Higher revision risk for unicompartmental knee arthroplasty in low-volume hospitals

Data from 5,791 cases in the Norwegian Arthroplasty Register

Mona Badawy[1], Birgitte Espehaug[2,3], Kari Indrekvam[1,4], Leif I Havelin[2,4], and Ove Furnes[2,4]

[1]Kysthospital in Hagevik, Hagavik; [2]The Norwegian Arthroplasty Register, Department of Orthopaedic Surgery, Haukeland University Hospital, Bergen; [3]Center for Evidence-based Practice, Bergen University College, Bergen; [4]Department of Clinical Medicine, Institute of Medicine and Dentistry, University of Bergen, Bergen, Norway.
Correspondence: monabadawy13@hotmail.com
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Background and purpose — Some studies have found high complication rates and others have found low complication rates after unicompartmental knee arthroplasty (UKA). We evaluated whether hospital procedure volume influences the risk of revision using data from the Norwegian Arthroplasty Register (NAR).

Materials and methods — 5,791 UKAs have been registered in the Norwegian Arthroplasty Register. We analyzed the 4,460 cemented medial Oxford III implants that were used from 1999 to 2012; this is the most commonly used UKA implant in Norway. Cox regression (adjusted for age, sex, and diagnosis) was used to estimate risk ratios (RRs) for revision. 4 different volume groups were compared: 1–10, 11–20, 21–40, and > 40 UKA procedures annually per hospital. We also analyzed the reasons for revision.

Results and interpretation — We found a lower risk of revision in hospitals performing more than 40 procedures a year than in those with less than 10 UKAs a year, with an unadjusted RR of 0.53 (95% CI: 0.35–0.81) and adjusted RR of 0.59 (95% CI: 0.39–0.90). Low-volume hospitals appeared to have a higher risk of revision due to dislocation, instability, malalignment, and fracture than high-volume hospitals.

The Norwegian Arthroplasty Register (NAR) has been registering knee arthroplasties since 1994 and has a registration-completeness of 99% (Espehaug et al. 2006).

In a study from the NAR, the 10-year survival probability was 80% for unicompartmental knee arthroplasty (UKA), as compared to 92% for the TKA (Furnes et al. 2007). The Finnish Arthroplasty Register had an even worse result, presenting a 60% survival rate for the UKA at 15-year follow-up (Koskinen et al. 2008). The Swedish Knee Arthroplasty Register and other database studies have also indicated that survival is higher in patients with TKA than in patients with UKA (Lyons et al. 2012, SKAR 2012).

High-volume centers and high-volume surgeons have reported excellent results in their studies and follow-up of UKA (Murray et al. 1998, Lisowski et al. 2011, Price and Svard 2011). Advantages of a unicompartmental knee arthroplasty over total knee arthroplasty, such as reduced risk of complications, faster recovery, and a more rapid discharge, have been described by some authors (Lombardi et al. 2009, Brown et al. 2012) but not by others (Lygre et al. 2010). Technical failures leading to malpositioning of the components (Argenson and Parratte 2006, Mercier et al. 2010) are associated with procedure volume. There is a learning curve with this procedure, as demonstrated by Hamilton et al. (2009), but the failure rate persisted despite modifications to improve surgical techniques.

The purpose of this study was to establish the numbers of UKA procedures performed annually at the different hospitals, to investigate a possible correlation between low hospital procedure volume and high risk of revision regarding the Oxford III unicompartmental knee arthroplasty using the data from the NAR, and to investigate possible variation in the reasons for revision. Our hypothesis was that technical errors would occur more often in the low-volume hospitals.

Method

The UKA procedure accounted for approximately 10% of the knee implants in Norway during the period of analysis (1999–2012). The number of surgeries has remained rela-

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Table 1. Characteristics of patients and procedures [a]

	Annual hospital volume (no. of procedures) < 10	11–20	21–40	> 40
No. of procedures	964	1,542	1,633	321
Male sex, %	47	45	46	43
Age [b], years	62	65	65	65
age range	36–90	36–91	35–92	39–88
≤ 60 years, %	37	31	29	28
Osteoarthritis, %	91	92	94	94
Year of surgery [c], %				
1999–2000	36	31	34	0.0
2001–2005	22	37	31	11
2006–2012	21	33	40	5.5
No. of hospitals	49	34	22	5

[a] Patient and procedure characteristics for 4,460 cemented medial Oxford III UKAs according to hospital volume categories, from 1999–2012.
[b] The values are given are median (range).
[c] The values are expressed as the percentage of implants in each volume group. The majority of hospitals, 36 of 51, contributed to more than one volume group.

