 (97.2)	1,099 (99.3)	2,409 (89.9)
No	348 (4.2)	104 (2.3)	4 (0.4)	240 (9.0)
Missing	57 (0.7)	22 (0.5)	4 (0.4)	31 (1.2)

*The values are given as the median, with the interquartile range in square brackets. †Surgeon experience has only been registered since 2011.

intraoperative complications for all short nails (54.2% and 9.1% of all intraoperative complications, respectively [n = 250]).

Reoperations

The number of and reasons for reoperations for each nail brand are listed in Tables III and IV. The TRIGEN INTERTAN demonstrated a higher risk of reoperation at 1 year (HRR, 1.31 [95% CI, 1.03 to 1.66]; p = 0.028) and 3 years (HRR, 1.31 [95% CI, 1.07 to 1.61]; p = 0.011) compared with the Gamma3. As the proportional hazard assumption was not met when comparing all short nails, the TRIGEN INTERTAN and Gamma3 were compared in a separate analysis, confirming a significant difference at 1 year (HRR, 1.309 [95% CI, 1.029 to 1.664]; p = 0.028) and 3 years (HRR, 1.315 [95% CI, 1.068 to1.619]; p = 0.010) postoperatively. There were no differences in the overall risk of reoperation between the short-nail brands when analyzed by fracture type (see Appendix Supplementary Table I). Survival curves for the different nail brands are shown in Figure 3-A. Hardware failure was the most prevalent cause of reoperation among all short-nail brands (Table IV).

TABLE III Reoperations at 1 and 3 Years: Short Nails*

	Total No. of Nails	Reoperations *(no. [%])*	HRR	95% CI	P Value
1 yr					
Gamma 3	4,496	153 (3.4)	1 (ref.)		
PFNA	1,107	35 (3.2)	0.910†	0.631-1.314	0.616
TRIGEN INTERTAN	2,680	119 (4.4)	1.308†	1.029-1.663	0.028
3 yr					
Gamma 3	4,496	201 (4.5)	1 (ref.)		
PFNA	1,107	56 (5.1)	1.094†	0.814-1.472	0.550
TRIGEN INTERTAN	2,680	160 (6.0)	1.311†	1.065-1.615	0.011

*Cox analysis adjusted for sex, age, and ASA class. The Gamma3 nail is the reference. †Proportional hazard assumption not fulfilled.

TABLE IV Reasons for Reoperation at 1 year: Short Nails*

	Gamma 3, N=4,496 *(no. [%])*	PFNA, N=1,107 *(no. [%])*	TRIGEN INTERTAN, N=2,680 *(no. [%])*
Total	153 (3.4)	35 (3.2)	119 (4.4)
Infection	3 (0.1)	7 (0.6)	9 (0.3)
Peri-implant fracture	32 (0.7)	8 (0.7)	15 (0.6)
Hardware failure	33 (0.7)	11 (1.0)	37 (1.4)
Cut-out	17 (0.4)	1 (0.1)	5 (0.2)
Nonunion	4 (0.1)	0 (0.0)	11 (0.4)
Unspecified sequelae (THA)†	47 (1.0)	5 (0.5)	26 (1.0)
Pain alone	5 (0.1)	3 (0.3)	5 (0.2)
Other‡	12 (0.3)	0 (0.0)	11 (0.4)

*Causes organized hierarchically; only 1 cause registered per patient. †Operation involving THA recorded in the Norwegian Arthroplasty Register. ‡All other reasons for reoperations except pain alone.

Long Nails

Of the 4,949 long nails, 2,121 were Gamma3 (Stryker), 159 were PFNA (Proximal Femoral Nail Antirotation; DePuy Synthes), 2,047 were TRIGEN INTERTAN (Intertrochanteric Antegrade Nail; Smith & Nephew), 382 were TRIGEN TAN/FAN (Trochanteric and Femoral Antegrade Nails; Smith & Nephew), and 240 were T2 Recon (Stryker) (Fig. 2-B).

