Optimal Usage of Unicompartmental Knee Replacement: a Study of 41,986 Cases from the National Joint Registry for England and Wales

A D Liddle D.Phil. MRCS[1], H Pandit D.Phil. FRCS(Orth)[1], A Judge PhD[1,2], DW Murray MD FRCS[1]

1. Nuffield Department of Orthopaedics, Rheumatology and Musculoskeletal Sciences, University of Oxford, UK.
2. MRC Lifecourse Epidemiology Unit, University of Southampton, UK.

Correspondence:
Prof. DW Murray, david.murray@ndorms.ox.ac.uk
NDORMS, Botnar Research Centre, Windmill Road, Oxford OX3 7LD, UK

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Abstract

Unicompartmental Knee Replacement (UKR) has advantages over Total Knee Replacement (TKR) but National Joint Registries (NJRs) report a significantly higher revision rate for UKR. As a result, most surgeons are highly selective, offering UKR to only a small proportion (≤5%) of patients requiring knee replacement and consequently performing very few each year. However, surgeons with large UKR practices have the lowest revision rates. Overall practice size is often beyond the surgeon's control and so case volume may only be increased by broadening indications, and offering UKR to a greater proportion of knee replacement patients. The aim of the study was to determine the optimal UKR usage (defined as the percentage of knee replacement practice comprised by UKR) to minimise the revision rate in a sample of 41,986 records from the NJR for England and Wales.

UKR usage has a complex, non-linear relationship with revision rate. Optimal results are achieved with usage between 40-60%. Surgeons with the lowest usage (≤5%) have the highest revision rates. With optimal usage, using the most frequently-used implant, 5 year survival is 96%, compared with 90% with low usage (≤5%) previously considered ideal. The revision rate of UKR is highest if narrow indications are used. The widespread use of broad indications, using appropriate implants, would give patients the advantages of UKR, without the high reported revision rate.

Introduction

Unicompartmental Knee Replacement (UKR) is the principal surgical alternative to Total Knee Replacement (TKR) in end-stage osteoarthritis of the knee. UKR has well-described advantages over TKR: less tissue is resected in UKR and therefore the blood-loss, morbidity and mortality are lower and the recovery is faster[1-4]; as a result, the costs associated with UKR are significantly lower than with TKR[5-7]. By preserving normal structures within the knee (principally the anterior cruciate ligament), UKR restores the normal kinematics of the knee, leading to better knee function[8-10]. However, these advantages are countered by the significantly higher revision rate for UKR reported by National Joint Registries (NJRs)[11-13]. As a result, most knee surgeons perform no UKRs, and those who do offer UKR often perform very few[14]. Despite this, the vast majority of knee surgeons believe UKR to be an effective operation in the right patient[15].

Some surgeons attribute the high revision rate to inappropriate patient selection, and advise only offering UKR to patients deemed 'ideal' on the basis of strict criteria concerning patient factors (age, activity level, weight), pattern of osteoarthritis (for instance, excluding patients with any evidence of patellofemoral disease) and presentation (restricting use to patients with pain isolated to the affected part of the knee)[16]. However, others question the evidence-base for these criteria and suggest that if the patho-anatomy is suitable then UKR should be undertaken, whatever the patient characteristics[17]. Depending on the criteria used, UKR usage (defined as the proportion of patients requiring knee replacement who are offered UKR) ranges from 5 to 47% of patients[5,18].

The revision rate of UKR is highly dependent on the number of cases the operating surgeon performs each year. In a recent study, surgeons performing ≤12 cases per year (the majority of surgeons) had double the revision rate of those performing more than 12[14]. This is supported by similar findings from NJRs in Sweden and New Zealand[11,19]. However, if the indications remain the same, surgeons have only limited scope to increase the number of UKRs they perform: surgeons rarely have any control over the population of patients presenting to their clinic. As a result, the main avenue surgeons have for increasing their UKR caseload is to increase the proportion of their knee replacement patients to whom they offer UKR. It is not clear how far surgeons can broaden their UKR usage before the benefits of performing more cases per year are outweighed by the negative effects of operating on patients deemed to be less ‘ideal’. Answering this question would allow surgeons who wish to increase their numbers, and improve their outcomes, to do so by broadening their indications for UKR. If the revision rate could be reduced to an acceptable level, then UKR would become a mainstream intervention, allowing more patients to benefit from its advantages. The aim of this study was to determine the optimal usage for UKR, using a large cohort from the NJR for England and Wales.