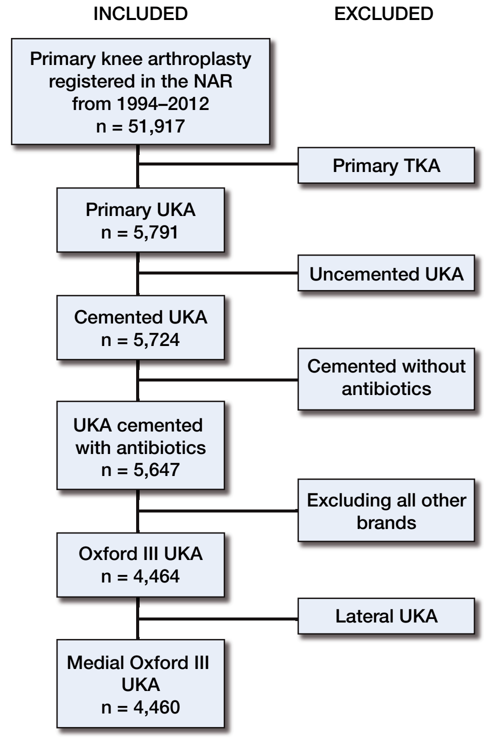

Figure 1. 4,460 unicompartmental knee arthroplasties (UKAs) were selected for inclusion in this study. Knees that were treated with total knee arthroplasty (TKA), lateral UKA, uncemented UKA, cemented UKA without antibiotics, and brands other than Oxford III were excluded.

tively unchanged from one year to the next. 447 UKAs were implanted in 2004, as compared to 458 in 2012, while numbers of TKA procedures have been constantly increasing. 51 hospitals performed UKAs in 2012. Annual hospital procedure volume was calculated for all hospitals as the number of cemented UKAs performed during a year.

We analyzed 4 hospital procedure volume groups using data from the NAR. Group 1 had a procedure volume of 1–10 UKAs annually, group 2 had 11–20, group 3 had 21–40, and group 4 had more than 40 UKA procedures annually. Any hospital with inconsistent procedure volume over time may have contributed to different volume groups, as patients were entered into the hospital volume groups according to the number of procedures at their hospital in the year of surgery. Thus, for every hospital each year was examined individually, and 36 of the 51 hospitals that performed the UKA procedure contributed to more than 1 volume group (Table 1).

UKA surgery has been registered in the NAR since 1994 (Figure 1). The Oxford III implant was first reported to the Norwegian Arthroplasty Register in 1999. Analyses were done only for this implant, since it is the most commonly used unicondylar knee implant in Norway, constituting 77% of all UKAs during the whole period. 3,955 patients were included and 505 (13%) of these patients had UKA surgery in both knees (Table 1).

The 4 volume groups were compared for risk of revision. Cox regression was used to estimate proportions without revision and relative risk (RR). We also analyzed the reason for revision in all 4 volume groups.

Revision was defined as a partial or complete removal/exchange of implant component(s) and was linked to the primary surgery by the unique national identification number of the patient.

Statistics

Survival analyses were performed with any revision of the implant as endpoint. Information on deaths or emigrations was retrieved from the Norwegian Resident Registration Office until December 2012. Kaplan-Meier survival percentages at 10 years are reported. To evaluate the effect of volume on prosthesis survival, we used the Cox regression model to calculate risk ratios (RRs). These are presented with 95% confidence intervals (CIs) and p-values relative to the lowest-volume group.

Adjustments were made for sex, age and diagnosis. Age was divided into 4 groups (< 60, 61–70, 71–80, and > 80). Diagnoses were divided into 2 groups (osteoarthritis (OA) and others). Adjusted Cox regression survival curves were constructed for hospital volume categories with volume as stratification factor. In a material restricted to revised implants, the Pearson chi-square test was used to test whether proportions of specific revision causes differed among volume groups. The log-rank test was used to compare implant survival among volume groups with revision due to pain only, infection, loosening, dislocation, instability, malalignment, fracture, or to progression of osteoarthritis (OA) as endpoint.