Baseline Data

Baseline data are presented in Table V. The mean patient age was 82.6 years. Of the 4,949 long nails, 74.5% were used in female patients and 90.3% were in patients classified as ASA 2 or 3. In terms of fracture type, 6.1% of the nails were used for A1 fractures, 29.7% for A2 fractures, 11.9% for A3 fractures, and 52.3% for subtrochanteric fractures.

Perioperative Data

Perioperative data are presented in Table VI. Most patients had spinal anesthesia (82.4%). The median duration of surgery was 85 minutes (IQR, 61 to 115 minutes).

Reoperations

The TRIGEN TAN/FAN had a significantly higher risk of reoperation at 1 year (HRR, 3.05 [95% CI, 2.10 to 4.42]; $p < 0.001$) and 3 years (HRR, 2.54 [95% CI, 1.82 to 3.54]; $p < 0.001$) compared with the long Gamma3 (Table VII). As the proportional hazard assumption was not met when comparing all long nails, the TRIGEN TAN/FAN and long Gamma3 were compared in a separate analysis, confirming a significant difference at 1 year (HRR, 2.923 [95% CI, 2.011 to 4.250]; $p < 0.001$) and 3 years (HRR, 2.462 [95% CI, 1.763 to 3.439]; $p < 0.001$) postoperatively. The risk of reoperation was significantly higher for the TRIGEN TAN/FAN nail for all fracture types except for AO/OTA A3 (see Appendix Supplementary Table II). Survival curves for the long-nail brands are shown in Figure 3-B. Hardware failure was the most prevalent cause of reoperation among all long-nail brands (Table VIII).

Discussion

In this national registry-based retrospective cohort study, our findings indicate that nail type may influence the risk of reoperation after trochanteric and subtrochanteric fractures. The use of a short TRIGEN INTERTAN nail was associated with an increased reoperation risk when analyzing all fracture types combined, but there were no differences between the nail brands when analyzing individual fracture types. The majority of reoperations occurred when the short TRIGEN INTERTAN was used in A3 and subtrochanteric fractures. When comparing long nails, we found an increased risk of reoperation with the use of a long TRIGEN TAN/FAN nail compared with the long Gamma3, which persisted in subanalyses of A1, A2, and subtrochanteric fractures. Hardware failure was the most common cause of reoperation for short and long nails alike, in contrast to previous studies, which identified cut-out as the major cause of failure[15,16]. This discrepancy is likely caused by the hierarchy for reoperations in our study. Because of this

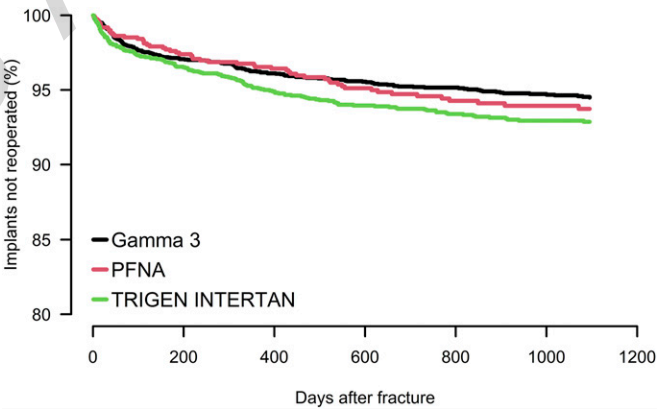

Fig. 3-A

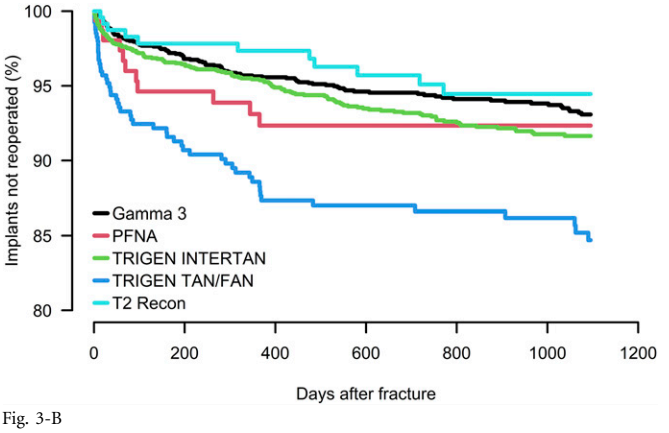

Fig. 3-B

Figs. 3-A and 3-B Three-year survival curves for short nails (**Fig. 3-A**) and long nails (**Fig. 3-B**), adjusted for sex, age, and ASA classification.

