Implant Survival After Minimally Invasive Anterior or Anterolateral Vs. Conventional Posterior or Direct Lateral Approach

An Analysis of 21,860 Total Hip Arthroplasties from the Norwegian Arthroplasty Register (2008 to 2013)

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Background: Since 2008, there has been an increase in the use of minimally invasive surgery (MIS) through an anterior or anterolateral approach for total hip arthroplasty (THA) in Norway. We compared the MIS approaches with the conventional posterior and direct lateral approaches in terms of revision rates and risk of revision.

Methods: On the basis of data in the Norwegian Arthroplasty Register, 21,860 THAs with an uncemented stem, performed between 2008 and 2013, were identified and included in the cohort. Of these THAs, 2,017 were done through an MIS anterior approach; 2,087, through an MIS anterolateral approach; 5,961, through a posterior approach; and 11,795, through a direct lateral approach. Follow-up ended on December 31, 2015. Two and 5-year survival rates were calculated using Kaplan-Meier survival analysis. Relative risk (RR) was calculated using Cox regression analysis, with adjustment for age, sex, primary diagnosis, American Society of Anesthesiologists (ASA) grade, femoral head size, cup fixation, type of articulation, and duration of surgery and using 6 revision end points based on cause: any cause, infection, dislocation, femoral fracture, aseptic loosening, and other/unknown cause. The median duration of follow-up was 4.3 years.

Results: There were no significant differences among the surgical approaches with regard to the 2 and 5-year survival rates or RR of revision due to any cause. The RR of revision due to infection was 0.53 (95% confidence interval [CI] = 0.36 to 0.80, p = 0.002) for the MIS anterior and anterolateral approaches and 0.57 (95% CI = 0.40 to 0.80, p = 0.001) for the posterior approach compared with the direct lateral approach. The RR of revision due to dislocation was 2.1 (95% CI = 1.5 to 3.1, p < 0.001) for the posterior approach compared with the direct lateral approach but no significant difference in risk was found when the MIS anterior and anterolateral approaches were compared with the direct lateral approach (RR = 0.71, 95% CI = 0.40 to 1.3, p = 0.25).

Conclusions: The revision rates and risk of revision associated with the MIS anterior and anterolateral approaches were not increased compared with those of the conventional posterior and direct lateral approaches.

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

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Use of minimally invasive surgery (MIS) with muscle-sparing anterior approaches has increased in recent years—from 0.9% in 2008 to 17.6% in 2013 as reported by the Norwegian Arthroplasty Register (NAR). According to the NAR, the MIS anterior approach[1] was used for 4.3% of primary total hip arthroplasties (THAs) in 2013 and the MIS anterolateral approach[2], for 13.5%. Simultaneously, there has been a reduction by nearly 20% in the use of the direct lateral approach—from 63.7% in 2008 to 44.4% in 2013.

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Traditionally, the most common approach in Norway was the direct lateral approach[3], which was used in >60% of all THAs from the start of the NAR in 1987 until 2009. The approach offers good exposure through the release of the gluteus minimus and anterior portion of the gluteus medius, but it carries the risk of permanent damage to the abductors[4], leading to a limp and lateral hip pain[5]. With the posterior approach[6], the external rotators of the hip are released to provide good exposure while avoiding the hip abductors, but it is associated with higher rates of dislocation[7,8]. The risk of dislocation can, however, be reduced by increasing the diameter of the femoral head component[9-11] and performing posterior soft-tissue repair[6].

Some investigators have reported that the MIS anterior approaches cause less pain postoperatively[12,13] and facilitate quicker rehabilitation, although these improvements seem short-term[12,14-17]. Others have reported a high rate of complications with these approaches[18,19]. There are also reports of a long learning curve[20]. Differences in revision rates between traditional approaches have also been found[8,21-23].

We therefore compared the implant survival rate and risk of revision of primary THAs performed through an MIS anterior or MIS anterolateral approach with those of primary THAs done through a direct lateral or posterior approach. Our null hypothesis was that there would be no difference in implant survival or risk of revision based on the approach.

