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Lääketieteellinen tiedekunta

PANULA, VALTTERI:
Tekonivelen sijoiltaanmenoon myötävaikuttavat tekijät lonkan tekonivelleikkauksen jälkeen

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Lonkan kokotekonivelleikkauksen jälkeinen sijoiltaanmenoriski on suurin ensimmäisten kolmen kuukauden aikana tekonivelleikkauksesta. Ensimmäisen vuoden aikana leikkauksesta sijoiltaanmenoja tapahtuu 66–69 %:ia. Sijoiltaanmenon vuoksi ensimmäisiä uusintaleikkauksia tehdään 17–21 %:ia lonkan kokotekonivelleikkauksen jälkeen. Sijoiltaanmenoriski on yleensä uusintaleikkauksen jälkeen suurempi verrattuna primaarileikkaukseen.

Sijoiltaanmenoriskiin yhdistetyt riskitekijät on pyritty luokittelemaan sekä potilas- että leikkausriippuvaisiin tekijöihin, mutta käytännössä useat eri tekijät vaikuttavat samanaikaisesti sijoiltaanmenoriskiin. Tämän tutkimuksen tarkoituksena oli selvittää lonkan primaaritekonivelleikkauksen jälkeiseen sijoiltaanmenoriskiin yhteydessä olevat tekijät käyttämällä apuna uudistettua Suomen Endoproteesirekisterin tietokantaa.

Tutkimusaineistoon sisällytettiin yhteensä 33 661 lonkan primaaritekonivelleikkausta vuosilta 2014–2018. Aineistoon sisältyi myös potilaita, joilta oli operoitu toinen tai molemmat lonkat. Tutkimuksen päätapahtumaksi määriteltiin mitkä tahansa tekonivelen osan poistot tai vaihdot, jotka johtuivat sijoiltaanmenosta. Sijoiltaanmenoriskiin yhteydessä olevat tekijät määritettiin Coxin yksi- ja monimuuttujamallien avulla. Ensimmäisiä uusintaleikkauksia sijoiltaanmenon takia tehtiin 265 kappaletta tutkimuksemme seuranta-aikana. Suurentunut riski sijoiltaanmenolle oli potilailla, jotka leikattiin taka-avauksessa ja joilla leikkaukseen johtanut syy oli reisiluun kaulan murtuma ja joiden ASA-luokka oli III–IV. Vastaavasti pienempi riski sijoiltaanmenolle oli tekonivelissä, joiden nupin halkaisija oli 36 mm verrattuna tekoniveliin, joiden nupin halkaisija oli 32 mm.

Potilaan uusintaleikkausriskiä tekonivelen sijoiltaanmenon takia kasvattivat murtuma toimenpiteen syynä, taka-avaus, korkeampi ASA-luokka ja pienempi nuppikoko. Mikäli potilaalla on useampi edellä mainituista riskitekijöistä, tulisi niihin kiinnittää erityistä huomiota potilaan hoidossa, jotta tulevaisuudessa pystyttäisiin vähentämään lonkan tekonivelten sijoiltaanmenojen lukumäärää.

Avainsanat: lonkan tekonivelleikkaus, uusintaleikkaus, sijoiltaanmeno

Posterior approach, fracture diagnosis and ASA class III–IV are associated with increased risk of revision for dislocation after total hip arthroplasty: An analysis of 33,337 operations from the Finnish Arthroplasty Register.

Risk factors for dislocation after total hip arthroplasty.

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Abstract

Background & Aims

Dislocation is one of the most common reasons for revision surgery after primary total hip arthroplasty (THA). Both patient related and surgical factors may influence the risk of dislocation. In this study we evaluated risk factors for dislocation revision after THA based on revised data contents of the Finnish Arthroplasty Register (FAR).

Materials and Methods

We analysed 33,337 primary THAs performed between May 2014 and January 2018 in Finland. Cox proportional hazards regression was used to estimate hazard ratios with 95% confidence intervals for first dislocation revision using 18 potential risk factors as covariates, such as age, sex, diagnosis, hospital volume, surgical approach, head size, BMI, ASA class, and fixation method.

Results

During the study period there were 264 first time revisions for dislocation after primary THA. Hazard ratio for dislocation revision was 3.1 (CI 1.7–5.5) for posterior compared to anterolateral approach, 3.0 (CI 1.9–4.7) for THAs performed for femoral neck fracture compared to THAs performed for osteoarthritis, 2.0 (CI 1.0–3.9) for ASA class III–IV compared to ASA class I, and 0.5 (0.4–0.7) for 36 mm femoral head size compared to 32 mm head size.

Conclusion

Special attention should be paid on patients with fracture diagnoses and ASA class III–IV. Anterolateral approach and 36 mm femoral heads decrease dislocation revision risk and should be considered for high risk patients.

Keywords

Total hip arthroplasty; revision; dislocation; ASA class; surgical approach; femoral neck fracture; femoral head size

Introduction

Dislocation is one of the most common reasons for revision surgery after primary total hip arthroplasty (THA) covering 17-21% of all first time revisions (1,2). Dislocation incidence during the first postoperative year after primary THA varies from 2% to 4% (3–5). The risk of dislocation is highest during the first 3 postoperative months, but dislocations may also occur later (3). Majority of the dislocations, from 66% to 69% occur during the first postoperative year (3,6,7).