The inclusion of bilateral knee arthroplasty may mean a violation of the assumption of independent observations in sur-

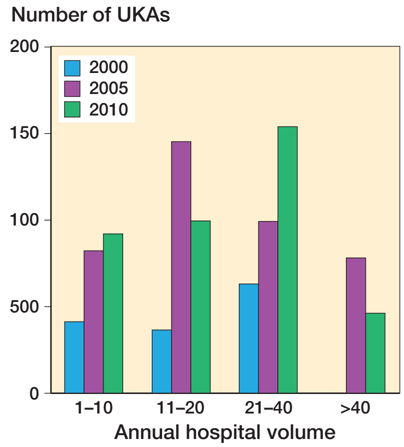

Figure 2. Bar graph showing the change in hospital procedure volumes over time, with the 3 columns indicating the years 2000, 2005, and 2010.

vival analyses. Studies have, however, shown that the effect on statistical precision is minor for survival analysis of knee replacements (Robertsson and Ranstam 2003). The proportional hazards assumption of the Cox model was tested based on scaled Schoenfeld residuals (Grambsch et al. 1995) and found to be valid for the factor annual hospital volume when investigated with the lowest-volume group as reference (p = 0.5). SPSS versions 20.0 and 21.0 and R software version 2.15.1 were used.

Results

In the first years of unicompartmental knee arthroplasty, none of the hospitals had the highest procedure volume (> 40 UKAs per year), but the number has slowly increased in the past 10 years (Figure 2). During the whole period, half of the hospitals contributed to the group of <10 procedures, one-third of the hospitals contributed to the 10- to 20-procedure group, one-fifth of the hospitals contributed to the 20- to 40-procedure group, and only 5 hospitals performed more than 40 UKAs a year (Table 1). 36 of the 51 hospitals changed volume category during follow-up and therefore contributed to more than 1 volume group.

The annual hospital volume group of < 10 UKA procedures annually accounted for 964 implants over the whole time period from 1999 to 2012 (22%), the 11–20 volume group accounted for 1,542 implants (35%), the 21–40 group accounted for 1,633 implants (37%), and the > 40 group accounted for 321 implants (7.2%) (Table 1).

The percentage of male patients who received a UKA was higher than in the usual sex distribution for total knee arthroplasty (TKA) (NAR 2013). Additionally, the UKA patients tended to be younger than the TKA patients: median age was 64 (NAR 2013) (Table 1).

In the unadjusted analysis, comparing the risk of revision between the 4 volume groups, the knees in the 11- to 20-procedure group had a lower risk of revision (RR = 0.77, CI: 0.62–0.96) than those in the < 10-procedure volume group. This was also true of the 21- to 40-procedure group (RR = 0.78, CI: 0.62–0.97) and the > 40-procedure group (RR = 0.53, CI: 0.35–0.81) (Table 2). The risks of revision for the different volume groups were similarly analyzed with adjustment for age, diagnosis, and sex. The hospital group with an annual volume of > 40 procedures had the lowest risk of revision compared to the lowest-volume group (RR = 0.59, CI: 0.39–0.90). We also found a linear trend in the groups: there were increasingly better results with increasing annual hospital volume (Figure 3 and Table 2).

The distribution of causes of revision among 514 revised Oxford III implants from 1999 to 2012—according to hospital volume—is shown in Table 3. The main difference between the groups was a higher incidence of revisions for “pain alone” in the high-volume group (> 40 procedures annually), but this was not statistically significant. Technical errors such as instability, fractures, malaligment, and dislocation as the reason for revision were more common in the lower-volume groups (16–21%) than in the highest-volume group (7.7%). However, log-rank tests did not show any statistically significant differences between the groups and the number of revisions was small, so these findings must be interpreted with caution.