Patients and Methods

A cohort study was conducted, using prospectively-collected data from the NJR for England and Wales. The NJR is the largest arthroplasty register in the world, containing records of 1.6 million joint replacements[13]. This study relates to an extract of 552,015 knee replacements performed between January 2003 and August 2012. In each case, a standardised dataset was recorded at primary surgery, including patient, unit and implant factors. Subsequent revision operations and mortality data are linked to this primary record using unique patient identifiers

8,820 cases were excluded primarily, (non TKR/UKR operations or no operation specified). Following determination of surgeon caseload and UKR proportion, all TKRs (463,520 cases), operations not performed for osteoarthritis (15,332 cases) and cases recorded as 'complex primaries' (22,357 cases) were excluded. 41,986 UKRs remained, and formed the study group.

The exposure of interest was UKR usage, defined as the percentage of all knee replacements that are UKRs. Usage was calculated per surgeon, per year. The end-point was revision rate as determined by survival analysis.

All covariates available in the NJR were examined. Datasets were complete for age, American Society of Anesthesiologists (ASA) score, gender, unit type (NHS/independent/Independent Sector Treatment Centre (ISTC)) and surgeon grade (consultant/non-consultant).

Body Mass Index (BMI) had a high proportion (52.9%) of missing values. To adjust for the effect of BMI, analyses were performed using the full dataset without BMI, the complete-case dataset, and a dataset where the BMI values were completed using multiple imputation (MI). Ten imputed datasets were created and analysed using Stata's Imputation by Chained Equations (ICE) procedure.[20] All exposure and confounding variables were included in the MI process, together with the outcome variable (Nelson-Aalen estimator and revision status).

Most UKRs performed in England and Wales (69.5%) use a single brand of implant (Oxford Knee (OUKR), Biomet Ltd, Bridgend, UK)[21]. Unlike most implants, the OUKR is designed for use with broad indications, and has a mobile bearing, which may alter its sensitivity to use by lower-volume surgeons. As this implant accounts for a high proportion of cases, and has specific attributes which may change the effect of the variable of interest, a sub-group analysis was performed, restricted to the patients receiving this specific implant.

Statistical Analysis

The effect of usage on revision rate was examined using Cox regression. Survival was censored at eight years to allow for the small number of recorded cases with longer follow-up (due to incomplete take-up in the early years of the NJR). Schoenfeld's residuals were employed to test the proportional hazards assumption. As a sensitivity analysis, the competing risk of death was accounted for using Fine and Gray's method[22].

The functional form of the effect of each predictor on the survival hazard was estimated by fitting fractional polynomials in the method described by Royston and Altman[23], corroborated by plotting the revision rate (expressed as revisions per 100 implant years) against each predictor. Smooth curves were fitted using locally-weighted scatterplot smoothing (LOWESS)[24].

Univariable and multivariable models were conducted. Non-linear relationships were fitted using linear splines to provide a quantitative estimate of the effect on survival at different values of the predictor. This method breaks the continuous predictor into sections in which the relationship is roughly linear, fitting linear regression models (known as linear splines) in each region; this method avoids the problems associated with categorization of continuous data[25]. Kaplan-Meier analysis was used to determine the survival that can be achieved using 'optimal' usage (as suggested by this study) and to compare it to the low usage levels previously considered 'ideal' (i.e., ≤5%).

All analyses were performed using Stata 12.1 for windows (Stata Corp. College Station, TX, USA).

Results

Following data cleaning and exclusions, there were 505,648 knees, of which 41,986 were UKRs. These cases were performed by 2649 surgeons. 1,311 (49.5%) surgeons performed at least one UKR; of those surgeons, most performed very few (81.4% performed fewer than 10 UKRs per year). The mean number of cases performed annually per surgeon was 2.8 (SD 7.7) for UKR and 31.1 (SD 33.1) for TKR. Excluding surgeons who perform no UKRs, these figures are 7.6 (11.2) and 45.2 (37.0). 8.3% of knee replacements were UKRs; the mean usage of UKRs was 5.9% (SD 12.7%). When restricted to surgeons performing both TKR and UKR, the mean usage of UKRs was 11.0% (SD 13.4%). Demographic, volume and usage data are presented in Table 1.