Both patient related and surgical factors may predispose to THA dislocation. Posterior approach, poor component positioning, small femoral head size, implant choice, poor repair of soft-tissues and surgeon experience have generally been accepted as risk factors for surgery related dislocations (3,4,6–8). Patient related risk factors for dislocation reported in earlier studies have been higher American Society of Anesthesiologist (ASA) class, female sex, older age, operative diagnosis, and neurological and cognitive disorders (3,6,7). In practice, the reason for THA dislocation is often multifactorial and patient-specific (9,10). Further, dislocation risk after revision surgery is remarkably higher than that after primary THA (10).

The Finnish Arthroplasty Register (FAR) has been collecting information on THAs since 1980. In earlier data from the FAR from 1996 to 2010 larger femoral head size clearly reduced the risk of dislocation (11). However, these data included several thousands of large head metal-on-metal THAs and hip resurfacing arthroplasties (HRA), which have been abandoned since then due to metal bearing related complications. The data contents of FAR has also been thoroughly revised in 2014 to include parameters such as surgical approach, BMI, ASA class, intra-operative bleeding and duration of the operation. Post data content revision FAR data on the dislocation risk have not been assessed earlier.

The objective of this study was to determine risk factors for revision for dislocation after primary THA first time in Finland based on the prospectively collected FAR data from 2014 to

2018 with the revised data contents. This is assessed now since some of the used variables have not been available in the FAR earlier.

Material and Methods

In Finland all orthopaedic units are obliged to provide all information essential for maintenance of the Finnish Arthroplasty Register to the Finnish National Institute for Health and Welfare. Dates of death are obtained from the Population Register Centre. Data completeness in primary THA in the FAR has varied from 91.1% to 95.2% during the years 1997–2015 (12). For revision THA data completeness is 85% (2). Finland is a relatively small country where registries and the healthcare system are publicly funded with 100% coverage of hospitals. In case of death patients are censored from the registry, and this information is updated regularly. Since May 19th 2014, all FAR THA data on implant components have been recorded electronically based on bar code reading. The data contents of FAR were also revised in 2014 also to include several new variables. These are: surgical approach, BMI, ASA class, intra-operative bleeding, duration of the operation, level of education of surgeon and assistant, mode of anesthesia, intra-operative complications, and previous operations. The end of the follow up time of the current study was January 31, 2018. Patient's minimum follow-up time ranged between 0–3.5 years. Revisions were linked to the primary operation through a patient specific personal identification number and laterality. The survival endpoint was defined as revision where any component, including isolated liner exchange, was removed or exchanged due to dislocation. Data from 33,337 uni- and bilateral THAs performed in Finland between years 2014 and 2018 were extracted from FAR and included in our study (Table 1).

Kaplan–Meier analysis was used to estimate the unadjusted cumulative revision probabilities for dislocation, with 95% confidence intervals (CI). Univariate and multivariable Cox proportional hazards regression models were used to estimate hazard ratios with 95% confidence intervals for first dislocation revision. Proportional hazards assumption of the Cox model was assessed by visual inspection of Kaplan-Meier curves and by using a test based on the scaled Schoenfeld residuals (13). Since sex did not fulfill the assumption of proportional hazards, it was used as a stratification variable. After stratification, only comparison ASA class I vs. ASA class II in the multivariable model showed minor violation of the proportional hazards according to the Schoenfeld residuals test (P=0.04). The corresponding Kaplan-Meier plot is available as an online appendix. However, we decided to present the data as such, not dividing follow-up in different time periods, to make our results easier to comprehend. We also performed a sensitivity analysis for the findings obtained for different surgical approaches using univariate Cox proportional hazards regression analysis in a subpopulation concerning only so called healthy standard patients (primary OA, ASA class I–II, cementless or hybrid THA, metal-on-UHXLPE or ceramic-on-UHXLPE bearing surface and head size 36 mm). Additionally, we assessed how the used surgical approach affected to the occurrence of revision due to dislocation among the patients with a diagnosis of femoral neck fracture. The following risk factors were considered as covariates: age group (⩽ 55, 56–65, 66–75, ⩾ 76 years), sex, diagnosis (primary osteoarthritis, fracture, other), hospital volume (low, medium, high), surgical approach (posterior, anterolateral, anterior), head size (28, 32, 36, >36 mm), BMI (< 25, 25–30, > 30 kg/m^2), ASA class (I, II, III–IV), fixation method (cementless, cemented, hybrid, reverse hybrid), previous operation to the same joint like osteotomy or osteosynthesis (yes, no), level of education of the surgeon (specialist, resident), level of education of the first assistant (specialist, resident, other), bleeding (<500ml, ⩾500ml), duration of the operation (minutes), anesthesia form (spinal, epidural, general), local infiltrative anesthesia (LIA) (yes, no), perioperative complication during surgery (no complication, calcar fracture, trochanteric fracture, femoral shaft fracture, acetabular fracture), bearing surface used (ceramic-on-ceramic, ceramic-on-ultra-highly cross-linked polyethylene (UHXLPE), metal-on-UHXLPE, ceramized metal-on-UHXLPE, other), and use of oblique liner (yes, no). The classification of the hospitals to the different volume groups was based on the average number of primary THAs performed annually during the study period: less than 240 (low), 240–480 (medium) and more than 480 (high). The number of hips available for analyses for each variable are presented in Table 1 and Appendix 1, so the number of missing values can be seen. Only patients without any missing data for variables of interest (N=21,706) were included in the final multivariable models. All statistical analyses were carried out using R version 3.4.2 (R Development Core Team, http://www.r-project.org). Implant survival was analyzed using R package *survival* (14). The level of significance was set at p< 0.05.