TABLE V Baseline Data: Long Nails

	Total	Gamma3	PFNA	TRIGEN INTERTAN	TRIGEN TAN/FAN	T2 Recon
Total no. of nails	4,949	2,121	159	2,047	382	240
Female *(no. [%])*	3,689 (74.5)	1,596 (75.2)	121 (76.1)	1,526 (74.5)	271 (70.9)	175 (72.9)
Age* *(yr)*	82.6 ± 9.0	82.8 ± 8.8	83.2 ± 8.6	82.7 ± 8.7	80.8 ±9.9	81.7 ± 9.9
Age group *(no. [%])*						
60-74 yr	981 (19.8)	394 (18.6)	28 (17.6)	385 (18.8)	117 (30.6)	57 (23.8)
75-79 yr	625 (12.6)	273 (12.9)	20 (12.6)	270 (13.2)	36 (9.4)	26 (10.8)
80-84 yr	918 (18.5)	414 (19.5)	33 (20.8)	374 (18.3)	58 (15.2)	39 (16.3)
85-89 yr	1,271 (25.7)	529 (24.9)	38 (23.9)	547 (26.7)	93 (24.3)	64 (26.7)
≥90 yr	1,154 (23.3)	511 (24.1)	40 (25.2)	471 (23.0)	78 (20.4)	54 (22.5)
ASA class *(no. [%])*						
ASA 1	112 (2.3)	51 (2.4)	2 (1.3)	41 (2.0)	12 (3.1)	6 (2.5)
ASA 2	1,609 (32.5)	685 (32.3)	44 (27.7)	683 (33.4)	132 (34.6)	65 (27.1)
ASA 3	2,861 (57.8)	1,229 (57.9)	100 (62.9)	1,183 (57.8)	205 (53.7)	144 (60.0)
ASA 4	367 (7.4)	156 (7.4)	13 (8.2)	140 (6.8)	33 (8.6)	25 (10.4)
Cognitive impairment *(no. [%])*						
Yes	1,135 (22.9)	472 (22.3)	36 (22.6)	495 (24.2)	82 (21.5)	50 (20.8)
No	3,283 (66.3)	1,420 (66.9)	103 (64.8)	1,334 (65.2)	256 (67.0)	170 (70.8)
Uncertain	423 (8.5)	186 (8.8)	9 (5.7)	172 (8.4)	38 (9.9)	18 (7.5)
Missing	108 (2.2)	43 (2.0)	11 (6.9)	46 (2.2)	6 (1.6)	2 (0.8)
Fracture type *(no. [%])*						
AO/OTA A1	304 (6.1)	134 (6.3)	12 (7.5)	140 (6.8)	17 (4.5)	1 (0.4)
AO/OTA A2	1,469 (29.7)	656 (30.9)	26 (16.4)	707 (34.5)	60 (15.7)	20 (8.3)
AO/OTA A3	589 (11.9)	190 (9.0)	8 (5.0)	298 (14.6)	40 (10.5)	53 (22.1)
Subtrochanteric	2,587 (52.3)	1,141 (53.8)	113 (71.1)	902 (44.1)	265 (69.4)	166 (69.2)
No. of hospitals used in	47	31	10	25	29	7

*The values are given as the mean and standard deviation.

hierarchy, cut-out may have been registered in addition to hardware failure but not registered as the main cause of reoperation.