The relationship between usage and revision rate was non-linear (Figure 1). In both the univariable and multivariable analyses, the lowest risk of revision was for those surgeons performing between 40 and 60% UKRs. From 0-20%, there was a statistically significant decline in revision risk; above 65%, there was a slight increase. Linear splines were fitted with knots placed at 20% and 65%. Hazard ratios for each of the sections are presented in Table 2.

A sub-group analysis of the 29,182 (69.5%) cases who received the mobile-bearing implant was performed. The functional form of the usage effect was similar to that of the other devices and of UKR overall. However, this device appeared more sensitive to the effect of usage: the revision rate was lower when performed by higher-usage surgeons, but slightly higher with very low usage of UKR. The position of the knots appeared to remain applicable (Figure 2). Hazard ratios for the single-prosthesis analysis are presented in Table 2.

Following model estimation, the characteristics of the patients in the three spline sections were characterised (Table 3). Patients operated upon by lower-usage surgeons are younger, and the mean ASA grade lower, compared to higher-usage surgeons. Both factors are statistically significant but the effect size is small.

In patients undergoing UKR with narrow usage (≤5%), the overall five year survival is 90% (95% confidence intervals 88.4%-91.6%). If usage was above 20%, this increased to 94% (95% CI 93.7-94.3). Usage in the optimal range (40%-60%) produced a five-year survival of 95% (95% CI 93.9-96.1), which increased to 96% (95% CI 94.9-96.0) if analysis is restricted to cases using the mobile bearing implant (Figure 3).

Discussion

Surgical volume has previously been demonstrated to be an important predictor of success after UKR[11,14,19]. However, the prevailing orthodoxy has been that to achieve the best results, UKR should be offered to only the most 'ideal' patients, who may comprise as few as 4-6% of all patients presenting for knee replacement[16,18,26]. As a result, and given that surgeons have little control over the population of patients presenting to them, most surgeons perform very few UKRs, and consequently achieve suboptimal rates of implant survival[14]. This study aimed to determine how far surgeons could broaden their indications (therefore increasing the percentage of patients to whom they offer UKR), before the positive effect of increasing surgical volume was outweighed by the negative effect of operating on patients who may be less 'ideal'.

This is a large study which accurately reflects practice on a national level. The main limitations of this study are common to all registry studies: there is limited data on indications, surgical technique and some patient factors (particularly co-morbidities), and no radiographic data is available to demonstrate the stage of disease of the patients studied. The validity of UKR usage (%UKR) as a surrogate for indications relies upon surgeons drawing their patients from a similar population. Whilst this is reasonable in most cases, it does not take tertiary referral practice into account. Whilst it is impossible to identify tertiary centres from the data we have available, this is only likely to become a problem in surgeons with the highest proportion of

UKRs. With this in mind, whilst we report good results in surgeons with very high UKR usage (>50%, for example), we do not suggest that surgeons with a general knee practice should perform such a high percentage. The maximum follow-up in this study is eight years; this is considered at most medium term in the context of joint replacement[27]. This may ascribe disproportionate weight to early modes of failure. Finally, the outcome measure, revision, has well-described limitations[28]. Whilst it is objective and easily-measured, it is insensitive to implants which function poorly but are not revised, and to reoperations where the components are left in situ. However, this measure is widely used within orthopaedics, and is the principal outcome measure used in NJRs. Future research should examine other outcome measures such as patient-reported outcome measures and non-revision reoperations.

