FACULTY OF MEDICINE

Reoperations after intramedullary nailing versus sliding hip screw in extracapsular hip fractures - An observational cohort study based on data from the Swedish Fracture Register and the Swedish Arthroplasty Register

Reoperationer efter märgspikning jämfört med glidskruv för extrakapsulära höftfrakturer - Observationell kohortstudie med data från Svenska Frakturregistret och Svenska Ledprotesregistret

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Table of Contents

Abbreviations

AO/OTA	AO foundation/Orthopedic Trauma Association
CI	Confidence interval
ExHFx	Extracapsular hip fracture(s)
HA	Hemiarthroplasty
HR	Hazard Ratio
IMN	Intramedullary nailing
RCT	Randomized controlled trial
SAR	Swedish Arthroplasty Register
SFR	Swedish Fracture Register
SHS	Sliding hip screw
THA	Total hip arthroplasty

Abstract

Background/Aim: Extracapsular hip fractures (ExHFx) are routinely treated with intramedullary nailing (IMN) or sliding hip screw (SHS). Increased use of IMN has been seen although it has been questioned due to higher complication rate. We aimed to compare IMN to SHS regarding the rate of conversion to hip arthroplasty and the rate of all reoperations.

Methods: In this observational cohort study, individuals over 60 years sustaining ExHFx were followed in Swedish Fracture Register (SFR) and Swedish Arthroplasty Register (SAR) regarding subsequent hip surgeries during 2012-2020 with a minimum follow-up of 2 years. AO/OTA types 31-A1, 31-A2 and 31-A3 non-pathological fractures primarily treated with IMN or SHS were included. The primary outcome was rate of conversion to arthroplasty after IMN vs SHS from SAR. Secondary outcome was rate of all reoperations from SFR and SAR.

Results: We included 20,589 patients (72% women) with mean age 83.5 ± 8.5 years. AO/OTA type 31-A2 (52%) was most prevalent, followed by 31-A1 (28%) and 31-A3 (20%). Total rate of conversion to arthroplasty was comparable after IMN and SHS (2.3% [n=296] vs 1.9% [n=148], p=0.102). When analyzing 31-A3 fractures only, rate of conversion was significantly lower after IMN vs SHS (2.1% [n=78] vs 3.6% [n=15], p<0.05).
Total reoperation rate was higher after IMN (4.5% [n=589] vs 3.3 [n=251], p<0.001). In 31-A2 fractures, IMN was associated with higher rate of any reoperation (4.5% [n=333] vs 3.6% [n=119], p<0.05), with more implant removal surgeries (0.8% vs 0.5%, p<0.05).

Conclusions: Considering rate of conversion arthroplasty, IMN and SHS perform equally well in general. But in type 31-A3 fractures, IMN seems to be a preferable choice of primary implant. IMN results in more reoperations overall, most palpable in type 31-A2 fractures. In clinical perspective, our data add to the controversy around 31-A2 fractures.

Populärvetenskaplig sammanfattning

Höftfrakturer är vanligt förekommande i västvärlden. Typiskt sker höftfrakturerna hos äldre patienter med nedsatt benstyrka vid fall i samma plan. Tidigare studier har visat att dödligheten efter höftfrakturer är hög, delvist på grund av att patientgruppen är äldre personer med underliggande sjukdomar. Höftfrakturer kan grovt delas in i två grupper: de så kallade intrakapsulära belägna innanför höftledskapseln, och de extrakapsulära belägna utanför ledkapseln i översta delen av lårbenet. I samband med att befolkningen i västvärlden åldras har man sett en ökning av extrakapsulära frakturer i förhållande till de intrakapsulära. Trokanter major och minor kallas de två utstående benutskott där muskler fäster sig i övre delen av lårbenet. Extrakapsulära frakturer sker i trokanterområdet, inklusive partiet 5 cm nedanför trokanterna.

Inför val av behandling är det viktigt att bedöma om frakturen är stabil eller ej. En enkel fraktur utan lossnade benbitar eller förskjutning är oftast stabil medan en uppsplittrad fraktur med multipla benbitar eller fraktur lokaliserad under trokanterna är oftast instabil. De extrakapsulära frakturerna kan klassificeras enligt stabilitet och utseende på röntgenbilder enligt ett internationellt system som heter AO/OTA. Typ 31-A1 är stabila medan 31-A2 kan vara både stabila och instabila frakturer, båda typerna ligger i trokanterområdet. Typ 31-A3 är instabila frakturer som går under trokanterna. Om den yttre väggen av lårbenet är skadad eller tunn minskar stabiliteten i frakturen.
Dessa frakturer behandlas i de allra flesta fall med kirugi som syftar till att sammanfoga benfragmenten och stabilisera frakturen, så att den kan läka. En stabiliserad fraktur medger belastning omedelbart efter operation. Klassiskt har man behandlat dessa frakturer med glidskruv och platta eller märgspik. Det förstnämnda har en skruv som borras upp genom lårbenshals och -huvud (översta delen av lårbenet) och en platta som fästs på utsidan av lårbenet. Skruven kan sedan glida i en hylsa i plattan, vilket tillåter att benkanterna närmar sig varandra vid belastning, vilket stabiliserar frakturen ytterligare och underlättar läkning. Märgspik är en längre spik som förs in i lårbensskaftet och fästs med skruvar, varav en skruv går upp i lårbenshals och -huvud. Det finns många studier som jämför dessa två typer och utfall av behandling, men det finns ingen entydighet vilken av behandlingsmetoderna som är bättre för de olika AO/OTA frakturtyperna.
En individ med höftfraktur kan drabbas av komplikationer i höften (t.ex. utebliven läkning, implantathaveri, infektion, smärta, artros). Då kan man operera om med en ny

sammanfogning med implantat/skruv osv., avlägsnande av tidigare implantat eller höftplastik. Höftplastik är en mer invasiv operation då man ersätter antingen endast övre delen av lårbenet med en protes (halvplastik) eller både övre delen av lårbenet och ledytan i bäckenet (helplastik).

Syftet med studien var att kartlägga hur de olika frakturtyperna fördelar sig och hur man opererar skadorna i Sverige. För att jämföra resultatet efter kirurgi har vi räknat hur många patienter reopereras med höftplastik eller annan operation på grund av komplikationer efter första kirurgiska behandlingen. Vi använde data angående frakturegenskaper, första behandling och reoperationer från Svenska Frakturregistret (SFR) och angående ledprotesoperationer från Svenska Ledprotesregistret (SLR).

Typ 31-A2 var den vanligaste frakturtypen (52%), följd av 31-A1 (28%) och 31-A3 (20%). Studien visade att de flesta typ 31-A1 frakturer opereras med glidskruv/platta i första hand, medan typ 31-A2 och 31-A3 opereras mestdels med märgspik.

När vi jämförde glidskruv/platta och märgspik i hela gruppen visade våra resultat ingen skillnad i andelen höftplastikopererade mellan behandlingsgrupperna. I grupp 31-A3 visade det sig dock att patienter som får märgspik som första behandling har färre reoperationer med höftplastik än dem som får glidskruv/platta. I de andra frakturgrupperna såg vi ingen skillnad av betydelse mellan behandlingsgrupperna.
Andra reoperationer var vanligare efter märgspik i gruppen som helhet; skillnaden berodde på en högre andel reopererade i grupp 31-A2, medan vi inte såg någon skillnad i de andra frakturgrupperna. Såkallade extraktionsoperationer, dvs. att man avlägsnar märgspiken var vanligare efter märgspik.
Risken för reoperation minskade med stigande ålder; vi tror det beror på att de äldre inte opereras om för mindre besvär (till exempel obehag vid frakturstället) eftersom riskerna med själva operation hos dem kan vara större än nyttan. Typ 31-A1 var riskfaktor för höftplastik, medan både typ 31-A2 och 31-A3 frakturer var riskfaktorer för annan reoperation (jämfört med typ 31-A1).

Det finns många studier som har jämfört märgspik och glidskruv/platta men de är ofta små och ger därför inte så mycket vetenskapligt belägg. Fördelen med vår studie var den stora mängden patienter. De allra flesta ledprotesoperationer registreras i SLR (96,0-98,5%) och vårt främsta utfallsmått är därför mycket pålitligt. Å andra sidan är komplettheten för reoperationsdata i SFR inte lika hög, och vi vet inte exakt hur stort mörkertalet för

reoperationer från denna källa är. Det finns få stora studier som har jämfört märgspik och glidskruv/platta gällande reoperationer och denna studie bidrar till att öka vetenskapligt belägg,
Alla komplikationer är inte lika allvarliga; t.ex. implanthaveri och infektion är allvarliga komplikationer medan obehag vid operationsstället är mindre allvarligt. Troligtvis görs många extraktionsoperationer pga. mindre allvarliga komplikationer. I Sverige opereras också många patienter med höftplastik pga. artros (ledsjukdom i brosket), och vi kunde tyvärr inte skilja mellan patienter som har utvecklat artros redan före frakturen och dem som fått besvär till följd av frakturen.