Materials and Methods

Since September 1987, primary THAs and subsequent revisions have been registered in the NAR with use of the unique identification number assigned to all citizens in Norway. The surgeon fills in the form immediately after surgery. The data recording by the register has been approved by the Norwegian Data Inspectorate, and all patients provide written informed consent before inclusion. The NAR has been validated[24], and >95% of primary THAs performed in Norway are reported to the register[25,26].

TABLE I Demographic Data for Patients in the NAR (2008-2013): Comparison of MIS Anterior, MIS Anterolateral, Conventional Posterior, and Conventional Direct Lateral Approaches

	No. (%)					
	MIS Anterior	MIS Anterolateral	Posterior	Direct Lateral	All	P Value
Total	2,017 (9.2)	2,087 (9.5)	5,961 (27.3)	11,795 (54.0)	21,860 (100)	
Sex						<0.001*
Male	675 (33.5)	762 (36.5)	2,106 (35.3)	4,564 (38.7)	8,107 (37.1)	
Female	1,342 (66.5)	1,325 (63.5)	3,855 (64.7)	7,231 (61.3)	13,753 (62.9)	
Age						
Mean ± SD *(yr)*	67 ± 11	67 ± 11	65 ± 12	64 ± 12	65 ± 12	<0.001†
Category						<0.001*
<55 yr	271 (13.4)	262 (12.6)	1,079 (18.1)	2,171 (18.4)	3,783 (17.3)	
55-64 yr	571 (28.3)	499 (23.9)	1,777 (29.8)	3,799 (32.2)	6,646 (30.4)	
65-74 yr	686 (34.0)	800 (38.3)	1,925 (32.3)	3,664 (31.0)	7,075 (32.4)	
≥75 yr	489 (24.2)	526 (25.2)	1,180 (19.8)	2,161 (18.3)	4,356 (19.9)	
ASA grade						<0.001*
1	491 (24.3)	360 (17.2)	1,323 (22.2)	3,007 (25.5)	5,181 (23.7)	
2	1,245 (61.7)	1,378 (66.0)	3,704 (62.1)	6,691 (56.7)	13,018 (59.6)	
3	263 (13.0)	321 (15.4)	863 (14.5)	1,931 (16.4)	3,378 (15.5)	
4	1 (0.0)	2 (0.1)	18 (0.3)	26 (0.2)	47 (0.2)	
Missing	17 (0.8)	26 (1.2)	53 (0.9)	140 (1.2)	236 (1.1)	
Deaths	111 (5.5)	79 (3.8)	269 (4.5)	745 (6.3)	1,204 (5.5)	<0.001†
Cup fixation						<0.001*
Uncemented	907 (45.0)	107 (5.1)	4,015 (67.4)	4,140 (35.1)	9,169 (41.9)	
Cemented	1,088 (53.9)	1,978 (94.8)	1,894 (31.8)	7,536 (63.9)	12,496 (57.2)	
Missing	22 (1.1)	2 (0.1)	52 (0.9)	119 (1.0)	195 (0.9)	
Diagnosis						<0.001*
Osteoarthritis	1,756 (87.1)	1,831 (87.7)	4,175 (70.0)	8,533 (72.3)	16,295 (74.5)	
Other	258 (12.8)	251 (12.0)	1,756 (29.5)	3,215 (27.3)	5,480 (25.1)	
Missing	3 (0.1)	5 (0.2)	30 (0.5)	47 (0.4)	85 (0.4)	

*Chi-square test. †Student t test.

As the use of MIS for THA increased from 0.1% in 2007 to 17.6% in 2013[26], patients who were operated on before 2008 were not included to allow for an initial learning curve. Nearly all (94%) of the MIS THAs reported to the NAR were done with an uncemented stem and either a cemented[27] or an uncemented cup. We therefore included only primary THAs done with an uncemented stem performed between 2008 and 2013, which led to inclusion of 21,860 hips in the cohort. All primary THAs were included, regardless of diagnosis. Since bilaterality has been shown to have negligible influence on the risk of revision[28,29], bilateral THAs were treated as 2 independent observations. A bilateral THA had been performed in 9.8% of the patients, with no difference in the rate of bilateral procedures associated with the different approaches.