The principal finding of this study is that increasing usage, up to around 50%, results in improved implant survival. Strikingly, this positive effect was most marked with the lowest usage (<20%). For every 10% that usage increased in this low usage group, the risk of revision decreased by 21%. There are two main explanations for this effect. The first is that any theoretical risk of operating on patients with less-than ideal characteristics (by conventional standards) is greatly outweighed by the positive effect of performing more UKRs each year. This is supported by previous literature demonstrating both the importance of surgical volume[11,14,19], and failing to demonstrate the benefit of excluding patients with non-ideal characteristics. These include patients with patellofemoral disease[29,30], obesity[31], high activity levels[17], or generalized, rather than compartment-specific, knee pain[32,33]. The second, and more surprising, finding is that surgeons with low UKR usage are not using UKR for those ideally suited. Low-usage surgeons implant UKR in younger patients than high-usage surgeons and all NJRs report poorer survival in younger patients whatever joint replacement they receive[11,34,35]. This may represent such surgeons offering UKR to patients with partial thickness disease who they deem 'too early' for TKR; such patients have a high revision rate with UKR or TKR[17,18]. As such, low-usage surgeons appear to be reserving UKR for the small subgroup of patients expected to have a poor result with TKR, rather than using UKR for the large number of patients who need knee replacement and in whom the pattern of disease is appropriate for UKR.

The secondary finding of this study was that the positive effect of high usage was more marked in the mobile-bearing implant. This device is specifically designed to be used with broad indications, whilst some other implants are not recommended for certain patient groups[36,37]. This sub-group analysis was performed as the mobile-bearing OUKR makes up the majority of UKR cases in the NJR, and therefore has a large effect on the overall findings of this study. By examining the effect of usage with this implant and 'others' (Table 2) it appears that usage of as high as 50% may not be appropriate in some designs. However, the 'others' category encompasses a range of different designs, some of which may be appropriate for broad indications and others which have narrower indications. Characteristics of implants vary and designs should be used within the manufacturers' recommended indications. With all designs, there is a limit to the acceptable usage; even in implants designed to have broad indications, the revision rate increases when usage is above 65% and surgeons must ensure indications are not too broad for the implant that they are using. The mobile-bearing OUKR is recommended when patients have antero-medial OA (implying bone on bone arthritis medially, full thickness cartilage laterally and functionally intact ligaments). This disease pattern is present in up to 50% of patients needing knee replacement[5,38,39].

This study has shown that surgeons who use UKR for a small proportion of their knee replacements tend to have high revision rates. Therefore we recommend that if surgeons wish to perform UKR, they should aim for at least 20% of their knee replacements to be UKRs (surgeons can broaden their indications even further if a device designed for broad indications is used). To achieve this they should use UKR in patients who have bone-on-bone arthritis in one compartment and in whom the remainder of the knee is functionally even if not anatomically normal. The procedure should not be reserved for rare patients in whom the remainder of the knee is pristine: in these cases, arthritis tends to be early and results are unpredictable. Those who do not perform UKR on a sufficient proportion of their patients to achieve reliable success should be discouraged from using it. If surgeons achieve high levels of UKR usage, patients would benefit from the advantages of UKR without the unacceptably high revision rate.

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Tables

Table 1: Demographics and outcomes overall. BMI – Body Mass Index (kg/m^3), UKR – Unicompartmental Knee Replacement. ASA – American Society of Anaesthesiologists. ISTC – Independent Sector Treatment Centre. Means and standard deviations are given by patient rather than by surgeon, hence the relatively high mean figures for UKRs per year and % UKR. The figures per surgeon are given in the text.

		Missing%	Mean	Median	SD	Range
Age		0	64.4	64.2	9.7	18.8-95.8
BMI		51.1	29.9	29.0	5	16-60
UKRs/yr		0	23.9	16.0	24.3	1-150
% UKR		0	28.2	24.1	19.6	0.5-100
Follow-up (yrs)		0	3.53	3.3	2.31	0.9-6
		Missing	Number		%	
Gender (male)		1	22,081		52.59	
Consultant performed		0	37,670		89.7	
ASA Grade	1	0	59,422		12.82	
	2		334,101		72.08	
	3		68,209		14.72	
	4		1,671		0.36	
	5		108		0.02	
Unit	NHS Hospital	0	26,150		63.14	
	Private Hospital		13,672		32.56	
	ISTC		1,804		4.3	
Outcome	Unrevised	0	38,442		91.56	
	Revised		2,087		4.97	
	Dead		1,457		3.47	

Table 2: Univariable and multivariable models (whole group and single-prosthesis analysis). HR – Hazard ratio for revision (eg, for every 10% increase in usage in spline 1 (between 0 and 20%, the probability of revision reduces by about a quarter). CI – confidence interval; ASA – American Society of Anaesthesiologists score; BMI – Body Mass Index; ISTC – independent sector treatment centres.