Från våra resultat och tidigare studier kan vi dra slutsatsen att märgspik är ett bättre alternativ för de instabila 31-A3-frakturerna när det gäller reoperationer med höftplastik. För de instabila 31-A1-frakturerna ser vi ingen skillnad i reoperationer, vilket är ny information eftersom märgspikning tidigare har kritiserats som överbehandling. Märgspikning resulterar i fler reoperationer totalt men troligen är ett antal av dessa reoperationer orsakade av mindre allvarliga komplikationer. Val av implantat efter 31-A2 frakturer är mest omstridd. Det kan behövas nya, högkvalitativa studier för att studera om det finns kliniskt betydelsefulla skillnader i utfall efter 31-A2-frakturer som är mest omstridda.

1 Introduction

1.1 Background

Hip fractures constitute a large share of our more severe fractures, leading to hospital admission and acute surgery. Proximal femoral fractures can be divided in extracapsular (pertrochanteric or subtrochanteric) and intracapsular (femoral neck and head) fractures by the location outside versus inside the joint capsule, respectively. Anatomical and physiological circumstances in extracapsular hip fractures (ExHFx) differ from the ones in intracapsular fractures. The trochanteric region, extending from intertrochanteric line (defined by line from greater trochanter to lesser trochanter) to transverse line at the inferior border of lesser trochanter, puts additional requirements for the biomechanical stability of the internal fixation (1). According to the AO foundation/Orthopedic Trauma Association (AO/OTA) international fracture classification system, extracapsular fractures are represented by 31-A1, 31-A2 and 31-A3 fracture groups (2, 3) *(Figure 1).* AO/OTA type A1 fractures are simple, two-fragment fractures and A2 are comminuted fractures with the lateral wall being intact. A3 fractures are unstable, reverse oblique or transverse fractures comprising the lateral femoral wall and can be simple or comminuted. The fractures can be further classified in three subgroups (31-A1.1-3, 31-A2.1-3, 31-A3.1-3) by increasing instability or comminution. 31-A1.1 to 31-A2.1 can be seen as stable fractures, whereas 31-A2.2 to 31-A3.3 are unstable, comminuted fractures.
ExHFx are routinely treated with internal fixation. Sliding hip screw with or without stabilizing plate (SHS) has classically been the treatment of choice. A screw is fixated in the femoral head and a plate is fixated extramedullary on the lateral wall of the femur; the plate and screw can slide towards each other and further stabilize the fracture. Intramedullary nailing (IMN) is the other common choice of fixation. The IMN is forced into the intramedullary space of the femoral shaft and is locked with screws.
Following ExHFx, perioperative and postoperative fracture-related complications may occur. Common fracture-related complications include a new fracture close to the implant, implant failure (e.g screw cut-out in femoral head), non-union or malunion, infection and pain at the site of surgery. In particular, the older designs of short IMN had a reputation of generating subsequent fractures adjacent to the distal tip of the nail (4). Depending on the type and severity of the complication and fitness of the individual for surgery, individuals might go through a reoperation. A reoperation is defined as any subsequent surgery following primary surgical treatment. Arthroplasty as a reoperation (“conversion to arthroplasty”), including

hemiarthroplasty (HA) and total hip arthroplasty (THA), is one of the most common reoperations reported in previous studies (5-7). In HA, the proximal femur is replaced by a prosthesis. In THA, both the proximal femur and the acetabular joint surface are replaced by a bowl-like cup. Other reoperations include re-fixation (new osteosynthesis), implant removal procedures, revision surgeries due to infection, and excision arthroplasty (e.g. Girdlestone procedure: removal of the femoral head and neck).

Intramedullary hip devices have improved after being first introduced in the late 60s, regaining more interest through biomechanical studies showing possible benefits with IMN (8-10). Several studies suggest that there has also been an improvement in complication rate and mortality after IMN during the past decades (7, 11, 12). Also, an increased use of IMN has been observed although the possible benefits have not been shown in high-quality studies (13-17). The evidence regarding implant choice remains therefore controversial (1).

The proportion of ExHFx in relation to intracapsular fractures has been growing as the population ages (18, 19). The growing number of aged individuals may theoretically lead to more comminuted ExHFx, as this fracture type supposedly affects those with most severe osteoporosis (19-22). An update on the demography of ExHFx in Sweden is needed. Also, reports on the reoperation rate after ExHFx on a national level are rare (5, 6, 13). As smaller clinical studies may be conducted at centers of excellence, and thereby lacking eternal validity, the results from everyday surgery must be scrutinized as well.

The Swedish Fracture Register (SFR) and the Swedish Arthroplasty Register (SAR) are national quality registers that prospectively collect data on individuals sustaining fractures and receiving arthroplasty treatment, respectively. SFR has retained data on over 600,000 fractures after being established in 2011, but the completeness for reoperations after hip fracture has not yet been evaluated (23). The accuracy of fracture classification according to AO/OTA has been validated in a previous study (24). Swedish Hip Arthroplasty Register started in 1979 and was lately merged with Swedish Knee Arthroplasty Register, building SAR. Up to date, all Swedish clinics performing hip arthroplasty are reporting to SAR. Retrieving reoperation data from SAR provides reliable data, as the completeness for THA is 98.5% and 96.0% for HA, and 90.9% for revisions of an arthroplasty (25).

1.2 Aim

We aimed to compare IMN to SHS primarily regarding the rate of conversion to arthroplasty and secondarily regarding the rate of any reoperation. We also aimed to determine predictors of these subsequent surgeries.

1.3 Research question(s)

Is there a difference in rate of conversion to arthroplasty or reoperation of any kind after IMN vs SHS in extracapsular hip fractures? Is age, gender, fracture type, type of injury, primary implant choice and surgeon experience associated with reoperation?

2 Material and Methods

2.1 Study Design

In this observational cohort study, individuals over 60 years registered in SFR 2012-2020 due to ExHFx were followed in SFR and SAR regarding subsequent hip surgeries i.e., primarily conversion arthroplasty surgeries.

In SFR, the treating orthopedic surgeons classified the fracture according to AO/OTA *(Figure 1).* An ICD code is generated based upon that classification. AO/OTA types 31-A1, 31-A2 and 31-A3 were included in this study. Atypical fractures, pathological fractures and fractures related to pre-existing prostheses and implants were reported by surgeons and were excluded. Cases were further divided in following primary treatment groups: IMN, SHS, other internal fixation methods than IMN/SHS, excision arthroplasty, primary arthroplasty (THA or HA), other unspecified surgery, and non-operative treatment. The treatment codes NFJ69 and NFJ89 were included in the SHS group and NFJ59 in the IMN group. First, the distribution of all primary treatment strategies between the AO/OTA groups was analyzed. After that, other primary treatment methods were excluded, leaving only SHS or IMN as primary treatment in the final analysis. *(Figure 2)*

The baseline characteristics of the primary treatment groups including age, sex, injury side (left/right), type of injury (high-energy/low-energy injury), type of implant used (antegrade long vs short vs retrograde IMN) and main surgeon experience (specialist, resident, assistant physician/non-specialist) were recorded from SFR. Distribution of primary surgical treatment within and between AO/OTA groups were recorded from SFR.

Primary outcome was the rate of conversion to arthroplasty following primary IMN vs SHS from SAR. Time from injury to reoperation, implant types and reason for conversion to arthroplasty were analyzed from SAR.

Secondary outcome was rate of any reoperation including all types of surgery from SFR and SAR. Reoperation was defined as any secondary surgery after primary treatment during the follow-up period. Since some patients had more than one reoperation, the first reoperation was analyzed, and reoperation rate was calculated as a proportion of patients who had at least one reoperation. Types of reoperations were divided in following groups: 1) arthroplasty from SFR and SAR, 2) reoperation with internal fixation, 3) implant removal, 4) excision arthroplasty/osteotomy and 5) other unspecified surgery.

Potential predictors of primary and secondary outcome (age, gender, AO/OTA type, type of injury, primary implant choice, surgeon experience) and survival time of primary implant for conversion and any reoperation were statistically analyzed.

