Operating time and survival of primary total hip replacements

An analysis of 31 745 primary cemented and uncemented total hip replacements from local hospitals reported to the Norwegian Arthroplasty Register 1987–2001

Arvid Småbrekke[1], Birgitte Espehaug[2], Leif I Havelin[2] and Ove Furnes[2]

[1]Department of Orthopaedic Surgery, Hammerfest Hospital, Sykehusveien 35, NO-9600 Hammerfest, [2]Norwegian Arthroplasty Register, Department of Orthopaedic Surgery, Haukeland University Hospital, NO-5021 Bergen, Norway.
Correspondence AS: Arvid.Smaabrekke@hammerfest-sykehus.no
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Background Some studies have found a significant decrease in operating time as a result of standardizing programs for hip surgery. To study the influence of operating time (skin to skin) on survival of total hip replacements, we investigated the operating time in local hospitals in Norway. We have found no other large published series of THRs investigating operating time and revision.

Patients and methods The study was based on 31 745 primary THRs reported to the Norwegian Arthroplasty Register from 47 local hospitals during 1987–2001. Operating time was divided into 7 categories, and for each category separate Kaplan-Meier curves and adjusted failure rate ratios were calculated.

Results The mean operating time for all local hospitals in Norway was 96 (68–130) min. Increasing operating volume from less than 10 THRs/hospital/year to more than 200 THRs/hospital/year was associated with a 25-min decrease in mean operating time in cemented THRs and a 35-min decrease in the case of uncemented THRs. With the operating time category of 71–90 min as reference category, cemented THRs that lasted more than 150 min had a two-fold increased (95% CI: 1.6–2.6) revision rate. For uncemented implants, the revision rate was 1.3 times higher (95% CI: 0.8–2.2). Cemented implants with operating time under 51 min and over 90 min were associated with an increased risk of revision due to aseptic loosening. Cemented implants with operating time over 150 min were associated with an increased risk of revision due to infection.

Interpretation Hospitals with long operating times should consider the potential benefit of reducing these times, as this may lead to lower revision rates and increased operating volumes. Shorter operation times could be achived by standardization programs, but one should bear in mind that for cemented implants very short operating times also increased revision risk due to aseptic loosening.

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Some studies have found a significant decrease in operating time as a result of standardizing programs for hip surgery (Patiala et al. 1984, Sommers et al. 1990). The cost effectiveness of short operating times is obvious as long as the quality of the procedure is maintained. We have found no other large published series of THRs investigating operating time and revision. To study the influence of operating time (skin to skin) on survival of total hip replacements, we investigated the operating time in local hospitals in Norway.

Patients and methods

The Norwegian Arthroplasty Register (NAR) was established in September 1987 (Havelin et al. 1993). Individual reports of total hip replacement operations have since been received from all 69 hospitals in Norway that perform this procedure. Information on primary operations and revisions, including the date of operation, the identity of the patient, indication, type of prosthesis and of cement, and operating time, is reported on a standard form by the orthopedic surgeon. An English translation of the form has been given in a previous report (Havelin 1999). At least 95% of all total hip replacements performed are reported to the register (Havelin et al. 2000). Implant failure is defined as the surgical removal or exchange of the whole or part of the implant. Linkage of information on the primary and subsequent operations is possible by use of the unique identification number assigned to each resident of Norway.

Study sample

In the period from 1987 to 2001, 66 650 primary total hip replacements were reported to the NAR. After exclusion of operations with unknown operating times, 66 030 operations remained. Of these, 33 837 were performed in local hospitals. Only operations from local hospitals were included since operating time has been found to vary between types of hospitals (Espehaug et al. 1999). Local hospitals have fewer training surgeons than central or university hospitals. We assumed a more homogenous patient material in local hospitals, as a result of reduced turnover of surgeons and adherence to standard procedures. The study sample included 28 890 operations in which both the acetabular and the femoral component were fixed to the bone with cement, and 2 855 operations in which both components were uncemented, and involved a total of 31 745 hips. The hybrid hips were excluded from the analysis.