		HR (95% CI)	P	HR (95% CI)	P	HR (95%CI)	P
		Univariable		Multivariable (whole group)		Multivariable (OUKR only)	
Usage group	Spline 1: 0-20% (per 10%)	0.76 (0.69-0.82)	<0.001	0.79 (0.73-0.87)	<0.001	0.74 (0.66-0.82)	<0.001
	Spline 2: 20-65% (per 10%)	0.95 (0.91-0.99)	0.02	0.96 (0.92-1.00)	0.082	0.94 (0.89-0.99)	0.027
	Spline 3: 65-100% (per 10%)	1.15 (0.98-1.34)	0.09	1.13 (0.97-1.32)	0.112	1.04 (0.83-1.25)	0.769
Age (per year)		0.96 (0.96-0.97)	<0.001	0.97 (0.96-0.97)	<0.001	0.97 (0.96-0.98)	<0.001
Gender (male)		0.89 (0.82-0.97)	0.008	0.91 (0.83-0.99)	0.027	0.87 (0.78-0.96)	0.008
Fixation (cemented)		1.09 (0.92-1.29)	0.282	1.08 (0.92-1.27)	0.348	1.31 (0.95-1.67)	0.115
ASA score		0.95 (0.88-1.03)	0.204	1.09 (1.01-1.18)	0.031	1.17 (1.06-1.28)	0.001
BMI		1.02 (1.01-1.04)	0.001	(excluded from multivariable models)			
Consultant performed		0.89 (0.78-1.02)	0.093	0.80 (0.70-0.92)	0.001	0.90 (0.76-1.04)	0.202
Unit type	NHS Hospital	(reference group)		(reference group)		(reference group)	
	Independent hospital	0.92 (0.84-1.02)	0.104	1.00 (0.90-1.10)	0.974	0.92 (0.81-1.03)	0.186
	ISTC	1.16 (0.92-1.46)	0.206	1.29 (1.02-1.63)	0.031	1.44 (1.29-1.75)	0.005
Surgical caseload (per 10 cases)		0.97 (0.96-0.9)	<0.001	0.97 (0.96-0.98)	<0.001	0.97 (0.96-0.98)	<0.001

Table 3: Characteristics of patients in different ratio groups.

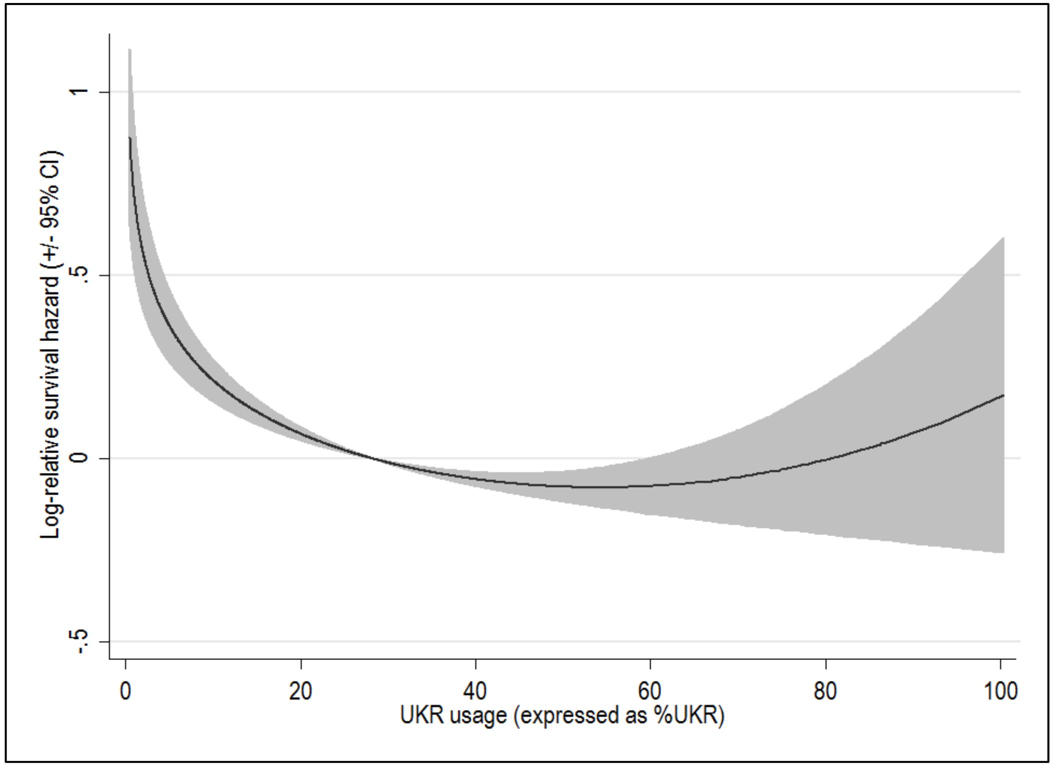
ASA – American Society of Anasethesiologists; PTIR – Patient Time Incidence Rate (revisions per 100 implant years). BMI Body Mass Index (kg/m^3)