Reason for conversion arthroplasty from SAR and all reoperations from SFR were classified in following groups: 1) osteoarthritis, 2) pain/discomfort, 3) healing disturbance, 4) new fracture, 5) avascular necrosis, 6) infection, and 7) other unspecified reason. Due to the different kinds of registering, healing disturbance is represented by "fracture malunion/nonunion" from SAR and SFR, "mechanical complication of implant" from SAR, and "implant failure" from SFR.
Mortality was defined as the frequency of patients who died 30 days or 1 year after the injury. Time-to-reoperation and time-to-arthroplasty were calculated from the date of injury to date of any secondary surgery and to conversion arthroplasty, respectively.

2.2 Statistical Methods

Statistical tests included Chi^2 and column proportion tests with Bonferroni correction for comparing categorical variables and proportions (gender, fracture side, type of injury, smoking, surgeon competence, reoperation rates, reasons for reoperation, implant types and types of surgery). Student's T-test was used for comparing continuous normally distributed variables (age). Mann-Whitney U test was used for comparing continuous, non-parametric variables (time-to-reoperation, time-to-arthroplasty). Potential predictors (age, gender, fracture type, primary implant used, surgeon experience) of conversion arthroplasty and any reoperation were analyzed first by univariate Cox regression for each variable, then by multivariate Cox regression. To minimize the confounding effect of high-energy injuries, we ran the same Cox regression analyses including low-energy injuries only. P values, Hazard ratio (HR) and 95% confidence intervals (CI) for HR were calculated for Cox regression analyses. For variables with multiple categories, the following categories were used as reference: male gender, low-energy injury, AO/OTA type A1, SHS as primary treatment and specialist as main surgeon. Kaplan-Meier analysis was used to assess cumulative implant survival. In Cox regression and Kaplan-Meier analyses, conversion arthroplasty versus any reoperation was defined as an "event" and patients who died were censored at the date of their death. Other patients were censored at the end of follow-up. P value <0.05 was considered statistically significant. SPSS was used for all statistical analyses.

3 Ethical Considerations

The Swedish Ethics Review Authority has approved the project. Due to the design of this observational study, there was no allocation to different treatments. Therefore, no patient received a "better" or "worse" treatment in purpose to study the treatment effect. Since the patient data was anonymized with a unique identity number, the patient's consent was not needed for registration. Personal health-related data is sensitive, and it might be uncomfortable for some individuals to have this data, although anonymous, collected and analyzed by a third party. Collecting and analyzing this data provides valuable information for further research and thereby, a potential benefit for our patients.

In addition, our results may affect the choice of implant and furthermore, the outcome for patients. This might result in better outcomes for patients sustaining ExHFx. On the other hand, our results might show that a certain implant is better than the other due to bias and lead to a worse outcome. At the same time, there are other multiple other important outcome measures, in addition to reoperations, that need to be considered. Our results are entirely based on statistical analysis, and due to the large amount of data we might detect statistical differences that do not exist, possibly leading to type I errors. Therefore, we intend to detect possible biases and describe them and other outcome measures in discussion.

4 Results

4.1 Overview

21,772 patients with AO/OTA type A1, A2 and A3 fractures were registered in SFR, 489 of which were excluded due to atypical or pathological fracture, or fracture close to a pre-existing implant resulting in 21,283 patients. *(Figure 2)*

When all treatment options were considered, the most prevalent type of fracture was A2 (50.9%), followed by A1 (29.4%) and A3 (19.7%). For the total cohort, IMN was the most common primary treatment strategy involving 60.9% of all patients, followed by SHS (35.9%). 2.4% of the patients received non-operative treatment. Other surgical treatment involved less than 1% of our cohort. In AO/OTA group analysis, SHS was the most common primary treatment in type A1 (62.2%), whereas IMN was the most prevalent primary treatment method in types A2 (68.3%) and A3 (88.5). Relatively, more patients were treated non-operatively in type A1 compared to A2 and A3 (7.0%, 0.3% and 0.8%, respectively).

After excluding patients primarily treated non-operatively and with other surgery than IMN and SHS (n=694), 20,589 patients were included in the final analysis (see Figure 1).

4.2 Characteristics

The distribution of AO/OTA types in final analysis was the following: 27.8% were included in group A1, 52.1% in A2 and 20.0% patients were included in group A3. Detailed characteristics of patients, fracture distribution and types of implants used in primary treatment are presented in *Table 1*. The mean age was 83.5 ± 8.5 years with a female over-representation (70.2%). The fractured side was equally distributed on the left (50.3%) and the right side (49.7%). Smoking was reported in 34.9% of the cases and was not analyzed further due to low response rate and risk for confounding. Most patients received their fracture due to low-energy injury (99.1%). IMN was more commonly performed after high-energy trauma in whole group analysis (1.0% vs 0.6%, $p<0.001$) and in AO/OTA type A1 (1.1% vs 0.5%, $p<0.05$). Specialist (62.1%) or resident (37.0%) were the most prevalent main surgeons. There was a statistically significant difference between IMN and SHS groups regarding main surgeon experience: surgery with SHS was relatively more often performed by specialists whereas IMN was more often performed by residents ($p<0.001$). The difference was significant in all AO/OTA groups, too. There were no statistically relevant differences in patient characteristics between the IMN and SHS groups regarding age and fracture side. The proportion of women was higher in the IMN group vs SHS group in type A1 fractures (68.6% vs 63.8). Median time from injury to primary treatment was 1 day in both treatment groups in all AO/OTA fractures. Median follow-up time was 4.5 years, ranging from a minimum of 2.0 years to a maximum 9.0 years.

4.3 Implant Types in Primary Treatment

Overall, IMN was more commonly used than SHS (63.0% and 37.0%, respectively). In AO/OTA groups, SHS was more commonly used than IMN in A1, whereas IMN was more prevalent in types A2 and A3 *(Figure 2).* Regarding intramedullary devices, the proportion of using long antegrade nails instead of short antegrade nails or retrograde nails increased from 7.6% in A1 to 69.1% in A3 *(Table 1).*

4.4 Primary Outcome – Conversion to Arthroplasty

In total, 444 patients had a conversion to arthroplasty. *(Table 2)*

Overall rate of conversion to arthroplasty resulted in 2.3% (n=296) after IMN and 1.9% (n=148) after SHS with no significant difference. In AO/OTA group analysis, there was a trend towards higher reoperation rates after IMN vs SHS in A1 (1.8% vs 1.5%, respectively) and A2 groups (2.5% vs 2.2%, respectively), although these results were not statistically significant. Rate of conversion was significantly lower after IMN vs SHS in A3 (2.1% vs 3.6%, respectively). THA was the main choice of implant (87.4% of all conversion arthroplasty procedures).

Healing disturbance was the most prevalent reason for arthroplasty in all fracture types and both treatment groups. In AO/OTA type A2, healing disturbance was more common after IMN vs SHS (1.6% vs 1.1%, $p<0.05$). *(Table 2)*

Median time to arthroplasty was 252 days in the IMN group and 327 days in the SHS group. In Kaplan-Meier analysis, estimated primary implant survival time was longer after IMN vs SHS in type A3 fractures ($p<0.05$) whereas there was a trend toward shorter survival time in A1 and A2 groups after IMN without significant differences. The Kaplan-Meier implant survival curves in Table 3 (A to D) show the trends of conversion over time after primary surgery. During the first year, IMN and SHS showed similar rates of conversion. In types A1 and A2, a trend towards higher rate after IMN was seen after 3-4 years. In type A3, the curves start diverging already at one year. *(Table 3)*

In univariate Cox regression analysis, lower age and AO/OTA type A2 were significant predictors for arthroplasty, whereas gender, type of injury, AO/OTA type A3, primary treatment choice and surgeon experience were not significant. In multivariate regression analysis, age and AO/OTA type A2 remained significant. A 1-year increase in age was associated with 4.3% risk reduction, and type A2 fracture was associated with 49.4% increase in risk compared to AO/OTA type A1. *(Table 4)*

The same analyses were undertaken including only low-energy injuries. Type A3 fracture was a significant predictor of conversion in univariate analysis (HR 1.397, 95 % CI 1.033 – 1.888, p=0.03) but not in multivariate analysis. Otherwise, we saw similar results in univariate and multivariate analysis (event n=413, censored n=19,065). The proportion of women remained lower in the A1 group treated with SHS compared to IMN (63.9% vs 69.1%).