Table 2. Cox regression analysis

Annual hospital volume	No. of UKAs	No. of revisions	10-year survival [a] (95% CI)	Cox Regression Analyses Unadjusted RR [b]	p-value	Adjusted RR [c]	p-value
< 10 procedures	964	147	78 (74–81)	1		1	
11–20 procedures	1,542	176	83 (81–86)	0.77 (0.62–0.96)	0.02	0.83 (0.66–1.03)	0.09
21–40 procedures	1,633	165	82 (79–85)	0.78 (0.62–0.97)	0.03	0.85 (0.68–1.06)	0.1
> 41 procedures	321	26	[d]	0.53 (0.35–0.81)	0.003	0.59 (0.39–0.90)	0.01
p-value for linear trend					0.002		0.02

[a] Kaplan-Meier estimated cumulative survival at 10 years (%)
[b] RR: risk ratio with the 95% CI in parentheses.
[c] Estimated risk ratio with adjustment for age, sex, and diagnosis with the 95% CI in parentheses.
[d] Last revision at 7.6 years (survival of 89, CI: 85–93).

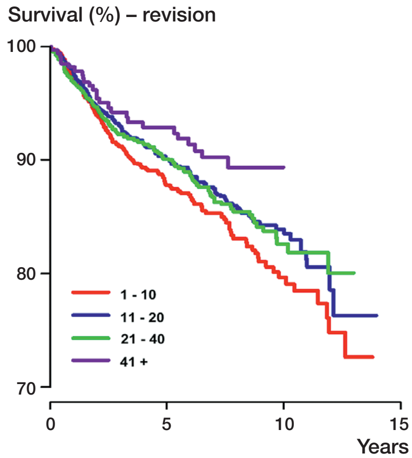

Figure 3. Cox-adjusted survival curve for cemented unicompartmental knee arthroplasty in Norway from 1999 to 2012, with revision for any reason as endpoint. The results of Cox regression analysis were adjusted for age, sex, and diagnosis. The results are shown for the 4 different hospital volume groups described in the text.

Discussion

Summary

This registry-based study confirmed that the risk of revision was significantly higher for hospitals performing less than 10 Oxford III UKA procedures a year than for those performing more than 40 Oxford III UKA procedures a year in Norway between 1999 and 2012.

Comparison to other studies

The New Zealand Joint Registry reports are consistent with our study, indicating that the UKA procedure is volume-dependent (NZJR 2014). Robertsson et al. (2001) also related increased risk of revision to the number performed by the unit (more or less than 23 per year), and concluded that the Oxford implant was more influenced by hospital volume than other commonly used brands. Baker et al. (2013) from the National Joint Registry of England and Wales (the NJR) recently reported that the risk of revision decreased as both center volume and surgeon volume increased for the Oxford implant most commonly used in England and Wales. Their study suggested a minimum annual procedure volume of 13—both regarding hospital volume and surgeon volume.

Some authors have suggested a lower threshold to revise a painful UKA to a TKA, claiming that revision rate is not an objective measurement for this particular implant (Goodfellow et al. 2010). A study from the NJR of England and Wales opposed this claim, suggesting a higher risk of revision for reasons other than pain compared to the TKA (Baker et al. 2012). This is supported by the study by Furnes et al. (2007).

Registry studies, as opposed to clinical studies, include all surgeons and all hospitals in the country. According to various registry reports, the average surgeon fails to achieve comparable results to those of surgeons in clinical studies conducted by inventor hospitals (Labek et al. 2011).This can be explained by factors such as lower surgical expertise regarding this particular procedure and implant.

UKA volume studies from the Swedish Knee Arthroplasty Register by Robertsson et al. (2001) and from the NJR of England and Wales by Baker et al. (2013) defined hospital procedure volume as the mean procedure volume for the hospital in a given period of time. We decided to measure hospital volume in a different way. The number of UKAs performed in each hospital each year was counted, and we compared the results for the annual hospital procedure volume groups accordingly. 36 of the 51 hospitals changed volume group during the study period. The advantage of this method of analysis is that if a hospital for 1 or more years belongs to the lowest-volume group, it actually reflects the rarity of the procedure that particular year. Less than 10 procedures a year means less than 1

Table 3. Reasons for revision [a]

	Annual hospital volume 1–10	11–20	21–40	> 40	Pearson [b] p-value	Log-rank [c] p-value
No. of revisions	147	176	165	26		
Cause of revision, n (%)						
Infection (n = 20)	3 (2.0)	7 (4.0)	9 (5.5)	1 (3.8)	0.5	0.8
Loosening, PE wear (n = 178)	51 (35)	64 (36)	54 (33)	9 (35)	0.9	0.2
Dislocation, instability, malalignment, fracture (n = 89)	23 (16)	30 (17)	34 (21)	2 (7.7)	0.4	0.2
Progression OA (n = 62)	18 (12)	20 (11)	22 (13)	2 (7.7)	0.9	0.5
Pain only (n = 126)	40 (27)	40 (23)	35 (21)	11 (42)	0.1	0.1
Other (n = 39)	12 (8.2)	15 (8.5)	11 (6.7)	1 (3.8)	0.8	0.4