Usage group*	0-20%	20-65%	65-100%
Number of Patients	17,734 (42.2%)	21,919 (52.2%)	2,333 (5.6%)
Mean Age (95% CI)	65.08 (62.90-63.26)	65.19 (65.03-65.36)	66.96 (66.43-67.50)
Mean ASA grade (95% CI)	1.80 (1.79-1.81)	1.87 (1.86-1.88)	1.81 (1.79-1.85)
Mean BMI (95% CI)**	29.90 (29.75-30.04)	30.05 (29.93-30.17)	29.14 (28.80-29.48)
Mean Surgeon volume, UKRs/year (95% CI)	9.68 (9.51-9.85)	31.16 (30.77-31.54)	63.10 (60.79-65.41)
Revision rate, revisions per 100 patient years (95% CI)	2.03 (1.87-2.20)	1.21 (1.17-1.26)	1.34 (1.08-1.59)

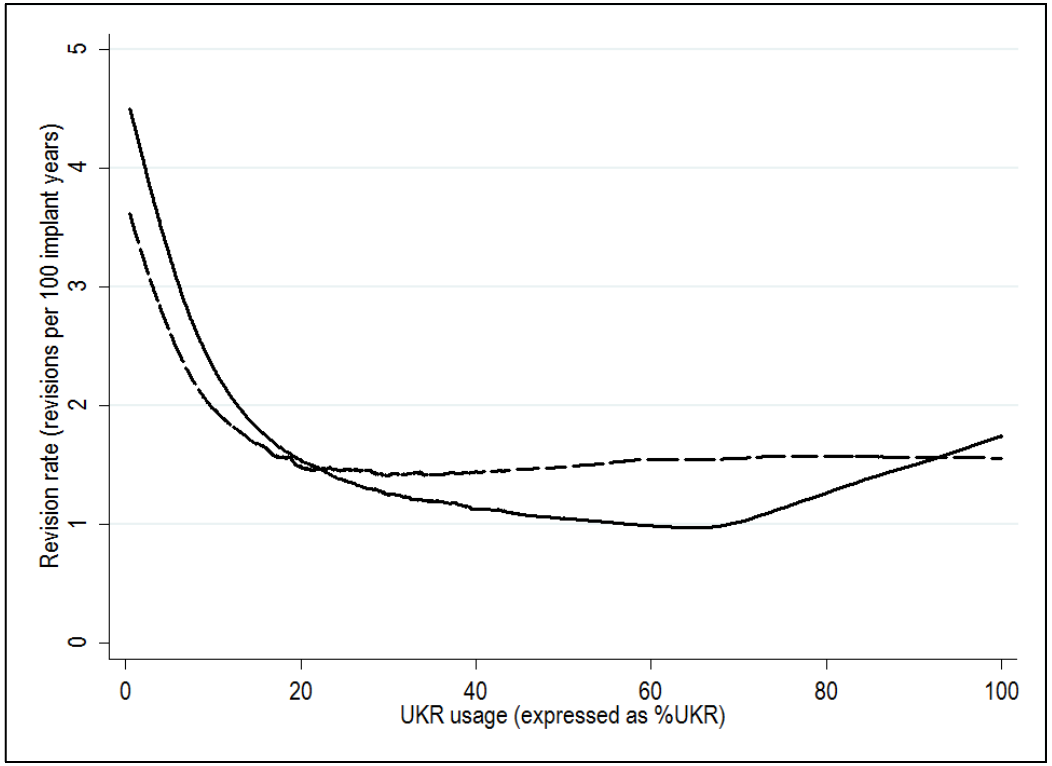
*Usage group: figures relate to the proportion of all knee replacements performed that are UKR.