4.5 Secondary Outcome – Any Reoperation

In final analysis, 840 patients underwent at least one reoperation after IMN or SHS. Overall rate of any reoperation was higher after IMN (4.5%) compared to SHS (3.3%) (p<0.001). The reoperation rates between the two fixation methods were comparable in groups A1 and A3, whereas the rate was significantly higher after IMN vs SHS in group A2 (4.5% vs 3.6%). *(Table 5)*

In Kaplan-Meier analysis, the estimated implant survival was lower after IMN in AO/OTA A2 (p<0.05). *(Table 6)*

Arthroplasty comprised the majority of first reoperations, followed by internal fixation and implant removal procedures. In general, internal fixation, implant removal surgeries and other unspecified surgeries were significantly more common after IMN. Also, healing disturbance and pain/discomfort were more common reasons for reoperation after IMN. In A2 fractures, implant removal surgeries were significantly more common after IMN (0.8% vs 0.5%), but not in A1 and A3 fractures. In A3 fractures, arthroplasty as the first reoperation was more prevalent after SHS (3.1% vs 1.5%). In this group, avascular necrosis was also more common after SHS (0.5% vs 0.1%), but comprised only 2 patients in the SHS group and 3 patients in the IMN group. *(Table 5)*

In univariate Cox regression analysis, lower age, high-energy injury, AO/OTA types A2 and A3, and IMN as primary treatment were significant predictors for any reoperation, whereas gender and surgeon experience were not. Age, A2 and A3 fractures remained significant in multivariate analysis. A 1-year increase in age was associated with 4.4% risk reduction. AO/OTA type A2 fracture was associated with 59.9% and type A3 fracture was associated with 95.1% increase in risk compared to AO/OTA type A1. *(Table 7)*

We ran the same analyses including low-energy injuries only (event n=777, censored n=18,699). In univariate and multivariate analysis, we saw similar results.

4.6 Mortality

Median survival time after injury was slightly longer after SHS in comparison to IMN although the range was wide (518 [range 0 - 3035] vs 469 [range 1 - 2887] days, p<0.001). In AO/OTA group comparison, the same trend was seen in all groups, but the difference was significant in group A2 only (527 [range 1-3035] vs 461 [range 1 – 2887] days, p<0.001).

The mortality did not differ between the implant groups. 30-days-mortality was 7.8% (n=594 after SHS and 8.1% (n=1047) after IMN (p=0.460). Corresponding 1-year-mortality was 26.9% (n=2053) and 25.9% (n=3361) (p=0.119). In AO/OTA groups, the mortality was similar between the two implants. Male patients had significantly higher overall mortality in both time units measured compared to female patients (1 year's mortality 33.0% (n=2025) vs 23.5% (n=3389), respectively, p<0.001).

5 Discussion

In the most unstable fractures, A3, we found a higher rate of conversion to arthroplasty after SHS compared to IMN. In contrast, there was a non-significant tendency of more conversions to arthroplasty after IMN in the more stable AO/OTA types A1 and A2. Healing disturbance was more common after IMN in A2 fractures.

Regarding the rate of any reoperation, IMN resulted in more reoperations than SHS in type A2 fractures but not in type A1 or A3 fractures. In type A2 fractures, implant removal surgeries were more common after IMN which possibly explains the higher rate of surgery in this group.

Lower age and AO/OTA type A2 fracture were predictors of conversion arthroplasty and any reoperation. Physical requirements might be higher for younger patients and the threshold for reoperation due to discomfort or other minor complications might be lower for patients in better fit for surgery. Interestingly, the most severe type A3 fracture was not a predictor of conversion, whereas it was a risk factor for any reoperation. There can be multiple reasons for these results; we can hypothesize that e.g., surgeons might not prefer to perform arthroplasty due to the injured femoral shaft in subtrochanteric fractures.

High-energy injuries were over-represented in the IMN treatment group. The classification of fractures in low-energy vs high-energy fractures has been criticized; similar to low-energy fractures, high-energy fractures in aged individuals are associated with osteoporosis and the future fracture risk is elevated in this group (26, 27). Therefore, we also included fractures classified as high-energy in our study. To address any concerns that high-energy injuries might result in injuries of a more severe and different kind, i.e., soft tissue injuries, we ran the same Cox regression analyses for low-energy injuries only, which showed similar results.

The literature shows conflicting evidence on implant choice. A relatively old Cochrane review, from 2010, suggested that SHS is superior to IMN, mainly due to a higher rate of intraoperative fracture or later fracture close to the implant (28). On the other hand, a literature review by Kaplan et al. 2008 suggests using SHS for the stable fractures and IMN for the unstable ones (29). As the outcome for newer intramedullary devices has improved, these results might not be up-to-date anymore (4). Unfortunately, fracture as a reason for conversion was unclearly defined in SAR and it was not possible to determine whether it concerned a new fracture around the implant or other post-traumatic complications. We classified these as new fractures for the purpose of not underestimating the number of fractures close to the implant. We found no difference between IMN vs SHS, which is in line with a previous meta-analysis by Bhandari et al. (4) comparing older and newer generations of IMNs who suggested that in more recent studies (1997-2005), fractures close to implant are not significantly more common after IMN vs SHS.

Also, IMN can be seen as a more invasive treatment than extramedullary fixation as it has been associated with medical complications, such as fat embolism syndrome (30). It has been suggested that mortality is higher after IMN (31, 32). We saw no difference in mortality between the treatment groups.

Regularly, there is discussion about implant costs regarding the choice of implant. The implant costs of SHS are lower, although long-term cost analysis is difficult to make. Hospital admission(s), complications and reoperations are associated with incremental costs that will exceed the costs of the primary implant (33, 34). In our opinion, the higher implant cost on IMN should not be a factor in deciding which implant to use.

In a randomized controlled trial (RCT) with 1000 patients with a follow-up time of one year, Parker et al. (7) did not find a significant difference in rate of conversion arthroplasty or any reoperation in AO/OTA groups. In our implant survival analysis, a large number of patients had a reoperation after the first year and differences in reoperation rates between treatment groups continued to grow later on. To detect differences in reoperation rate, a follow-up time of one year might be insufficient. We saw a higher rate of implant removal surgeries after IMN, in contrast to a Finnish register study by Ponkilainen et al. 2020 (17) reporting no difference in any rate of implant removal surgeries after fixation with IMN vs SHS (around

4% in both groups). The approach to implant removal surgeries might differ between countries which possibly explains our different results.
In stable ExHFx, IMN tends to be criticized as “overtreatment”, as studies have identified a similar or even higher reoperation risk coupled to this implant (5, 35). We saw an equal outcome in this group. This might be a question of more modern implants used in our study and increasing familiarity with IMN through the learning curve in our country (36).

A previous RCT with a follow-up of one year reported no difference in reoperation rate after type A2 fractures (37). A smaller register study (38) reported non-significantly higher reoperation rates after SHS in unstable A2.2, A2.3 and A3. The A2 group of fractures are heterogeneous, varying from stable A2.1 to unstable A2.2 and A2.3 fractures; it might be more appropriate to analyze them in subgroups.

Parker’s large RCT showed better mobility after IMN but no difference in complications related to fracture healing or reoperations (7). The controversy is strongest among A2 fractures, and studies focusing on this particular type only show inconsistent results. An RCT (39) suggested less pain at six months, a better postoperative quality of life and activity score for daily living after IMN at one year, but no difference in mobility. Other RCTs showed no difference in quality of life (37) or in physical function and mobility score (40). Studies on post-fracture patient-reported outcome are important, but there is need for larger high-quality studies for minimizing selection bias and to find reliable differences between implant types after type A2 fractures. Also, many studies did not differentiate between the different types of trochanteric fractures using AO/OTA classification, making it difficult to generalize the results. If the higher total reoperation rate after IMN is concerned, more high-quality studies are required. On the other hand, we can grade the severity of complications leading to these reoperations as we see no difference in conversion to arthroplasty.

We saw the highest reoperation rates in AO/OTA type A3 fractures, the rates of which were comparable with the rates in a Norwegian register study of 2716 patients by Matre et al., who found 6.4% after SHS and 3.8% after IMN at one year (6).
Previous studies have shown that SHS is more likely to cause medialization, rendering an unfavorable outcome regarding mobility (6, 41). The fractured lateral wall allows medialization of the femoral shaft by the effect of the adductor muscles. Intramedullary fixation also shifts the load axis more medially, giving biomechanically better stability in unstable ExHFx (10). Considering previous evidence and our results showing higher rate of

conversion to arthroplasty, we support the recommendation that SHS should not be used in type A3 fractures.