Two and 5-year implant survival rates were calculated using Kaplan-Meier survival analysis for the MIS anterior, MIS anterolateral, conventional posterior, and conventional direct lateral approaches. The relative risk (RR) of revision for any cause was calculated by comparing the 4 different approaches. To ensure a sufficient number of patients in each group, the RR of revision due to infection, dislocation, femoral fracture, aseptic loosening (cup and/or stem), or other/unknown cause was calculated by comparing the MIS anterior and MIS anterolateral approaches as 1 group with the conventional posterior and the direct lateral approaches. Analyses were also performed to identify a potential learning curve associated with the MIS approaches.

Statistical Methods

Follow-up ended on December 31, 2015, unless the implant had been revised or the patient had died before that date. A revision means removal, addition, or exchange of a part, or the whole, of the implant. Kaplan-Meier survival analysis was used to calculate 2 and 5-year survival rates of the implant, and the log-rank test was used to compare implant survival among the groups. The Cox proportional hazard model, with adjustments for age, sex, primary diagnosis, American Society of Anesthesiologists (ASA) grade, femoral head size, cup fixation, type of articulation, and duration of surgery (categorized as ≤60 minutes, 61 to 90 minutes, and >90 minutes), was used with 6 revision end points based on cause: any cause, infection, dislocation, femoral fracture, aseptic loosening, and other/unknown cause. To test that the Cox proportional hazard model assumption was fulfilled, we calculated the scaled Schoenfeld residuals for each covariate and visually inspected the plots[30].

To look for case-mix bias, we performed sensitivity analysis using the Cox proportional hazard model with the same adjustments but including only patients <75 years old, ASA grades of 1 and 2, head sizes of ≤32 mm, and primary osteoarthritis as the indication for the THA with the same end points.

TABLE II Femoral Head Size and Articulation for Patients in the NAR (2008-2013): Comparison of MIS Anterior, MIS Anterolateral, Conventional Posterior, and Conventional Direct Lateral Approaches

	No. (%)				
	MIS Anterior	MIS Anterolateral	Posterior	Direct Lateral	All
Total	2,017 (9.2)	2,087 (9.5)	5,961 (27.3)	11,795 (54.0)	21,860 (100)
Head size*					
<32 mm	509 (25.2)	1,077 (51.6)	1,636 (27.4)	8,439 (71.5)	11,661 (53.3)
32 mm	960 (47.6)	887 (42.5)	3,696 (62.0)	2,831 (24.0)	8,374 (38.3)
>32 mm	533 (26.4)	119 (5.7)	607 (10.2)	487 (4.1)	1,746 (8.0)
Missing	15 (0.7)	4 (0.2)	22 (0.4)	38 (0.3)	79 (0.4)
Articulation*					
Metal-conventional polyethylene	30 (1.5)	1 (0.0)	306 (5.1)	1,233 (10.5)	1,570 (7.2)
Metal-cross-linked polyethylene	391 (19.4)	1,351 (64.7)	2,005 (33.6)	2,934 (24.9)	6,681 (30.6)
Ceramic-conventional polyethylene	3 (0.1)	0 (0.0)	295 (4.9)	1,447 (12.3)	1,745 (8.0)
Ceramic-cross-linked polyethylene	1,344 (66.6)	716 (34.3)	2,145 (36.0)	4,777 (40.5)	8,982 (41.1)
Ceramic-ceramic	217 (10.8)	12 (0.6)	915 (15.3)	1,053 (8.9)	2,197 (10.0)
Other/missing	32 (1.6)	7 (0.3)	295 (4.9)	351 (3.0)	685 (3.1)

*P < 0.001 (chi-square test).

TABLE III Duration of Surgery for Patients in the NAR (2008-2013): Comparison of MIS Anterior, MIS Anterolateral, Conventional Posterior, and Conventional Direct Lateral Approaches

	No. (%)				
Approach	≤60 min	61-90 min	>90 min	Missing	Total
MIS anterior	177 (8.8)	1,032 (51.2)	774 (38.4)	34 (1.7)	2,017 (100)
MIS anterolateral	344 (16.5)	1,179 (56.5)	530 (25.4)	34 (1.6)	2,087 (100)
Posterior	2,055 (34.5)	2,497 (41.9)	1,303 (21.9)	106 (1.8)	5,961 (100)
Direct lateral	2,048 (17.4)	5,893 (50.0)	3,634 (30.8)	220 (1.9)	11,795 (100)
Total	4,624 (21.2)	10,601 (48.5)	6,241 (28.5)	394 (1.8)	21,860 (100)