Results

In the present study we analyzed data from 33,337 THAs performed in Finland between years 2014 and 2018 (Table 1). Largest age group in terms of performed primary THA were the patients from 66 to 75 years (37%). Majority of the study population were women (19,002; 57%). Most of the patients had an ASA class II (49%) or combined III and IV (39%), and received a THA with cementless fixation (62%) and with a metal-on-UHXLPE (50%) or ceramic-on-UHXLPE (28%) bearing surface. The main reason for primary THA was primary osteoarthritis (87%) and the most common surgical approach was posterior approach (80%) (Table 1). The overall Kaplan–Meier survival revision for dislocation as the end-point at 3.5 years was 98.9% (CI: 98.8–99.1).

Posterior surgical approach was significantly associated with increased risk of revision for dislocation when compared to the anterolateral approach in both univariate analysis [HR 2.6 (CI 1.7–4.1, p<0.001)] (Table 2) and in multivariable analysis [HR of 3.1 (CI 1.7–5.5, p<0.001)] (Table 3). Anterior approach was not associated to dislocation revision in univariate analysis [HR 2.9 (CI 0.9–9.6), p=0.09] (Table 2), but in multivariable analysis anterior approach had an increased risk of revision [HR 3.6 (CI 1.0–13.1), p=0.05] (Table 3). In the sensitivity analysis HR for posterior compared to anterolateral approach for dislocation revision was 2.1 (CI 0.7–5.8, p=0.2). Also, THAs performed for femoral neck fracture had an increased risk of revision for dislocation when compared to THAs performed for primary OA in univariate analysis [HR 3.6 (CI 2.5–5.2, p<0.001)] (Table 2), and in multivariable analysis [HR 3.0 (CI 1.9–4.7, p<0.001)] (Table 3). Patients who received THA for other reasons were not associated to dislocation revision in univariate analysis [HR 1.5 (CI 1.0–2.1), p=0.05] (Table 2) or in multivariable analysis [HR 1.4 (CI 0.9–2.2), p=0.2] (Table 3).

Patients with higher ASA class had significantly increased risk of revision for dislocation in univariate analysis [ASA II vs. ASA I HR 1.8 (CI 1.0–3.0, p=0.03) and ASA III–IV vs. ASA I HR 2.7 (CI 1.6–4.5, p<0.001)], and in multivariable analysis [ASA III–IV vs. ASA I HR 2.0 (CI 1.0–3.9, p=0.04)] (Tables 2 and 3). In the multivariable analysis ASA class II compared to ASA class I was not significant [HR 1.7 (CI 0.9–3.3, p=0.09)](Table 3).

The use of 36 mm femoral head size decreased the risk of revision for dislocation compared to 32 mm head in univariate analysis [HR 0.6 (CI 0.5–0.8, p<0.001)] (Table 2), and in multivariable analysis [HR 0.5 (CI 0.4–0.7, p<0.001)] (Table 3). We found no association between the risk for dislocation revision and the use of other head sizes (28 mm and >36 mm) in univariate analysis [28 mm vs. 32 mm HR 0.8 (CI 0.2–2.4, p=0.7) and >36 mm vs. 32 mm HR 1.1 (CI 0.4–3.1, p=0.8)], or in multivariable analysis [28 mm vs. 32 mm HR 0.5 (CI 0.1–3.4, p=0.4) and >36 mm vs. 32 mm HR 0.4 (CI 0.0–2.6, p=0.3)] (Tables 2 and 3).

We found a significantly increased risk of revision for dislocation in univariate, but not in multivariable analysis for the following parameters: high hospital volume vs. low hospital volume; intraoperative bleeding ≥ 500 ml vs < 500ml; the use of epidural anesthesia; and cemented or hybrid fixation vs. cementless fixation (Table 2). There was a significantly decreased risk of revision for dislocation in the univariate but not in the multivariable analysis for: the use of LIA; and ceramic-on-ceramic, ceramic-on-UHXLPE, or ceramized metal-on-UHXLPE vs. metal-on-UHXLPE (Table 2).

The demographics of the used surgical approaches and the occurrence of revision due to dislocation among the patients with femoral neck fracture diagnosis are described in the Table 4. There were dislocation revisions only among patients who had been operated using posterior approach (Table 4). Therefore, we were not able to perform further statistical analyses on subject.

Data on all tested variables can be found from Appendix 1 – 3.

Discussion

Dislocation is still one of the main reasons for revision operation after primary THA (2,15,16). We used FAR data from 2014 to 2018 to assess risk factors for dislocation revisions after the primary THA and found that in our material posterior approach, fracture diagnosis, and ASA class III–IV increased dislocation revision risk when compared to anterolateral approach, primary OA diagnosis, and ASA class I. In addition, in our study femoral head size 36mm had decreased dislocation revision risk compared to head size 32mm.