The reoperation rates presented might be an underestimation, as we are not including any individuals waiting for an arthroplasty. Regrettably, the waiting list for elective hip surgery can be relatively long in Sweden. Patients with more acute complications such as infection at the implant site are in need of more urgent surgery and might therefore be over-represented in this study. As the mortality is high, some patients will die before or be too frail to undergo secondary surgery. Also, patient characteristics, like functional level and comorbidities, affect the outcome of primary treatment, mortality rate and the willingness to perform secondary surgery in case of complications. SFR does not record data on pre-operative function level or comorbidities. There is a tendency of under-reporting of reoperations to the SFR, i.e., the general reoperation rates from SFR have to be interpreted with some caution. Still, we expect the possible underreporting from SFR to apply to both treatment groups equally, and we estimate the possible bias to be small.

In addition, some possible confounding effects by the higher proportion of women and high-energy injuries in the IMN group cannot be ruled out. Although our study design cannot be compared with RCTs, matching the groups could minimize the confounding effect.

Neither do our register data provide specifications on implant type i.e., different designs or brands of implants and perioperative details such as complications or difficulties during surgery. The addition of a trochanteric stabilizing plate to SHS might eventually increase stability in unstable fractures (42). A meta-analysis by Queally et al. 2014 (43) did not find sufficient evidence for differences between different nail designs. As mentioned before, the outcome after IMN has improved during past decades and is most likely associated with newer implant designs and learning curve through increased use of IMN.

As a result of our relatively long follow-up time, arthroplasties due to osteoarthritis that is not related to the actual fracture may increase our conversion rates.

Retrieving reoperation data from SAR provides reliable data, as the completeness is very high for any first arthroplasty and satisfactory for revision arthroplasties (25). As both SFR and SAR contain the unique personal identity number of the patient and the side of fracture/surgery, a reliable linkage between acute treatment and any secondary procedure in the hip is done. A register study offers the benefits of a very large cohort and can provide evidence with good external validity as it is based on everyday surgery. It is a valuable complement to RCTs, in particular as RCTs are difficult to conduct on frail elderly with sufficient power and a long enough follow-up time to detect clinically relevant differences between treatment groups.

6 Conclusion

Considering the rate of conversion arthroplasty, IMN and SHS perform equally well in general. But in type 31-A3 fractures, IMN seems to be a preferable choice of primary implant. IMN results in more reoperations overall than SHS mainly due to implant removal procedures, most palpable in type 31-A2 fractures. Lower age and type 31-A2 fracture seem to be predictors of conversion and any reoperation. Type 31-A3 fracture was a predictor of any reoperation, but not of conversion. In clinical perspective, our data add to the controversy around A2 fractures: Either we can choose to be concerned regarding more IMN reoperations and ask for more high-quality studies. Alternatively, we can be satisfied with two equally good treatment regimens when looking at the same rate of conversions to arthroplasty.

7 Declaration of Work

Data from SFR and SAR were extracted and linked by patients' identity number by register personnel. Statistical analysis, writing process, and figures were primarily performed by the student. The supervisor contributed with feedback, corrections, and discussion throughout all parts of the project.

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9 Tables and figures

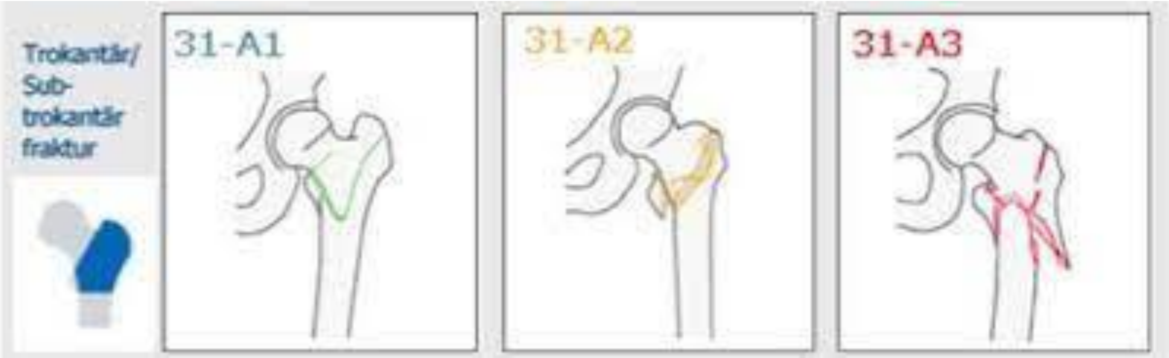


Figure 1: ***Fracture classification scheme from Swedish Fracture Register (3)*.***
31-A1 is a simple and stable, and 31-A2 is a comminuted stable or unstable intertrochanteric fracture.
31-A3 is an unstable, reverse oblique or transverse subtrochanteric fracture.
**Image used with copyright permission from Swedish Fracture Register.*

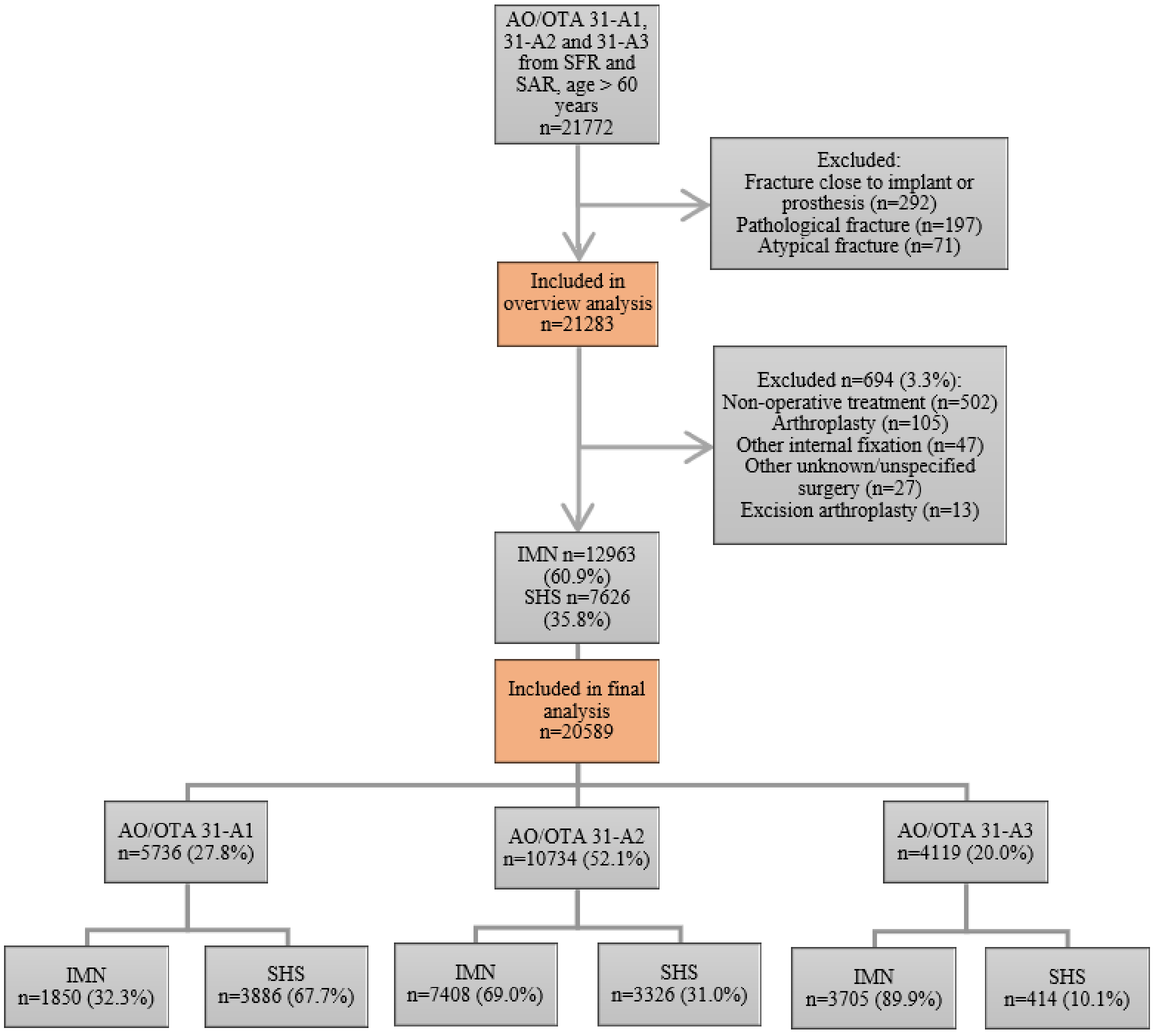


Figure 2*: Flow chart of patients excluded and finally included in final analysis.*
AO/OTA type 31-A1, 31-A2 and 31-A3 fractures from Swedish Fracture Register (SFR) and Swedish Arthroplasty Register (SAR) were included. After excluding fractures close to pre-existing implant, pathological and atypical fractures, an overview analysis regarding distribution of fracture types and treatment methods was done. In the next step, other treatment methods than intramedullary nailing (IMN) and sliding hip screw (SHS) were excluded. The graph shows distribution of AO/OTA groups and IMN versus SHS as primary treatment of patients included in final analysis.
AO/OTA = AO foundation/Orthopedic Trauma Association. IMN = Intramedullary nailing. SHS = Sliding hip screw.