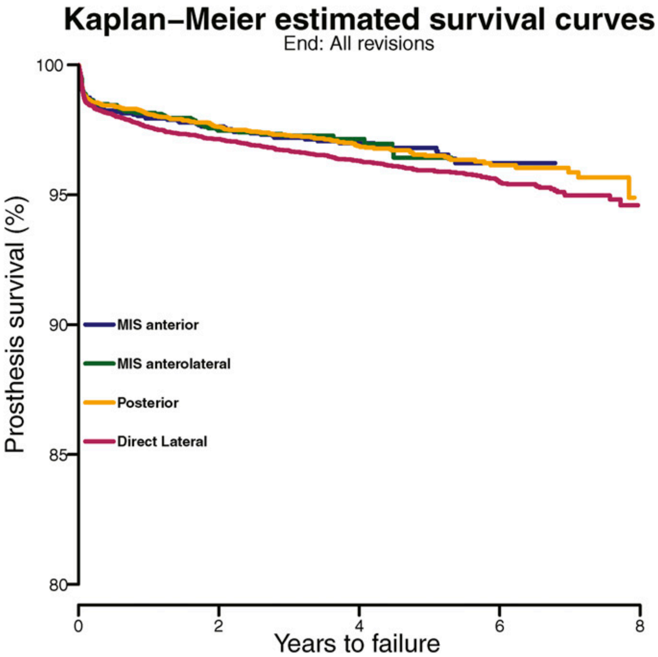

Fig. 1

Kaplan-Meier estimated survival curves comparing MIS anterior, MIS anterolateral, posterior, and direct lateral approaches to THA with revision due to any cause as the end point.

The effect of a potential learning curve associated with the MIS approaches was evaluated by repeating the Cox proportional hazard model with exclusion of the first 50 MIS THAs[31] done at each hospital as well as by evaluating whether the revision rates had changed during the study period.

Two and 5-year implant survival rates and the RR with the 95% confidence interval (CI) are presented. The significance level was set at $p < 0.05$. Statistical analyses were performed using IBM SPSS Statistics, version 23, and the statistical program Rstudio, version 2.15.0[32].

Results

The groups differed in terms of age distribution. There were few uncemented cups in the MIS anterolateral group and a larger percentage of primary diagnosis other than osteoarthritis in the direct lateral and posterior groups (Table I). There were also differences among the groups in terms of the size of the femoral head component and the type of articulation (Table II). The mean duration of surgery was 90 minutes (95% CI = 89 to 91 minutes) for the MIS anterior approach, 83 minutes (95% CI = 82 to 84 minutes) for the MIS anterolateral approach, 77 minutes (95% CI = 76 to 78 minutes) for the posterior approach, and 85 minutes (95% CI = 84 to 85 minutes) for the direct lateral approach. When the duration of surgery was categorized as ≤60, 61 to 90, or >90 minutes, the posterior group was found to have a larger percentage of operations of short duration and the MIS anterior group, a larger percentage of operations of longer duration (Table III).

The median duration of follow-up was 4.3 years (95% CI = 4.2 to 4.3) overall, whereas it was 4.6 years (95% CI = 4.5 to 4.8) for the MIS anterior approach, 3.3 years (95% CI = 3.2 to 3.3) for the MIS anterolateral approach, 4.3 years (95% CI = 4.2 to 4.3) for the posterior approach, and 4.6 years (95% CI = 4.6 to 4.7) for the direct lateral approach. Between 3.8% and 6.3% of the patients died during the study period (Table I).

There was no significant difference in implant survival among the approaches at 2 or 5 years ($p = 0.187$ for overall survival (Fig. 1, Table IV). The RR of revision due to any cause, compared with the risk with the direct lateral approach, was 0.90 (95% CI = 0.68 to 1.20) for the MIS anterior approach, 0.95 (95% CI = 0.71 to 1.27) for the MIS anterolateral approach, and 0.90 (95% CI = 0.75 to 1.08) for the posterior approach (Table V). There was an increased risk of revision due to infection after surgery through the direct lateral approach; compared with that approach, the RR was 0.53 (95% CI = 0.36 to 0.80, $p = 0.002$) for the MIS anterior and anterolateral approaches and 0.57 (95% CI = 0.40 to 0.80, $p = 0.001$) for the posterior approach (Fig. 2).