Several studies have compared intramedullary nails and sliding hip screws[17,18], 2 different nail designs[19-22], or short and long nails[21,23-29]. The current study is, as far as we know, the first national observational study comparing several nail designs with regard to reoperation risk. There is an ongoing discussion regarding the possible benefit of a long nail in the treatment of unstable intertrochanteric and subtrochanteric fractures. In the American Academy of Orthopaedic Surgeons (AAOS) and National Institute for Health and Care Excellence (NICE) guidelines, no specification of nail length is given, whereas the Norwegian national guidelines recommend a long nail[3,4,30,31]. We did find a slightly increased reoperation risk with the use of the short TRIGEN INTERTAN in unstable fracture patterns, inspiring further research into the possible benefits of a long versus short nail in these cases. A recent study from the Danish Multidisciplinary Hip Fracture Registry also indicates a benefit of long nails in unstable fractures[32].

Adequate fracture reduction and correct positioning of the lag screw are important factors in obtaining a good result regardless of the implant chosen[23,33,34]. Comparisons of nail designs, including a lag screw versus helical blade, and single versus double lag screw, have been performed to investigate risk of reoperation[23,24], but no design has been clearly demonstrated to be superior. The helical blade design was developed to reduce risk of cut-out by increasing bone density around the blade. In our study, the nail brands providing a helical blade (short and long PFNA) had risk of reoperation comparable to the other brands. Double lag screws have been introduced to some nail designs to potentially reduce the risk of rotational instability, fracture collapse, and failure, but there is no definitive clinical evidence suggesting superior results[35,36]. In our study, the long TRIGEN TAN/FAN and the long T2 Recon nail provide double lag screws. The short and long TRIGEN INTERTAN nails provide integrated lag screws. We did not find any significant benefit to either design. On the contrary, when analyzing all fracture types combined, the short TRIGEN INTERTAN and the long TRIGEN TAN/FAN had a higher

TABLE VI Perioperative Data: Long Nails

	Total	Gamma3	PFNA	TRIGEN INTERTAN	TRIGEN TAN/FAN	T2 Recon
Total no. of nails	4,949	2,121	159	2,047	382	240
Anesthesia method *(no. [%])*						
General	647 (13.1)	190 (9.0)	16 (10.1)	343 (16.8)	77 (20.2)	21 (8.8)
Spinal	4,077 (82.4)	1,827 (86.1)	131 (82.4)	1,628 (79.5)	290 (75.9)	201 (83.8)
Other	184 (3.7)	83 (3.9)	11 (6.9)	66 (3.2)	10 (2.6)	14 (5.8)
Missing	41 (0.8)	21 (1.0)	1 (0.6)	10 (0.5)	5 (1.3)	4 (1.7)
Duration of surgery* *(min)*	85 [61-115]	78 [60-104]	84 [60-120]	86 [65-113]	100 [80-130]	116 [81-145]
Surgeon experience† *(no. [%])*						
<3 years	347 (8.4)	218 (13.5)	5 (3.5)	111 (6.0)	8 (2.5)	5 (2.3)
≥3 years	3,645 (87.9)	1,314 (81.6)	133 (92.4)	1,699 (91.3)	294 (93.0)	205 (94.5)
Missing	155 (3.7)	78 (4.8)	6 (4.2)	50 (2.7)	14 (4.4)	7 (3.2)
Intraoperative complications *(no. [%])*						
No	4,552 (92.0)	1,945 (91.7)	145 (91.2)	1,905 (93.1)	343 (89.8)	214 (89.2)
Yes	232 (4.7)	94 (4.4)	4 (2.5)	88 (4.3)	27 (7.1)	19 (7.9)
Missing	165 (3.3)	82 (3.9)	10 (6.3)	54 (2.6)	12 (3.1)	7 (2.9)
Prophylactic antibiotics *(no. [%])*						
Yes	4,882 (98.6)	2,097 (98.9)	158 (99.4)	2,022 (98.8)	370 (96.9)	235 (97.9)
No	50 (1.0)	16 (0.8)	0 (0.0)	21 (1.0)	9 (2.4)	4 (1.7)
Missing	17 (0.3)	8 (0.4)	1 (0.6)	4 (0.2)	3 (0.8)	1 (0.4)