We found that posterior approach was associated with increased risk for dislocation revision compared to anterolateral approach. Similar results have also been found in previous studies (7,17,18). In the Dutch Arthroplasty Register revision for dislocation risk has been from 0.5 to 0.6 for the straight lateral, anterolateral, and anterior approaches while when compared to posterior approach (8). A Norwegian register study found 2.1-fold risk for dislocation revision for posterior approach compared to the anterolateral approach (18). It has previously been suggested that patients belonging to risk groups should be operated using lateral approaches (7). Our results support this proposal. Anterior approach had an increased risk of revision due to dislocation compared to the anterolateral approach in the current study, but the total amount of THAs performed using anterior approach was very small. In sensitivity analysis the difference of dislocation revision rate between posterior and anterolateral approach was no longer statistical significant. Sensitivity analysis included approximately 21% of all operations included, so lower power may be the reason for the non-significant result. Anterior and posterior approaches have been associated to have better patient reported outcome measures compared to anterolateral and direct lateral approaches. Patients operated on posterior approach had less postoperative pain in Numeric Rating Scale (NRS) pain scores during the activity and in rest compared to patients operated on anterolateral approach (19). In the present study there were dislocation revisions only among patients` with pre–operative femoral neck fracture diagnosis who were operated on posterior approach. This finding is consistent with those of prior studies (20–22).

Australian registry has reported two times higher and the Swedish registry four times higher dislocation revision risk for patients whose THA was operated due to femoral neck fracture compared to patients who were operated due to OA (7,23). Our results are in accordance with these registry findings with 3-fold dislocation revision risk for THA operated due to femoral neck fractures compared to those operated for primary OA. Special attention on implant choice and approach should be followed when treating fracture patients.

Another factor associated with increased dislocation revision risk in our multivariable model was ASA class III–IV compared to ASA class I. A previous study stated that patients with an ASA class of II or higher had an increased risk of dislocation in the Dutch Register (8). In our data, ASA class II was a risk factor only in univariate analysis, but otherwise our results support the findings from the Dutch Register. Patients with increased ASA class have more comorbidities and are more fragile which might predispose them for dislocations. In addition, threshold to operate these patients may be higher and, therefore, the primary situation may already be more demanding which might increase the dislocation risk.

Large femoral head size has been previously associated with a decreased risk of revision for dislocation. Based on FAR data on 42,379 THAs and HRAs, the use of 28 mm femoral heads has been reported to have 10-fold dislocation revision risk compared to the >36 mm femoral heads (11). However, this previous study included several thousand large head metal-on-metal THAs and HRAs and, therefore, is not directly comparable to the current study, which did not include any metal-on-metal bearings. In previous studies the dislocation revision risk has been reported to be equal for 32 and 36 mm heads (7,11). A large registry study conducted by the Nordic Arthroplasty Registry Association from 2003 to 2014 found no difference between 36 mm and 32 mm heads in relation to dislocation revision risk (24), contrary to our current finding of lower risk with 36 mm heads. A recent report from the Dutch Arthroplasty Register stated that 36 mm heads reduced the risk of revision for dislocation compared to 32 mm heads, although, this finding considered only THAs performed from the posterior approach (8). Based on these most recent data, 36 mm femoral heads should be considered instead of 32 mm heads for patients with high dislocation risk.

A study of 192,275 THAs from Australia found a higher risk of revision for dislocation for the 36 mm femoral heads with the metal-on-XLPE bearing compared to ceramic-on-cross-linked polyethylene, and ceramic-on-ceramic bearing surfaces (25). Based on our research bearing surface material was not, at short term, associated with dislocation revision rate. Further, oblique liners intended to prevent dislocations did not reduce dislocation revision risk compared to conventional liners in our study. However, we did not assess oblique liners implant wise. It is possible that there are individual products which are effective in this respect. Further research is needed to assess the possible dislocation preventive effect of oblique liners.

Previous literature has presented multiple other factors possibly associated with dislocation risk. One study from the New Zealand registry found lower dislocation revision risk for cemented implants (26). Even though majority of the studies have not found any association between age and dislocation risk (7,11,23), contradictive data also exists (27). Relationship between sex and dislocation rate has as well been conflicting in earlier literature (7,23). In our data, sex and age did not have significant associations with dislocation revision risk in either uni- or multivariable analysis. Fixation type, and hospital volume were associated with dislocation revision in the univariate analysis, however, these differences diminished in the multivariable model. Based on our data intra-operative bleeding, mode of anesthesia, duration of the operation, level of education, previous operations or intra-operative complications were not associated with dislocation revision rate, and we are not aware of any opposite findings.

We acknowledge that our study has several limitations. Comorbidity data of the patients were not available, although ASA class presents a crude estimate of medical condition. In addition, we were unable to assess radiographs and implant positioning. Further, we did not have data on closed repositions of dislocated THA. It is possible that some patients have suffered one or two dislocation and their hip has stabilized after that without a revision operation.

In conclusion, posterior approach compared to anterolateral approach, fracture diagnosis compared to primary OA and ASA class III–IV compared to ASA class I were associated with increased risk for dislocation revision. Head size 36mm was associated with decreased revision risk compared to 32mm heads. These factors should be taken in to consideration especially while treating patients with increased dislocation risk.

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Figure Legends

Table 1. Demographic data.

Table 2. Univariate analysis of possible predictors for revision for dislocation.

Table 3. Statistically significant predictors for revision for dislocation in the multivariable analysis. Only patients without any missing data for variables of interest (N=21,706) were included in the final multivariable models.