The RR of revision due to dislocation using the posterior approach was more than double (2.1, 95% CI = 1.5 to 3.1, $p < 0.001$) that of the direct lateral approach. The RR was 0.71 (95% CI = 0.40 to 1.3, $p = 0.25$) for the MIS approaches compared with the direct lateral approach (Fig. 3). No significant differences were found in the risk of revision due to femoral fracture, aseptic loosening, or other/unknown cause (Table V).

The sensitivity analyses also showed an increased risk of infection with use of the direct lateral approach, with RRs of 0.42 (95% CI = 0.22 to 0.80, $p = 0.008$) and 0.45 (95% CI = 0.25 to 0.80, $p = 0.006$) for the MIS anterior and anterolateral

TABLE IV Kaplan-Meier Analysis of 2 and 5-Year Implant Survival* for Patients in the NAR (2008-2013): Comparison of MIS Anterior, MIS Anterolateral, Conventional Posterior, and Conventional Direct Lateral Approaches†

	2-Year Survival Rate (95% CI)	5-Year Survival (95% CI) *(%)*	Implants Remaining in the Analysis After 5 Years
MIS anterior	97.6 (97.0-98.2)	96.8 (96.0-97.6)	792
MIS anterolateral	97.5 (96.9-98.1)	96.5 (95.5-97.5)	185
Posterior	97.6 (97.2-98.0)	96.4 (95.8-97.0)	2,153
Direct lateral	97.2 (96.8-97.6)	96.0 (95.6-96.4)	4,861

*Follow-up ending December 31, 2015. †P = 0.187 (log-rank test) for overall survival, with <0.05 considered the level of significance.

TABLE V Cox Regression Analysis of Relative Risk of Revision for Patients in the NAR (2008-2013)*

Cause of Revision/Approach	RR	95% CI	P Value†
Revision due to any cause (n = 789)			
Direct lateral			
MIS anterior	0.90	0.68-1.2	0.47
MIS anterolateral	0.95	0.71-1.3	0.74
Posterior	0.90	0.75-1.1	0.25
Revision due to infection (n = 244)			
Direct lateral			
MIS anterior/anterolateral	0.53	0.36-0.8	0.002
Posterior	0.57	0.40-0.8	0.001
Revision due to dislocation (n = 154)			
Direct lateral			
MIS anterior/anterolateral	0.71	0.40-1.3	0.25
Posterior	2.1	1.5-3.1	<0.001
Revision due to femoral fracture (n = 62)			
Direct lateral			
MIS anterior/anterolateral	0.85	0.40-1.8	0.67
Posterior	0.87	0.43-1.7	0.69
Revision due to aseptic loosening (n = 206)			
Direct lateral			
MIS anterior/anterolateral	1.3	0.84-1.9	0.26
Posterior	0.80	0.55-1.6	0.22
Revision due to other causes (n = 142)			
Direct lateral			
MIS anterior/anterolateral	1.2	0.72-1.9	0.55
Posterior	1.0	0.66-1.6	0.93

*Adjusted for age, sex, primary diagnosis, ASA grade, size of femoral head component, cup fixation, type of articulation, and duration of surgery. Follow-up ending December 31, 2015. †P values of <0.05 were considered significant.

approaches and the posterior approach, respectively, compared with the direct lateral approach. We also found an increased risk of revision due to dislocation with the posterior approach (RR = 2.62, 95% CI = 1.53 to 4.47, $p < 0.001$) compared with the direct lateral approach.

Excluding the 50 first MIS procedures for every hospital did not alter the risk of revision or implant survival. Comparing revision rates among different time periods did not reveal changes for the MIS approaches that differed significantly from those of the conventional approaches during the study period.