Statistics

Survival analysis was performed with revision of one or both prosthetic components as the endpoint. Statistics Norway (Oslo, Norway) provided information on deaths and emigration until 1 April 2001. The survival times of implants in patients who had died or emigrated without failure of the prosthesis, were recorded at the date of death or emigration. The analyses of total hip replacements where both components were cemented or uncemented were performed separately. Furthermore, the analyses were performed with different types of endpoint, defined as revision due to aseptic loosening, revision due to deep infection and revision due to dislocation.

Kaplan-Meier survival curves were estimated for the following operating time categories: less than 51 min, 51–70 min, 71–90 min, 91–110 min, 111–130 min, 131–150 min, and longer than 150 min. Cox regression analyses provided unadjusted and adjusted failure rate ratios (RRs) for operating time with adjustment for possible confounding by gender, age, diagnosis, annual hospital operating volume, surgical procedure, perioperative complication, brand of prosthesis and type of cement (in analyses based on cemented prostheses). For uncemented prostheses, prosthesis brands were grouped as being either of design I or design II. Design I included circumferentially hydroxyapatite-coated, porous-coated or rough sandblasted stems, combined with hydroxyapatite-coated, porous-coated cups, while design II included all other types of uncemented prosthesis. In the Cox models, the covariates operating time, age and annual hospital operating volume were categorized and represented with indicator variables since the assumption of a log-linear relationship between these factors and the failure rate might be violated. The representation of all covariates is given in Table 1.

Generalized additive models for survival data using smoothing splines (Therneau and Grambsh 2000) were applied to further investigate possible threshold effects or nonlinearity in the relationship between operating time and revision risk. The analyses provided graphical displays of the relationship and tests for linearity and nonlinearity in effects.

To further control for confounding, we performed analyses for a subgroup of patients operated on for primary coxarthrosis including only Charnley implants cemented with Palacos or Simplex cement, where the surgical approach was lateral without trochanteric osteotomy. For uncemented implants, analyses were performed among patients operated on due to primary coxarthrosis. Additional analyses were performed for hip replacements where no perioperative complication had been reported, for hip replacements with no previous surgery, and for hip replacements performed at high-volume hospitals, respectively.

Table 1. Representation of variables included in multiple regression analyses based on 28 890 cemented (C) and 2 855 uncemented (UC) primary total hip replacements performed at local hospitals in Norway between 1987 and 2001. Values are number and percentages

Variables		Cemented impl.		Uncemented impl.	
Operating time, min	< 51	460	1.6	253	8.9
	51–70	4673	16	762	27
	71–90	10170	35	960	34
	91–110	6631	23	424	15
	111–130	4322	15	275	9.6
	131–150	1638	5.7	101	3.5
	>150	996	3.4	80	2.8
Gender	Male	8297	29	1139	40
	Female	20593	71	1716	60
Age at primary operation, years					
C: <60	UC: <50	1696	5.9	670	24
C: 60–69	UC: 50–59	8132	28	1198	42
C: 70–79	UC: 60–69	14294	50	797	28
C: >79	UC: >69	4768	17	190	6.7
Primary diagnosis	Coxarthrosis	21754	76	1594	57
	Other	6842	24	1226	44
	Unknown	294	35		
Systemic antibiotic	No	633	2.2	19	0.7
	Yes	28240	98	2833	99
	Unknown [a]	17	3		
Trochanteric osteotomy	No	25056	87	2801	99
	Yes	3612	13	27	1.0
	Unknown*	222	27		
Operative approach	Lateral	21571	75	1832	65
	Posterolateral	7108	25	1006	35
	Other or unknown [a]	211	17		
Prosthesis (cup/stem)					
C: Charnley	UC: Design I	15604	54	1241	44
C: Exeter	UC: Design II	1396	4.8	1609	57
C: Titan		2150	7.4		
C: Spectron/ITH		1066	3.7		
C: MHS/Bio–Fit		1199	4.2		
C: Other		7448	26		
Unknown [a]		27	5		
Cement (cup/stem)	Palacos	19350	67		
	Simplex	2073	7.2		
	Boneloc [b]	608	2.1		
	CMW3 [b]	1771	6.2		
	CMW1 [b]	4453	16		
	Palacos/Simplex	505	1.8		
	Other or unknown [a]	130			
Perioperative complication	No	28174	97.6	2747	96.2
	Yes	705	2.4	108	3.8
	Unknown [a]	11			
Annual hospital volume, number of operations	1–10	293	1.0	600	21
	11–20	951	3.3	949	33
	21–30	1979	6.9	633	22
	31–50	6078	21	220	7.7
	51–80	8245	29	0	0
	81–130	7226	25	320	11
	131–200	3658	13	133	4.7
	>200	460	1.6	0	0