Table 4. The used surgical approaches and the occurrence of revision due to dislocation among patients with femoral neck fracture diagnosis (N=1,366).

Contribution of authors

All authors participated in designing the protocol. MV, RK and LE performed statistical analyses. All the authors participated in interpreting the results, and writing and revising of the manuscript. All the authors read and approved the final manuscript.

Table 1. Demographic data.

	N / mean	% / S.D.	N / mean revision for dislocation	% / S.D.
Number of hips	33337		264	
Age				
≤ 55	4507	14	29	11
56–65	8333	25	55	20
66–75	12399	37	99	38
≥ 76	8091	24	81	31
Number of hips available	33330		264	
Sex				
Female	19002	57	161	61
Male	14317	43	103	39
Number of hips available	33319		264	
ASA class				
I	4013	12	16	6
II	16117	49	112	43
III–IV	12567	39	133	51
Number of hips available	32697		261	
Preoperative diagnosis				
OA	27965	87	192	76
Fracture	1366	4	33	13
Other	2984	9	30	11
Number of hips available	32315		255	
Surgical approach				
Anterolateral (modified Hardinge)	6151	19	22	9
Posterior	26203	80	235	90
Anterior (Smith–Peterson)	298	1	3	1
Number of hips available	32652		260	
Intraoperative bleeding				
< 500 ml	21839	70	159	63
≥ 500 ml	9542	30	94	37
Number of hips available	31381		253	
Anesthesia form (compared to all others)				
Epidural	791	2	13	4

Spinal	30119	76	237	78
General	2532	6	21	7
Nerve block	6	0	0	0
LIA	6237	16	34	11
Number of hips available	32604		260	
Fixation				
Cementless	18655	62	133	54
Cemented	3008	10	33	13
Hybrid	6837	23	69	28
Reverse hybrid	1650	5	12	5
Number of hips available	30150		247	
Bearing				
Metal-on-UHXLPE	12652	50	132	63
Ceramic-on-ceramic	2786	11	13	6
Ceramic-on-UHXLPE	7063	28	51	24
Ceramized metal-on-UHXLPE	1445	6	3	2
Other	1161	5	11	5
Number of hips available	25107		210	
Femoral head size (mm)				
28	347	1	3	1
32	7836	24	87	35
36	23958	74	158	63
>36	311	1	4	1
Number of hips available	32452		252	

N = number, ASA class = American Society of Anesthesiology classification, OA = primary osteoarthritis, LIA = local infiltrative anesthesia, UHXLPE = ultra-highly crosslinked polyethylene

Table 2. Univariate analysis of possible predictors for revision for dislocation.

	Hazard ratio	95% CI	p-value
Age			0.05
≤ 55	Reference		
56–65	1.0	0.7 – 1.6	0.9
66–75	1.2	0.8 – 1.9	0.3
≥ 76	1.6	1.0 – 2.4	0.04
ASA class			<0.001
I	Reference		
II	1.8	1.0 – 3.0	0.03
III–IV	2.7	1.6 – 4.5	<0.001
Surgical approach			<0.001
Anterolateral (modified Hardinge)	Reference		
Posterior	2.6	1.7 – 4.1	<0.001
Anterior (Smith–Peterson)	2.9	0.9 – 9.6	0.09
Femoral head size (mm)			0.002

28	0.8	0.2 – 2.4	0.7
32	Reference		
36	0.6	0.5 – 0.8	<0.001
>36	1.1	0.4 – 3.1	0.8
Preoperative diagnosis			<0.001
OA	Reference		
Fracture	3.6	2.5 – 5.2	<0.001
Other	1.5	1.0 – 2.1	0.05
Intraoperative bleeding			
< 500 ml	Reference		
≥ 500 ml	1.3	1.0 – 1.7	0.04
Anesthesia form (compared to all others)			
Epidural	2.0	1.2 – 3.6	0.01
Spinal	0.8	0.5 – 1.3	0.3
General	1.1	0.7 – 1.7	0.7
LIA	0.6	0.5 – 0.9	0.02
Bearing			<0.001
Metal-on-UHXLPE	Reference		
Ceramic-on-ceramic	0.4	0.2 – 0.7	0.003
Ceramic-on-UHXLPE	0.7	0.5 – 1.0	0.03
Ceramized metal-on-UHXLPE	0.2	0.1 – 0.6	0.006
Other	0.9	0.5 – 1.6	0.7
Fixation			0.02
Cementless	Reference		
Cemented	1.6	1.1 – 2.4	0.01
Hybrid	1.4	1.1 – 1.9	0.01
Reverse hybrid	1.4	0.8 – 2.5	0.3
Hospital volume			0.06
Low	Reference		
Medium	1.3	1.0 – 1.8	0.08
High	1.4	1.0 – 1.9	0.03

ASA class = American Society of Anesthesiology classification, OA = primary osteoarthritis, LIA = local infiltrative anesthesia, UHXLPE = ultra-highly crosslinked polyethylene

Table 3. Statistically significant predictors for revision for dislocation in the multivariable analysis. Only patients without any missing data for variables of interest (N=21,706) were included in the final multivariable models.