Discussion

In this study, the overall revision rates and risk of revision with the MIS approaches were similar to those of the conventional approaches. There was a higher risk of revision due to infection after use of the direct lateral approach than after use of the MIS approaches or the posterior approach, whereas the risk of revision due to dislocation following the MIS anterior, MIS anterolateral, or direct lateral approach was reduced compared with that after the posterior approach.

Our study has limitations. The analyses included only THAs done with an uncemented stem. There is evidence that cemented prostheses are associated with lower revision rates, especially in older patients[33]. Although the comparison of implant survival and risk of revision among the approaches should still hold, if the use of MIS caused a shift from cemented stems to uncemented stems and subsequently higher revision rates, this would not be evident from our study. Our results also might not apply to cemented stems, as the MIS approach might affect the quality of cementation and as a consequence the revision rates.

The median follow-up was short, 4.3 years. However, the observed time period covers the introduction of the MIS approaches and subsequent learning curves. One would expect the revisions to have occurred early if they were a result of improper surgical technique associated with the learning curve. We did not detect an effect of the learning curve that has been reported to be associated with the MIS approaches[18-20,31]. The NAR records the hospital where the primary surgery was carried out, but not the surgeon who performed it. We therefore

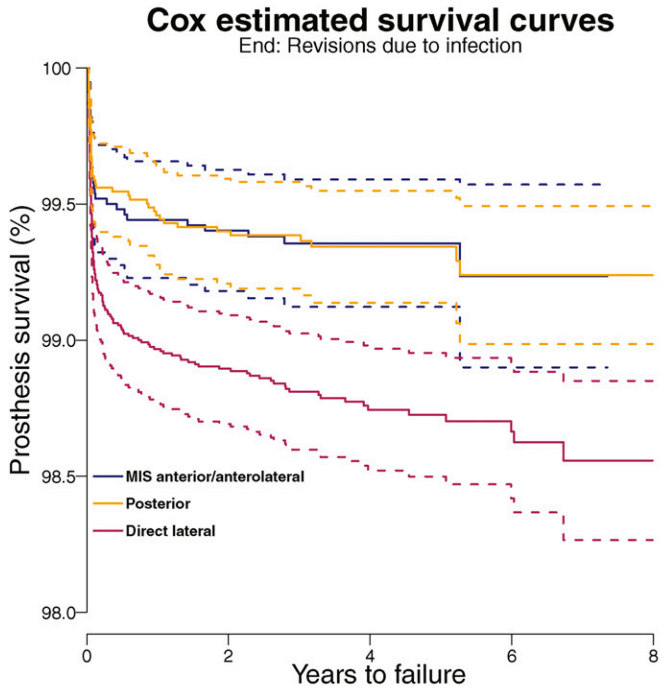

Fig. 2

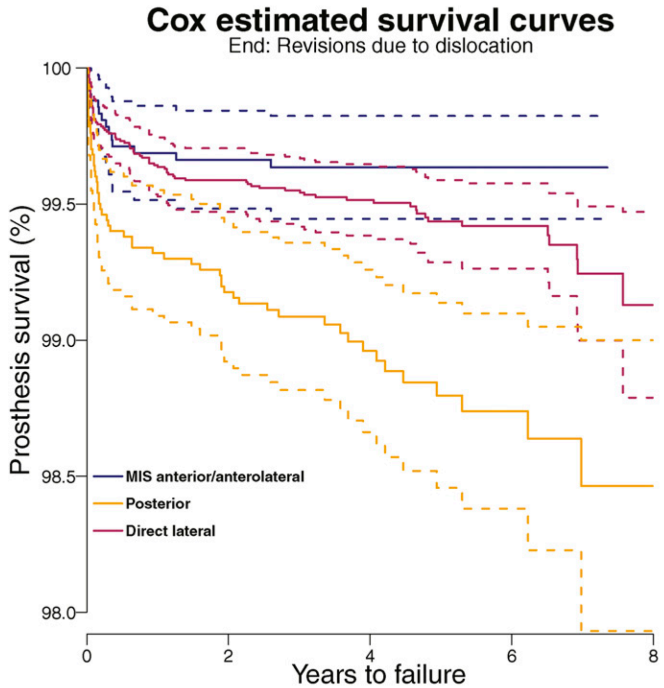

Fig. 3

Fig. 2 Cox regression analysis comparing MIS anterior, MIS anterolateral, posterior, and direct lateral approaches to THA with revision due to infection as the end point. Adjustments were made for age, sex, primary diagnosis, ASA grade, femoral head size, cup fixation, type of articulation, and duration of surgery. The dotted lines show the 95% CIs. **Fig. 3** Cox regression analysis comparing MIS anterior, MIS anterolateral, posterior, and direct lateral approaches to THA with revision due to dislocation as the end point. Adjustments were made for age, sex, primary diagnosis, ASA grade, femoral head size, cup fixation, type of articulation, and duration of surgery. The dotted lines show the 95% CIs.

do not know if one or several surgeons were performing a specific approach at a given a hospital or if one or several surgeons started performing the MIS once it was introduced to the hospital.

Except for implant survival, no data on the clinical outcomes were included in our study because this was a register study with end points of revision or the death of patient. Amlie et al.[34] collected data on patient-reported outcomes following lateral, posterior, MIS anterior, and MIS anterolateral approaches in a portion of the same population as was evaluated in our study. They showed similar outcomes following use of the posterior and MIS anterior and anterolateral approaches but significantly worse limping, pain, and Hip Disability and Osteoarthritis Outcome Scores (HOOS)[35] following the lateral approach.