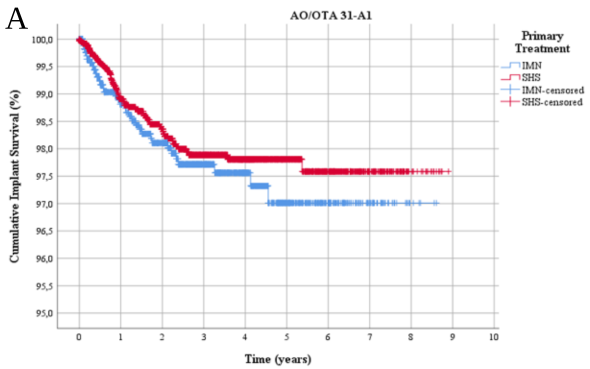
AO/OTA	31-A1			31-A2			31-A3			All			
Primary treatment	**IMN**	**SHS**	Sig.	**IMN**	**SHS**	Sig.	**IMN**	**SHS**	Sig.	**IMN**	**SHS**	Sig.	**Total**
Age, mean±SD	83.4 ± 8.4	83.0 ± 8.7		83.8 ± 8.4	84.0 ± 8.3		82.9 ± 8.7	82.3 ± 8.7		83.5 ± 8.5	83.4 ± 8.5		83.5 ± 8.5
Gender, n (%)													
- Female	1269 (68.6)	2479 (63.8)	‡	5329 (71.9)	2363 (71.0)		2699 (72.8)	305 (73.7)		9397 (71.7)	5147 (67.5)	‡	14444 (70.2)
Fracture side, n (%)													
- Right	931 (50.3)	2004 (51.6)		3642 (49.2)	1635 (49.2)		1821 (49.1)	196 (47.3)		6394 (49.3)	3835 (50.3)		10229 (49.7)
Type of injury, n (%)													
- High-energy	20 (1.1)	20 (0.5)		50 (0.7)	21 (0.6)		59 (1.6)	4 (1.0)		129 (1.0)	45 (0.6)		174 (0.9)
- Low-energy	1725 (93.2)	3693 (95.0)	†	7001 (94.5)	3169 (95.3)		3503 (94.5)	391 (94.4)		12229 (94.3)	7253 (95.1)	†	19482 (99.1)
- Unknown	105 (5.7)	173 (4.5)		357 (4.8)	136 (4.1)		143 (3.9)	19 (4.6)		605 (4.7)	328 (4.3)		
Main surgeon, n (%)													
- Specialist	942 (52.7)	2388 (63.2)		4019 (56.2)	2291 (70.7)		2418 (67.4)	334 (83.1)		7371 (58.9)	5010 (67.6)		12381 (62.1)
- Resident	822 (46.0)	1351 (35.8)	‡	3081 (43.1)	919 (28.4)	‡	1153 (32.2)	65 (16.2)	‡	5048 (40.4)	2333 (31.5)	‡	7381 (37.0)
- Assistant Physician / Non-specialist	23 (1.3)	39 (1.0)		52 (0.7)	29 (0.9)		14 (0.4)	3 (0.7)		89 (0.7)	71 (1.0)		160 (0.8)
Type of nail, n (%)													
- Short antegrade femoral nail	1687 (91.2)			6133 (82.8)			1102 (29.7)			8922 (68.8)			
- Long antegrade femoral nail	140 (7.6)			1191 (16.1)			2560 (69.1)			3891 (30.0)			
- Retrograde nail	23 (1.2)			84 (1.1)			43 (1.2)			150 (1.2)			
Total	**1850**	**3886**		**7408**	**3326**		**3705**	**414**		**12963**	**7626**		**20589**

Table 1: ***Patients included in final analysis - Patient and fracture characteristics, and types of implants used in primary treatment.***
In group 31-A1, the proportion of women and high-energy injuries were higher in IMN group versus SHS. In all AO/OTA groups, SHS was more commonly performed by a specialist. Smoking was reported by 35 % of the cohort patients and was not analyzed further due to low response rate. Otherwise, there were no significant differences in patient and fracture characteristics. The proportion of long nails vs short nails was higher in 31-A3 group vs 31-A1.
Chi^2 with column proportion tests using the Bonferroni correction was used to assess p-values.
*IMN = Intramedullary nailing. SHS = Sliding hip screw. Sig. =Significance (p-values). *p<0.05. †p<0.01. ‡p<0.001*

AO/OTA type	31-A1			31-A2			31-A3			All groups		
Primary treatment	**IMN**	**SHS**	Sig.	**IMN**	**SHS**	Sig.	**IMN**	**SHS**	Sig.	**IMN**	**SHS**	Sig.
No conversion	1816 (98.2)	3826 (98.5)		7224 (97.5)	3253 (97.8)		3627 (97.9)	399 (96.4)		12667 (97.7)	7626 (98.1)	
Conversion	34 (1.8)	60 (1.5)		184 (2.5)	73 (2.2)		78 (2.1)	15 (3.6)	*	296 (2.3)	148 (1.9)	
Reason for conversion												
- Healing disturbance	17 (0.9)	34 (0.9)		120 (1.6)	36 (1.1)	*	49 (1.3)	10 (2.4)		186 (1.4)	80 (1.0)	*
- Osteoarthritis	8 (0.4)	12 (0.3)		25 (0.3)	9 (0.3)		9 (0.2)	2 (0.5)		42 (0.3)	23 (0.3)	
- Pain					2 (0.1)						2 (0.0)	
- New fracture	5 (0.3)	6 (0.2)		23 (0.3)	15 (0.5)		15 (0.4)			43 (0.3)	21 (0.3)	
- Avascular necrosis	4 (0.2)	8 (0.2)		13 (0.2)	7 (0.2)		5 (0.1)	2 (0.5)		22 (0.2)	17 (0.2)	
- Infection				3 (0.0)	4 (0.1)			1 (0.2)		3 (0.0)	5 (0.0)	
Total	**1850**	**3886**		**7408**	**3326**		**3705**	**414**		**12963**	**7626**	
Time from injury to conversion in days, median (range)	349 (31-1663)	337.5 (1-1961)		219.5 (7-2519)	259 (20-1510)		279.5 (12-1761)	376 (23-927)		252 (7-2519)	327 (1-1961)	

Table 2: ***Primary outcome – Conversion to Arthroplasty.***
Rate of conversion to arthroplasty was significantly higher after SHS versus IMN in group 31-A3, but not in 31-A1 or 31-A2. Healing disturbance, (including mechanical complications from Swedish Fracture Register and implant failure from Swedish Arthroplasty Register), was more common after IMN in AO/OTA type 31-A2.
Chi^2 with column proportion tests using the Bonferroni correction was used to assess p-values.
*IMN = Intramedullary nailing. SHS = Sliding hip screw. Sig. =Significance (p-values). *$p<0.05$.*

A



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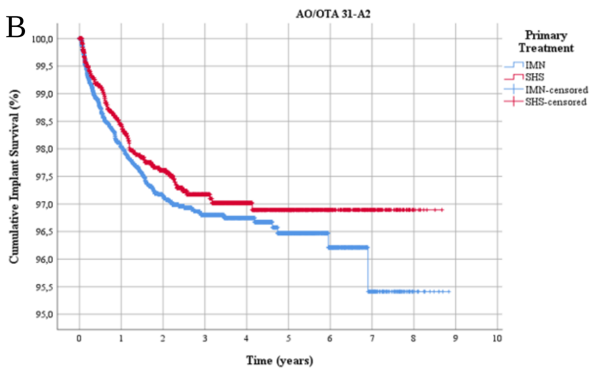