**BMI data has a high number of missing values; these results relate to 20,530 patients (the groups contain 7,523; 11,524 and 1,433 patients respectively).

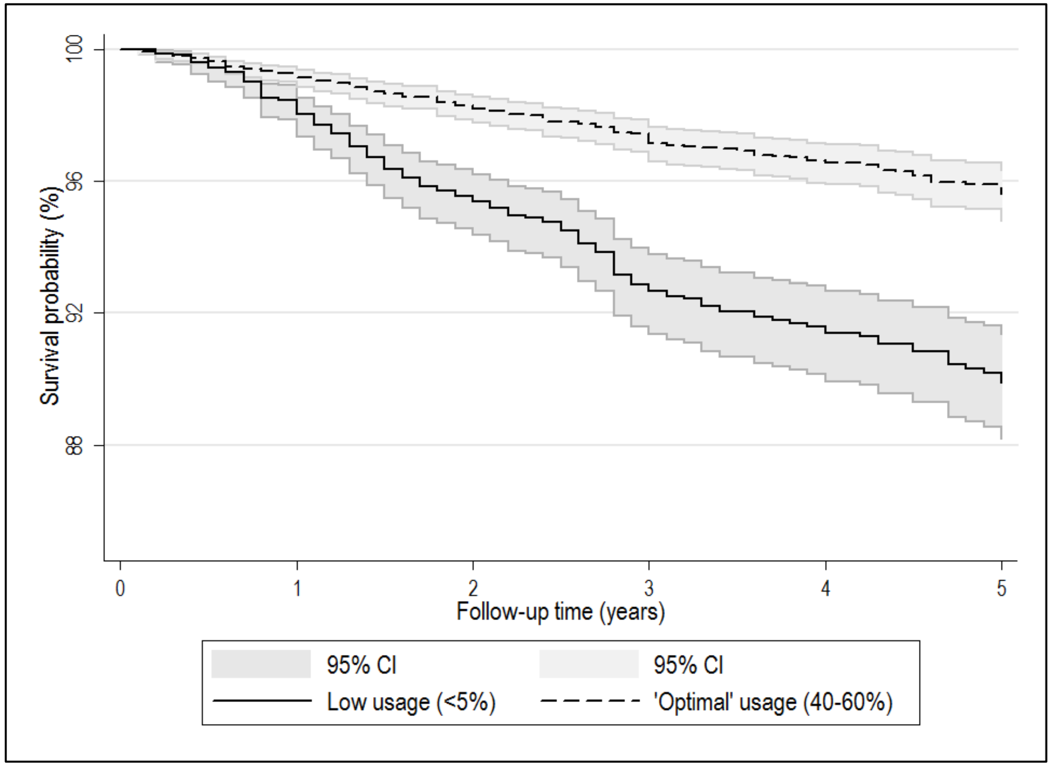
Figures



1. Fractional polynomial plot demonstrating the effect of increasing usage on the survival hazard (multivariable model). 95%CI; 95% confidence intervals.



2. Comparison of the effect of usage on revision rate in the mobile-bearing Oxford UKR (black line) and all other UKRs (dotted line)



3. Kaplan-Meier plot of revision rates in the first eight years following UKR. The dotted line indicates optimal usage as suggested by this study (40-60% usage), the black line represents usage <5%.