	Hazard ratio	95% CI	p-value
ASA class			0.09
I	Reference		
II	1.7	0.9 – 3.3	0.09
III–IV	2.0	1.0 – 3.9	0.04
Surgical approach			<0.001
Anterolateral (modified Hardinge)	Reference		
Posterior	3.1	1.7 – 5.5	<0.001

Anterior (Smith–Peterson)	3.6	1.0 – 13.1	0.05
Femoral head size (mm)			0.004
28	0.5	0.1 – 3.4	0.4
32	Reference		
36	0.5	0.4 – 0.7	<0.001
>36	0.4	0.0 – 2.6	0.3
Preoperative diagnosis			<0.001
OA	Reference		
Fracture	3.0	1.9 – 4.7	<0.001
Other	1.4	0.9 – 2.2	0.2
Bearing			0.1
Metal-on-UHXLPE	Reference		
Ceramic-on-ceramic	0.6	0.3 – 1.3	0.2
Ceramic-on-UHXLPE	0.9	0.6 – 1.3	0.5
Ceramized metal-on-UHXLPE	0.3	0.1 – 1.0	0.06
Other	0.6	0.2 – 1.3	0.2

ASA class = American Society of Anesthesiology classification, OA = primary osteoarthritis, UHXLPE = ultra-highly crosslinked polyethylene

Table 4. The used surgical approaches and the occurrence of revision due to dislocation among patients with femoral neck fracture diagnosis (N=1,366).

Characteristic	Total number of patients with pre-operative femoral neck fracture			Number of revisions due to dislocation			Number of patients without subsequent dislocation		
	N available	N	%	N available	N	%	N available	N	%
Number of hips	1366			33			1333		
Surgical approach	1341			33			1308		
Anterolateral (modified Hardinge)		247	(18)		0	(0)		247	(19)
Posterior		1083	(81)		33	(100)		1050	(80)
Anterior (Smith–Peterson)		11	(1)		0	(0)		11	(1)

Appendices

Appendix 1. Patient and surgical characteristics at the time of primary operation.

Values are mean S.D. for continuous variables and total number (%) for categorical variables.

Characteristic	Total			Dislocation			No dislocation		
	N available	N / mean	% / S.D.	N available	N / mean	% / S.D.	N available	N / mean	% / S.D.
Number of hips	33337			264			33073		
Age (years)	33330			264			33066		
≤ 55		4507	(13.5)		29	(11.0)		4478	(13.6)
56–65		8333	(25.0)		55	(20.8)		8278	(25.0)
66–75		12399	(37.2)		99	(37.5)		12300	(37.2)
≥ 76		8091	(24.3)		81	(30.7)		8010	(24.2)
Sex	33319			264			33055		
Male		14317	(43.0)		103	(39.0)		14214	(43.0)
Female		19002	(57.0)		161	(61.0)		18841	(57.0)
ASA physical status classification	32697			261			32436		
ASA I		4013	(12.3)		16	(6.1)		3997	(12.3)
ASA II		16117	(49.3)		112	(42.9)		16005	(49.4)
ASA III–IV		12567	(38.4)		133	(51.0)		12434	(38.3)
Body mass index (kg/m2)	30045			239			29806		
< 25		8345	(27.8)		68	(28.5)		8277	(27.8)
25–30		12309	(41.0)		100	(41.8)		12209	(40.9)
> 30		9391	(31.2)		71	(29.7)		9320	(31.3)
Preoperative diagnosis	32315			255			32060		
Primary osteoarthritis		27965	(86.6)		192	(75.3)		27773	(86.6)
Fracture		1366	(4.2)		33	(12.9)		1333	(4.2)
Other		2984	(9.2)		30	(11.8)		2954	(9.2)
Hospital volume	33333			264			33069		
Low		13042	(39.1)		86	(32.6)		12956	(39.2)
Medium		10279	(30.9)		87	(32.9)		10192	(30.8)
High		10012	(30.0)		91	(34.5)		9921	(30.0)
Level of education (surgeon)	29853			237			29616		
Orthopedic specialist		28438	(95.3)		223	(94.1)		28215	(95.3)
Resident		1415	(4.7)		14	(5.9)		1401	(4.7)
Level of education (assistant)	29003			232			28771		
Orthopedic specialist		2877	(9.9)		25	(10.8)		2852	(9.9)

Resident		8162	(28.2)		66	(28.4)		8096	(28.2)
No		1189	(4.1)		6	(2.6)		1183	(4.1)
Other		16775	(57.8)		135	(58.2)		16640	(57.8)
Surgical approach	32652			260			32392		
Anterolateral (modified Hardinge)		6151	(18.8)		22	(8.5)		6129	(18.9)
Posterior		26203	(80.3)		235	(90.4)		25968	(80.2)
Anterior (Smith–Peterson)		298	(0.9)		3	(1.1)		295	(0.9)
Intraoperative bleeding	31381			253			31128		
< 500 ml		21839	(69.6)		159	(62.8)		21680	(69.6)
≥ 500 ml		9542	(30.4)		94	(37.2)		9448	(30.4)
Duration (min)	27645	78	(28)	220	79	(30)	27425	78	(28)
Anesthesia (spinal)	32604			260			32344		
No		2485	(7.6)		23	(8.8)		2462	(7.6)
Yes		30119	(92.4)		237	(91.2)		29882	(92.4)
Anesthesia (epidural)	32604			260			32344		
No		31813	(97.6)		247	(95.0)		31566	(97.6)
Yes		791	(2.4)		13	(5.0)		778	(2.4)
Anesthesia (general)	32604			260			32344		
No		30072	(92.2)		239	(91.9)		29833	(92.2)
Yes		2532	(7.8)		21	(8.1)		2511	(7.8)
Anesthesia (nerve block)	32604			260			32344		
No		32598	(100.0)		260	(100.0)		32338	(100.0)
Yes		6	(0.0)		0	(0.0)		6	(0.0)
Anesthesia (LIA)	32604			260			32344		
No		26367	(80.9)		226	(86.9)		26141	(80.8)
Yes		6237	(19.1)		34	(13.1)		6203	(19.2)
Complications during surgery (fracture)	31395			249			31146		
No		30993	(98.7)		246	(98.8)		30747	(98.7)
Yes		402	(1.3)		3	(1.2)		399	(1.3)
Previous operation to the same joint	28071			220			27851		
No		27466	(97.8)		212	(96.4)		27254	(97.9)
Yes		605	(2.2)		8	(3.6)		597	(2.1)
Fixation	30150			247			29903		
Cementless		18655	(61.9)		133	(53.8)		18522	(61.9)
Cemented		3008	(10.0)		33	(13.4)		2975	(10.0)
Hybrid		6837	(22.7)		69	(27.9)		6768	(22.6)
Reverse hybrid		1650	(5.4)		12	(4.9)		1638	(5.5)
Bearing	25107			210			24897		