A strength of our study was that it involved a large number of patients compared with the numbers studied in randomized trials. We know of only 1 other study, by Sheth et al., comparing the risk of revision after the anterior approaches with that after the posterior and direct lateral approaches[36]. The majority of the operations in that study were through the posterior approach (75%), with the anterolateral approach used in 10% and the anterior approach, in 4%. Sheth et al. also found similar implant survival rates among the different approaches, and they reported a reduced risk of revision due to dislocation after the anterior approaches as compared with the posterior approach.

The risk of periprosthetic joint infection after primary THA is increasing[37]. Our study showed a significant increase in the risk of revision due to infection when the lateral approach had been used. To our knowledge, this finding has not been previously described in the literature, and we do not have an explanation for it. A shorter duration of surgery could perhaps explain the difference between the direct lateral and posterior approaches but would not explain the difference between the MIS approaches and the direct lateral approach. Less tissue damage with use of the MIS and posterior approaches could be a factor, but there are studies indicating that the direct lateral approach does not cause more muscle damage[13,14] than the MIS anterior or anterolateral approach. The positioning of the patient during surgery could perhaps be of influence, as could the release of a relatively large muscle (i.e., the gluteus medius and minimus), but our study offers no definite explanation for the difference in the infection rates. Case-mix or selection bias is a possible explanation, even though the sensitivity analysis supported the finding. These findings do, however, suggest that the MIS anterior, MIS anterolateral, or posterior approach might be better than the direct lateral approach when attempting to reduce the risk of a periprosthetic joint infection, even though additional studies are needed before concluding that the direct lateral approach increases the risk of infection.

Dislocations, especially recurrent dislocations and those requiring revision, have large consequences for affected patients[10]. Although the risk of dislocation is reduced by increasing the size of the femoral head component and performing posterior soft-tissue repair[6], we found the posterior approach to be associated with more than twice the risk of revision due to dislocation after THA when compared with the 3 other approaches. Other studies have also shown an increased risk of revision due to dislocation when the posterior approach was used[21,22]. Some surgeons prefer to instruct their patients to refrain from a full range of motion for the first weeks after THA[38], even though studies indicate that this does not prevent dislocation and hinders rehabilitation[39,40]. It seem safer to allow full mobilization immediately after surgery with the MIS anterior or MIS anterolateral approach than after the posterior approach, but patients operated on via the posterior approach can also be mobilized immediately, albeit with a possibly higher risk.

Our study covers the period when MIS anterior and anterolateral approaches were introduced and gained popularity in Norway. As a consequence, we expected to find higher revision rates and risks of revision after use of those approaches than after the more common conventional approaches. This was not the case; the risk of revision for all causes was similar among the approaches. The follow-up in our study was relatively short, and additional studies are needed to determine whether there are long-term differences in implant survival. Additional studies are also needed to ascertain if our findings apply to THAs with a cemented stem. ■

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