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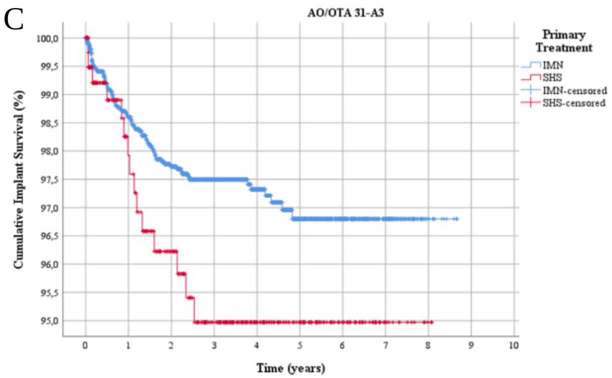


D

AO/OTA	**31-A1**		**31-A2**		**31-A3**	
Primary implant survival, % (SE)	IMN	SHS	IMN	SHS	IMN	SHS
- 1 year	98.8 (0.3)	98.9 (0.2)	98.0 (0.2)	98.4 (0.2)	98.6 (0.2)	97.9 (0.8)
- 2 years	98.1 (0.4)	98.4 (0.2)	97.1 (0.2)	97.6 (0.3)	97.7 (0.3)	96.2 (1.1)
- 3 years	97.7 (0.4)	97.9 (0.3)	96.8 (0.2)	97.2 (0.3)	97.5 (0.3)	95.0 (1.3)
- 5 years	97.0 (0.6)	97.8 (0.3)	96.5 (0.3)	96.9 (0.4)	96.8 (0.4)	95.0 (1.3)
Estimate, days (SE)	3068.395 (13.03)	3184.227 (8.382)	3118.688 (9.637)	3081.391 (9.844)	3082.468 (9.356)	2824.276 (31.728)
- 95% CI	3042.817 - 3093.972	3167.798 - 3200.656	3099.8 - 3137.577	3062.097 - 3100.684	3064.13 - 3100.997	2762.09 - 2886.463
- Chi-Square (p-value)	0.673 (0.412)		1.075 (0.3)		3.997 (0.046)	

Table 3: ***Kaplan Meier implant survival plots for conversion arthroplasty after intramedullary nailing and sliding hip screw represented in (A) AO/OTA type 31-A1, (B) AO/OTA type 31-A2, (C) AO/OTA type 31-A3, and (D) responding implant survival rates, and estimated primary implant survival according to Kaplan Meier survival analysis.***

Conversion arthroplasty was defined as an event (n=444). Deceased patients and patients who did not receive arthroplasty during follow-up time were censored at the date of death or end of follow-up, respectively. The Log Rank test shows a significantly higher implant survival for IMN compared to SHS ($p<0.05$) in 31-A3.

IMN = intramedullary nailing. SHS = sliding hip screw. SE = Standard error. 95% CI = 95% Confidence interval.

(A) Univariate analysis	B	S.E.	Wald	df	Sig.	HR	95 % C.I.	Event/censored (n)
Age	-0.041	0.005	62.466	1	<0.001	0.959	0.950 – 0.969	
Female gender	0.041	0.107	0.145	1	0.703	1.042	0.844 – 1.286	
Low-energy injury (reference)			2.009	2	0.366			
- High-energy	0.385	0.381	1.019	1	0.313	1.469	0.696 – 3.102	
- Unknown	0.215	0.210	1.050	1	0.306	1.240	0.833 – 1.871	
AO/OTA 31-A1 (reference)			10.763	2	0.005			
- 31-A2	0.395	0.121	10.763	1	0.001	1.485	1.173 – 1.881	444/20141
- 31-A3	0.286	0.146	3.825	1	0.05	1.331	0.999 – 1.773	
IMN as primary treatment	0.166	0.101	2.714	1	0.099	1.18	0.969 – 1.438	
Specialist as main surgeon (reference)			1.158	3	0.763			
- Resident	0.010	0.101	0.010	1	0.921	1.010	0.829 – 1.230	
- Junior doctor	0.226	0.504	0.201	1	0.654	1.253	0.467 – 3.364	
- Unknown	0.241	0.244	0.976	1	0.323	1.272	0.789 – 2.051	

(B) Multivariate analysis	B	S.E.	Wald	df	Sig.	HR	95% C.I.	Event/censored (n)
Age	-0.044	0.005	66.755	1	<0.001	0.957	0.947 – 0.967	
Female gender	0.208	0.111	3.541	1	0.060	1.231	0.991 – 1.529	
Low-energy injury (reference)			0.444	2	0.801			
- High-energy	0.044	0.387	0.013	1	0.909	1.045	0.489 – 2.233	
- Unknown	0.139	0.211	0.436	1	0.509	1.149	0.760 – 1.737	
AO/OTA 31-A1 (reference)			10.622	2	0.005			
- 31-A2	0.401	0.127	9.926	1	0.002	1.494	1.164 – 1.917	404/20141
- 31-A3	0.227	0.160	2.000	1	0.157	1.254	0.916 – 1.717	
IMN as primary treatment	0.063	0.111	0.319	1	0.572	1.065	0.857 – 1.323	
Specialist as main surgeon (reference)			0.861	3	0.835			
- Resident	0.21	0.102	0.044	1	0.835	1.021	0.837 – 1.247	
- Junior doctor	0.331	0.504	0.432	1	0.511	1.393	0.518 – 3.743	
- Unknown	0.165	0.245	0.454	1	0.500	1.179	0.730 – 1.904	

Table 4: (A) Univariate and (B) multivariate Cox regression analysis for conversion arthroplasty.

In univariate analysis, lower age and AO/OTA type 31-A2 were associated with conversion to arthroplasty, whereas gender, type of injury, primary treatment method and main surgeon competence were not. In multivariate analysis, the same variables remained significant versus non-significant predictors.

Reference categories used in multichotomous variables: Gender – male. Type of injury – low-energy injury. AO/OTA - type 31-A1. Primary treatment – Sliding hip screw. Main surgeon – specialist.

Event/censored represents the number of patients included in analysis.

IMN = Intramedullary nailing. S.E. = Standard error. df = Degrees of freedom. HR = Hazard ratio. C.I. = Confidence interval for Hazard ratio.