*The values are given as the median, with the interquartile range in square brackets. †Surgeon experience has only been registered since 2011.

risk of reoperation. Even though the differences in subanalyses of fracture types did not reach significance, there was a tendency toward a higher reoperation rate for the short TRIGEN INTERTAN when used in unstable fracture patterns, whereas the TRIGEN TAN/FAN performed inferiorly for all fracture types except A3. The T2 Recon, which has a proximal screw design similar to that of the TRIGEN TAN/FAN nail, did not have an increased risk of reoperation compared with the long Gamma3. Hardware failure was the most common reason for reoperation for the short TRIGEN INTERTAN and the long TRIGEN TAN/FAN nails.

TABLE VII Reoperations at 1 and 3 Years: Long Nails*

	Total No. of Nails	Reoperations *(no. [%])*	HRR	95% CI	P Value
1 yr					
Gamma3	2,121	82 (3.9)	1 (ref.)		
PFNA	159	11 (6.9)	1.814†	0.966-3.405	0.064
TRIGEN INTERTAN	2,047	86 (4.2)	1.085†	0.802-1.469	0.597
TRIGEN TAN/FAN	382	43 (11.3)	3.045†	2.099-4.416	<0.001
T2 Recon	240	6 (2.5)	0.642†	0.280-1.472	0.295
3 yr					
Gamma3	2,121	113 (5.3)	1 (ref.)		
PFNA	159	11 (6.9)	1.304†	0.702-2.422	0.401
TRIGEN INTERTAN	2,047	136 (6.6)	1.234†	0.961-1.584	0.099
TRIGEN TAN/FAN	382	52 (13.6)	2.539†	1.823-3.536	<0.001
T2 Recon	240	11 (4.6)	0.809†	0.435-1.504	0.502

*Cox regression analysis adjusted for sex, age, and ASA class. The Gamma3 nail is the reference. †Proportional hazard assumption not fulfilled.

TABLE VIII Reasons for Reoperation at 1 Year: Long Nails*

	Gamma3, N = 2,121 *(no. [%])*	PFNA, N = 159 *(no. [%])*	TRIGEN INTERTAN, N = 2,047 *(no. [%])*	TRIGEN TAN/FAN, N = 382 *(no. [%])*	T2 Recon, N = 240 *(no. [%])*
Total	82 (3.9)	11 (6.9)	86 (4.2)	43 (11.3)	6 (2.5)
Infection	10 (0.5)	1 (0.6)	16 (0.8)	6 (1.6)	1 (0.4)
Peri-implant fracture	5 (0.2)	1 (0.6)	8 (0.4)	2 (0.5)	1 (0.4)
Hardware failure	27 (1.3)	4 (2.5)	23 (1.1)	14 (3.7)	2 (0.8)
Cut-out	4 (0.2)	0 (0.0)	5 (0.2)	3 (0.8)	0 (0.0)
Nonunion	7 (0.3)	2 (1.3)	5 (0.2)	4 (1.0)	0 (0.0)
Unspecified sequela (THA)†	23 (1.1)	0 (0.0)	17 (0.8)	3 (0.8)	2 (0.8)
Pain alone	0 (0.0)	1 (0.6)	4 (0.2)	3 (0.8)	0 (0.0)
Other‡	6 (0.3)	2 (1.3)	8 (0.4)	8 (2.1)	0 (0.0)

*Causes organized hierarchically; only 1 cause registered per patient. †Operation involving THA recorded in the Norwegian Arthroplasty Register. ‡All other reasons for reoperations except pain alone.