Metal-on-UHXLPE	12652	(50.4)	132	(62.9)	12520	(50.3)
Ceramic-on-ceramic	2786	(11.1)	13	(6.2)	2773	(11.1)
Ceramic-on-UHXLPE	7063	(28.1)	51	(24.3)	7012	(28.2)
Ceramized metal-on-UHXLPE	1445	(5.8)	3	(1.4)	1442	(5.8)
Other	1161	(4.6)	11	(5.2)	1150	(4.6)
Oblique liner	30228		228		30000	
No	23658	(78.3)	173	(75.9)	23485	(78.3)
Yes	6570	(21.7)	55	(24.1)	6515	(21.7)
Femoral head size (mm)	32452		252		32200	
32	7836	(24.1)	87	(34.5)	7749	(24.1)
36	23958	(73.8)	158	(62.7)	23800	(73.9)
>36	311	(1.0)	4	(1.6)	307	(0.9)
28	347	(1.1)	3	(1.2)	344	(1.1)

Appendix 2. Univariate analysis of all predictors with incident of revision for dislocation.

Characteristic	Hazard ratio	95% CI	p-value
Age			0.05
≤ 55	Reference		
56–65	1.0	(0.7 – 1.6)	0.9
66–75	1.2	(0.8 – 1.9)	0.3
≥ 76	1.6	(1.0 – 2.4)	0.04
ASA physical status classification			<0.001
ASA I	Reference		
ASA II	1.8	(1.0 – 3.0)	0.03
ASA III – IV	2.7	(1.6 – 4.5)	<0.001
Body mass index (kg/m2)			0.9
< 25	Reference		
25 – 30	1.0	(0.7 – 1.3)	0.9
> 30	0.9	(0.7 – 1.3)	0.7
Preoperative diagnosis			<0.001
Primary osteoarthritis	Reference		
Fracture	3.6	(2.5 – 5.2)	<0.001
Other	1.5	(1.0 – 2.1)	0.05
Hospital volume			0.06
Low	Reference		
Medium	1.3	(1.0 – 1.8)	0.08
High	1.4	(1.0 – 1.9)	0.03
Level of education (surgeon)			
Orthopedic specialist	Reference		
Resident	1.2	(0.7 – 2.1)	0.4
Level of education (assistant)			0.6