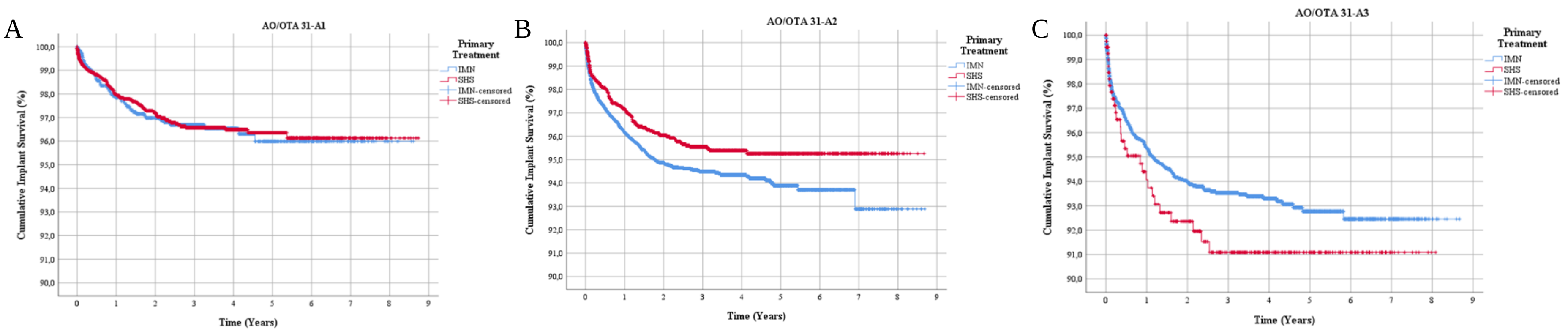
AO/OTA	31-A1			31-A2			31-A3			All groups		
Primary surgery	**IMN**	**SHS**	**Sig**	**IMN**	**SHS**	**Sig**	**IMN**	**SHS**	**Sig**	**IMN**	**SHS**	**Sig**
No reoperation, n (%)	1800 (97.3)	3783 (97.3)		7075 (95.5)	3207 (96.4)		3499 (94.4)	385 (93.0)		12374 (95.5)	7375 (96.7)	
Any reoperation, n (%)	50 (2.7)	103 (2.7)		333 (4.5)	119 (3.6)	*	206 (5.6)	29 (7.0)		589 (4.5)	251 (3.3)	‡
- Arthroplasty from SFR+SAR	30 (1.6)	58 (1.5)		161 (2.2)	67 (2.0)		56 (1.5)	13 (3.1)	*	247 (1.9)	138 (1.8)	
- Internal fixation	4 (0.2)	19 (0.5)		61 (0.8)	25 (0.8)		64 (1.7)	11 (2.7)		129 (1.0)	55 (0.7)	*
- Implant removal	11 (0.6)	13 (0.3)		62 (0.8)	16 (0.5)	*	55 (1.5)	2 (0.5)		128 (1.0)	31 (0.4)	‡
- Excision arthroplasty		3 (0.1)		9 (0.1)	2 (0.1)		1 (0.0)			10 (0.1)	5 (0.1)	
- Other unspecified reoperation	5 (0.3)	10 (0.3)		40 (0.5)	9 (0.3)		30 (0.8)	3 (0.7)		75 (0.6)	22 (0.3)	†
Reason for reoperation												‡
- Healing disturbance	25 (1.4)	59 (1.5)		208 (2.8)	73 (2.2)		125 (3.4)	21 (5.1)		358 (2.8)	153 (2.0)	†
- Osteoarthritis	7 (0.4)	10 (0.3)		21 (0.3)	8 (0.2)		9 (0.2)	1 (0.2)		37 (0.3)	19 (0.2)	
- Pain/discomfort	7 (0.4)	6 (0.2)		30 (0.4)	6 (0.2)		23 (0.6)	1 (0.2)		60 (0.5)	13 (0.2)	†
- New fracture	3 (0.2)	4 (0.1)		14 (0.2)	8 (0.2)		7 (0.2)			24 (0.2)	12 (0.2)	
- Avascular necrosis	3 (0.2)	5 (0.1)		6 (0.1)	4 (0.1)		3 (0.1)	2 (0.5)	*	12 (0.1)	11 (0.1)	
- Infection	4 (0.2)	8 (0.2)		36 (0.5)	10 (0.3)		17 (0.5)	4 (1.0)		57 (0.4)	22 (0.3)	
- Other unspecified reason	1 (0.1)	11 (0.3)		18 (0.2)	10 (0.3)		22 (0.6)			41 (0.3)	21 (0.3)	
Total	**1850**	**3886**		**7408**	**3326**		**3705**	**414**		**12963**	**7626**	

Table 5: Secondary outcome – Any reoperation.

Overall, reoperation rate was higher after IMN vs SHS. Secondary internal fixation, implant removal surgeries and other unspecified surgery was more common after IMN. Pain/discomfort and healing disturbance were more common after IMN. In 31-A2 group, IMN was associated with a higher rate of reoperations and implant removal was significantly more common after IMN compared to SHS.

Chi^2 with column proportion tests using the Bonferroni correction was used to assess p-values.

*SFR = Swedish Fracture Register. IMN = Intramedullary nailing. SHS = Sliding hip screw. Sig. = Significance (p-values). *$p<0.05$. †$p<0.01$. ‡$p<0.001$*



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AO/OTA	31-A1		31-A2		31-A3	
Primary implant survival, % (SE)	IMN	SHS	IMN	SHS	IMN	SHS
- 1 year	97.8 (0.4)	98.0 (0.2)	96.2 (0.2)	97.2 (0.3)	95.3 (0.4)	94.1 (1.3)
- 2 years	97.0 (0.5)	97.2 (0.3)	94.9 (0.3)	96.0 (0.4)	94.0 (0.4)	92.1 (1.5)
- 3 years	96.7 (0.5)	96.6 (0.3)	94.5 (0.3)	95.5 (0.4)	93.5 (0.5)	91.1 (1.6)
- 5 years	96.0 (0.6)	96.4 (0.4)	93.9 (0.4)	95.3 (0.4)	92.8 (0.5)	91.1 (1.6)
Estimate, days (SE)	3037.578 (15.043)	3086.861 (10.260)	2994.513 (10.963)	3032.601 (12.055)	2959.595 (14.171)	2712.804 (42.270)
- 95% CI	3008.095 - 3067.063	3066.753 - 3106.970	2973.026 - 3016.970	3008.973 - 3056.229	2931.820 - 2987.370	2629.955 - 2795.652
- Chi-Square (p-value)	0.015 (0.903)		5.451 (0.020)		1.625 (0.202)	

Table 6: Any reoperation - Kaplan Meier implant survival plot for (A) AO/OTA 31-A1, (B) AO/OTA 31-A2, and (C) AO/OTA 31-A3, and (D) corresponding implant survival table and estimated implant survival time according to Kaplan Meier analysis.

Any reoperation after primary treatment was defined an "event". Deceased patients and patients who did not receive reoperation were censored at the date of death or end of follow-up, respectively. SHS was associated with significantly higher estimated implant survival in AO/OTA 31-A2.
IMN = intramedullary nailing. SHS = sliding hip screw. S.E. = Standard error. 95% C.I. = 95 % confidence interval.

(A) Univariate analysis	B	S.E.	Wald	df	Sig.	HR	95% C.I.	Event/censored (n)
Age	-0.044	0.004	137.103	1	<0.001	0.957	0.949 – 0.964	
Female gender	-0.051	0.076	0.450	1	0.502	0.950	0.818 – 1.103	
Low-energy injury (reference)			14.099	2	0.001			
- High-energy	0.838	0.232	13.015	1	<0.001	2.312	1.466 – 3.644	
- Unknown	0.181	0.155	1.365	1	0.243	1.199	0.885 – 1.624	
AO/OTA 31-A1 (reference)			52.569	2	<0.001			
- 31-A2	0.476	0.094	25.845	1	<0.001	1.609	1.339 – 1.933	840/19743
- 31-A3	0.753	0.104	52.488	1	<0.001	2.123	1.732 – 2.602	
IMN as primary treatment	0.332	0.075	19.381	1	<0.001	1.394	1.202 – 1.615	
Specialist as main surgeon (reference)			3.200	3	0.362			
- Resident	0.011	0.073	0.24	1	0.876	1.011	0.876 – 1.167	
- Junior doctor	0.137	0.381	0.130	1	0.719	1.147	0.544 – 2.418	
- Unknown	0.303	0.173	3.085	1	0.079	1.354	0.965 – 1.899	

(B) Multivariate analysis	B	S.E.	Wald	df	Sig.	HR	95% C.I.	Event/censored (n)
Age	-0.045	0.004	130.056	1	<0.001	0.956	0.949 – 0.964	
Female gender	0.112	0.079	2.010	1	0.156	1.118	0.958 – 1.304	
Low-energy injury (reference)			2.827	2	0.243			
- High-energy	0.366	0.238	2.376	1	0.123	1.442	0.905 – 2.297	
- Unknown	0.114	0.155	0.538	1	0.463	1.121	0.826 – 1.520	
AO/OTA 31-A1 (reference)			34.804	2	<0.001			
- 31-A2	0.469	0.098	22.697	1	<0.001	1.599	1.318 – 1.939	840/19743
- 31-A3	0.699	0.115	33.996	1	<0.001	1.951	1.559 – 2.443	
IMN as primary treatment	0.112	0.083	1.812	1	0.178	1.119	0.950 – 1.317	
Specialist as main surgeon (reference)			2.615	3	0.455			
- Resident	0.048	0.074	0.424	1	0.515	1.049	0.908 – 1.213	
- Junior doctor	0.311	0.381	0.666	1	0.414	1.365	0.647 – 2.880	
- Unknown	0.237	0.173	1.873	1	0.171	1.268	0.903 – 1.780	

Table 7: (A) Univariate and (B) multivariate Cox regression analysis for any reoperation.

In univariate analysis, lower age, high-energy injury, AO/OTA types 31-A2 and 31-A3, and intramedullary nailing as primary treatment were predictors of any reoperation, whereas gender and main surgeon experience were not significant predictors. In multivariate analysis, age, AO/OTA types 31-A2 and 31-A3 remained significant predictors.

Reference categories used in multichotomous variables: Gender – male. Type of injury – low-energy injury. AO/OTA - type 31-A1. Primary treatment – Sliding hip screw. Main surgeon – specialist.

Event/censored represents the number of patients included in analysis.

IMN = Intramedullary nailing. S.E. = Standard error. df = Degrees of freedom. HR = Hazard ratio. C.I. = Confidence interval for Hazard ratio.