Strengths and Limitations

To our knowledge, there are no previous registry-based studies comparing outcomes of different intramedullary nail brands in the treatment of trochanteric and subtrochanteric fractures[37]. In a registry-based study, the sample size is large, yielding great statistical power and allowing for the assessment of infrequent outcomes, such as reoperations. Some primary fracture patterns are rare, and some intramedullary nail brands are used less frequently. A sufficiently powered randomized controlled trial would be difficult, or even impossible, to perform within a reasonable time. Analyses of data from a registry with high completeness, such as the NHFR, may reveal significant differences in outcomes between implants or patients' baseline characteristics. We were able to compare various short and long nails used in the treatment of different fracture subgroups. Patient characteristics were similar for the groups, and selection bias was unlikely. In the Norwegian health-care system, the hospital or region decides on the implant by tender (bidding process based on multiple criteria), further reducing the risk of selection bias. Finally, a study based on data from a national registry with high coverage and completeness has high external validity, as it describes the "real-life situation," not just that of selected centers, surgeons, or patients.

There are important limitations to this study. The completeness of registration in the NHFR is calculated by a comparison with information from the Norwegian National Population Register and is lower for reoperations than for primary operations, 72% versus 86%[12]. The underreporting of complications represents a possible bias, but we have no reason to suspect differences in the reporting of reoperations between implants. The percentage of primary operations as well as reoperations reported to the NHFR differed among the reporting hospitals, but none of the implants were limited to 1 hospital alone and none of the implants were used only in hospitals with a reporting percentage that was lower than average. This reduces the risk of systematically missing cases of reoperations after the use of any particular implant. While implant selection is done by tender in the Norwegian health-care system, confounding by indication cannot be completely controlled for, or addressed, even though the individual surgeon does not decide on implant type, representing possible bias. In our study, we were not able to categorize mechanical complications in further detail than hardware failure, cut-out, and nonunion. Therefore, any hardware failure modes unique to any particular design could not be identified. In addition, individual patients' radiographic images were not available, and thus, we could not investigate whether a reoperation could have been caused by surgery-related factors associated with increased risk of reoperation, such as inappropriate reduction or suboptimal nail placement[15,33,34].

Our study showed variable adherence to the Norwegian national guidelines, as stable fractures were occasionally treated with a long nail and unstable fractures were occasionally treated with a short nail; this was not limited to selected brands. A beneficial effect of a long nail in reverse obliquity and subtrochanteric fractures has, however, not been confirmed in the existing literature, and internationally recognized guidelines such as those of the AAOS and NICE[3-5] do not specifically recommend a long nail. The short TRIGEN INTERTAN had a slightly increased reoperation risk, particularly following the treatment of A3 and subtrochanteric fractures, but we found no association between unstable fracture types and increased reoperation risk when short nails in general were used for treatment.

We do not have information on surgeon volume, but one may argue that the learning curve is probably comparable for all nail brands. Since most operations had been performed by surgeons with ≥3 years of experience, we were not able to properly investigate whether the performance of the different nail brands was influenced by surgeon experience. One previous study from Denmark, however, concluded that unstable trochanteric fractures should be treated by experienced

surgeons[38]. This was not confirmed in an earlier study from the NHFR[39].

Finally, when conducting subanalyses of the AO/OTA fracture types, some groups were too small to be included in statistical analyses. One limitation of the AO/OTA classification is the heterogeneous grouping of A2 fractures, including both fractures with stable (A2.1) and unstable (A2.2 and A2.3) fracture patterns. If these subgroups were unevenly distributed between the different short and long nail types, this may have influenced our results. Unfortunately, subclassification of the A2 fractures is not registered in the NHFR.

Conclusions

In conclusion, in this registry-based cohort study, we found that the short TRIGEN INTERTAN was associated with a slightly increased reoperation risk compared with other short nails in widespread use in Norway, but the clinical relevance of this finding is uncertain. In analyses of long nails, the TRIGEN TAN/FAN nail was associated with a higher risk of reoperation in the treatment of trochanteric and subtrochanteric fractures.

Appendix

eA Supporting material provided by the authors is posted with the online version of this article as a data supplement at jbjs.org (http://links.lww.com/JBJS/H605). ■

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