[a] 514 revisions with medial Oxford III UKA; distribution of reasons for revision by hospital volume groups. The reasons for revision are hierarchical from top to bottom. When more than one reason was reported, the top reason in the hierarchy was used as endpoint in the analyses. Pain as a cause of revision was used as endpoint in analyses and is shown in the table only when pain was the only reason reported.
[b] Pearson chi-square test of independence, p-value.
[c] Log-rank test to compare the survival distributions, p-value.
PE: polyethylene; OA: osteoarthritis.

procedure a month, and according to the authors' experience, even if a surgeon has had a reasonable surgery volume during previous years, continuous training in a technically demanding procedure is essential to achieve reproducible results. One could argue the opposite way, that mean volume over the whole time period is a more reliable method: if hospital A suddenly reduces its annual procedure volume to less than 10 but in the preceding 5 years has had a high annual procedure volume of > 40, it knows the procedure so well that one year with a low volume will not have an impact on the results.

Strengths and limitations

One limitation of the present study was the lack of information on surgeon procedure volume, and there was no information regarding the correct/incorrect indication for the subsequent revisions and primary procedure. However, we know that surgeon procedure volume is generally low, and this could influence the hospital results.

Baker et al. (2013) investigated the surgeon volume in addition to the hospital volume, and suggested that surgeon volume was more important than hospital volume. We agree that this is probably a correct appraisal. In 2010, we sent a request to all 43 units performing UKA in Norway to manually count the surgeon volume for 2 specific years. We received an answer from 39 of the departments, and the enquiry suggested that the overall surgeon volume was low, even in the highest-volume hospitals. Thus, the distribution of low-volume surgeons was considered to be relatively equal in all the groups. This is, however, a limitation of the study, and makes interpretation of hospital volume difficult. Hospitals with a high procedure volume cannot guarantee their patients excellent results if they only provide low-volume surgeons.

Explanations and mechanisms

There has been no overall improvement in UKA implant survival over time in Norway, in contrast to total knee arthroplasty (NAR 2013).

The total number of UKA procedures has not changed in the last 10 years in the NAR (447 UKAs in 2004 as opposed to 458 UKAs in 2013); it has not increased like the TKA procedure (Badawy et al. 2013). However, some hospitals have increased their annual procedure volume over the last 10 years (Figure 2).

Patient selection and indication for surgery are important factors that contribute to better results with the UKA procedure. In addition, standardization and procedure of care is important. The learning curve and improved surgical techniques are also probable reasons for better outcome. All these factors are possible explanations for better results in high-volume centers.

We found that a high hospital procedure volume was beneficial for survival of the Oxford III UKA implant. Analysis of the reasons for revision indicated that there was a higher number of dislocations, more instability, more malalignment, and a greater number of fractures in the lower-volume groups support the statement regarding the Oxford III, as a possibly technically demanding implant. However, the numbers of revisions in each group were too small to allow us to make any conclusions regarding the differences between the groups. Whether or not this applies to all UKA brands remains to be investigated in registries that have other brands in sufficient volumes.

Possible implications and future research

There is concern about the consistently inferior implant survival rates for the UKA compared to the TKA in the worldwide arthroplasty registries. The proportion of revisions and the reasons for failure must be addressed and investigated further. The UKA implants require thorough surgical technique, correct patient selection, and correct indication for surgery in addition to strict indications for revision. This can only be achieved through centralization of the procedure. The NAR has encouraged surgeons through the annual reports to limit this procedure to a few dedicated surgeons in as few hospitals as possible, to achieve revision risk that is comparable with that of the TKA procedure.

MB: study design, data collection, and drafting of manuscript. BE: data acquisition, data analysis, and revision of manuscript. KI: revision of manuscript. LIH: data collection and revision of manuscript. OF: study design, collection and interpretation of data, statistics, and revision of manuscript.

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