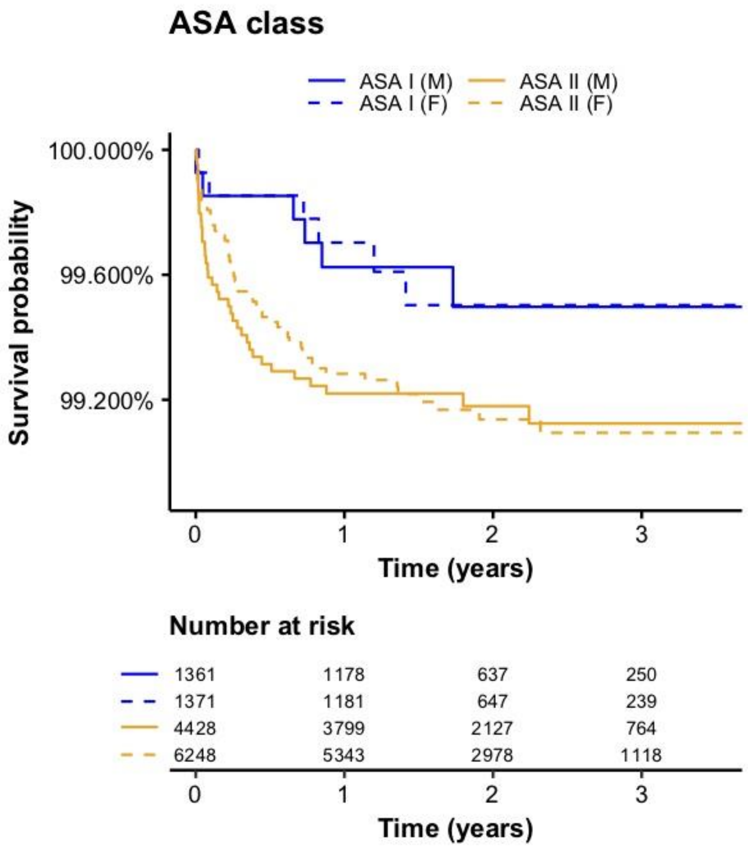
Orthopedic specialist	Reference		
Resident	1.0	(0.6 – 1.5)	0.9
No	0.6	(0.2 – 1.5)	0.3
Other	1.0	(0.6 – 1.5)	0.9
Surgical approach			<0.001
Anterolateral (modified Hardinge)	Reference		
Posterior	2.6	(1.7 – 4.1)	<0.001
Anterior (Smith – Peterson)	2.9	(0.9 – 9.6)	0.09
Intraoperative bleeding			
< 500 ml	Reference		
≥ 500 ml	1.3	(1.0 – 1.7)	0.04
Duration (min)	1.0	(1.0 – 1.0)	1.0
Anesthesia (spinal)			
No	Reference		
Yes	0.8	(0.5 – 1.3)	0.3
Anesthesia (epidural)			
No	Reference		
Yes	2.0	(1.2 – 3.6)	0.01
Anesthesia (general)			
No	Reference		
Yes	1.1	(0.7 – 1.7)	0.7
Anesthesia (LIA)			
No	Reference		
Yes	0.6	(0.5 – 0.9)	0.02
Complications during surgery (fracture)			
No	Reference		
Yes	0.9	(0.3 – 2.9)	0.9
Previous operation to the same joint			
No	Reference		
Yes	1.7	(0.8 – 3.4)	0.1
Fixation			0.02
Cementless	Reference		
Cemented	1.6	(1.1 – 2.4)	0.01
Hybrid	1.4	(1.1 – 1.9)	0.01
Reverse hybrid	1.4	(0.8 – 2.5)	0.3
Bearing			<0.001
Metal-on-UHXLPE	Reference		
Ceramic-on-ceramic	0.4	(0.2 – 0.7)	0.003
Ceramic-on-UHXLPE	0.7	(0.5 – 1.0)	0.03
Ceramized metal-on-UHXLPE	0.2	(0.1 – 0.6)	0.006
Other	0.9	(0.5 – 1.6)	0.7
Oblique liner			
No	Reference		
Yes	1.3	(0.9 – 1.7)	0.1
Femoral head size (mm)			0.002

32	Reference		
36	0.6	(0.5 – 0.8)	<0.001
>36	1.1	(0.4 – 3.1)	0.8
28	0.8	(0.2 – 2.4)	0.7

Appendix 3. Multivariable analysis of all predictors with incident of revision for dislocation. Only patients without any missing data for variables of interest (N=21,706) were included in the final multivariable models.

Characteristic	Hazard ratio	95% CI	p-value
Age (years)			0.8
≤55	Reference		
56–65	1.2	(0.7 – 2.2)	0.5
66–75	1.3	(0.7 – 2.4)	0.3
≥76	1.3	(0.7 – 2.6)	0.4
ASA physical status classification			0.09
ASA I	Reference		
ASA II	1.7	(0.9 – 3.3)	0.09
ASA III – IV	2.0	(1.0 – 3.9)	0.04
Preoperative diagnosis			<0.001
Primary osteoarthritis	Reference		
Fracture	3.0	(1.9 – 4.7)	<0.001
Other	1.4	(0.9 – 2.2)	0.2
Surgical approach			<0.001
Anterolateral (modified Hardinge)	Reference		
Posterior	3.1	(1.7 – 5.5)	<0.001
Anterior (Smith – Peterson)	3.6	(1.0 – 13.1)	0.05
Intraoperative bleeding			
< 500 ml	Reference		
≥ 500 ml	1.3	(0.9 – 1.7)	0.1
Anesthesia (spinal)			
No	Reference		
Yes	0.6	(0.2 – 2.1)	0.4
Anesthesia (epidural)			
No	Reference		
Yes	1.4	(0.6 – 3.1)	0.5
Anesthesia (general)			
No	Reference		
Yes	0.9	(0.2 – 3.4)	0.9
Anesthesia (LIA)			
No	Reference		
Yes	0.8	(0.5 – 1.3)	0.4
Fixation			0.9

Cementless	Reference	
Cemented	1.2 (0.7 – 2.3)	0.5
Hybrid	1.0 (0.7 – 1.5)	1.0
Reverse hybrid	1.2 (0.5 – 3.0)	0.7
Bearing		0.1
Metal-on-UHXLPE	Reference	
Ceramic-on-ceramic	0.6 (0.3 – 1.3)	0.2
Ceramic-on-UHXLPE	0.9 (0.6 – 1.3)	0.5
Ceramized metal-on-UHXLPE	0.3 (0.1 – 1.0)	0.06
Other	0.6 (0.2 – 1.3)	0.2
Femoral head size (mm)		0.004
32	Reference	
36	0.5 (0.4 – 0.7)	<0.001
>36	0.4 (0.0 – 2.6)	0.3
28	0.5 (0.1 – 3.4)	0.4
Hospital volume		0.1
Low	Reference	
Medium	1.4 (1.0 – 2.0)	0.07
High	1.3 (0.9 – 2.0)	0.2



Kaplan-Meier plot of ASA class I vs. ASA class II in the multivariable model after stratification.