[a] Category not included in regression models, [b] At least one component

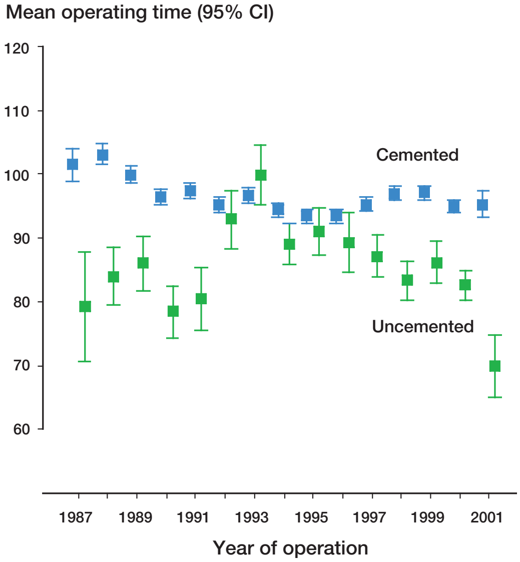


Figure 1. Mean operating times of 28 890 cemented and 2 855 uncemented primary total hip replacements performed at local hospitals in Norway between 1987 and 2001, by year of operation.

Following the 75 percentile for annual operating volume, high-volume hospitals were defined as hospitals with 98 or more operations per year for cemented implants and 30 or more operations per year for uncemented implants.

We used the statistics software programs SPSS version 11.0 (SPSS Inc., Chicago, IL) and S-Plus 2000 (MathSoft Inc., Seattle, WA). The generalized additive models were run based on S-Plus functions (plotterm and gamterms) provided by Therneau and Grambsch at http://www.mayo.edu/hsr/people/therneau/book/book.html.

Results

Mean operating time (skin-to-skin) for 47 local hospitals in Norway was 96 (68–130) min. Operating times were on average 10 min shorter for uncemented implants (86 min) than for cemented implants (96 min). We found small variations in mean operating time throughout the study period (Figure 1).

Male gender, young age and diagnoses other than primary coxarthrosis were associated with relatively long operating times, along with perioperative complications and specific procedure characteristics such as a lateral surgical approach and trochanteric osteotomy (Table 2). Mean operating time was reduced by 25 min for cemented hip replacements and 35 min for uncemented implants when hospitals operating more than 200 THRs/year were compared to hospitals with 10 or less operations (Figure 2).

Table 2. Details of 28 890 cemented (C) and 2 855 uncemented (UC) primary total hip replacements performed at local hospitals in Norway between 1987 and 2001, according to operating time

	Duration of the primary operation (min)					
Variables	Cemented implants			Uncemented implants		
	<51	91–110	>150	<51	91–110	>150
No. of hospitals	21	46	44	11	25	17
No. of hospitals with > 10 THRs	6	44	26	2	12	2
Median annual hospital volume	100	64	49	114	17	11
Males (%)	26	29	33	29	46	43
Age < 60 years (%)	3.9	6.7	9.9	37	74	80
Median age	75	73	72	63	56	53
Primary coxarthrosis (%)	77	75	58	75	52	22
Palacos cement (%)	84	64	71			
C: Charnley prosthesis (%)	30	56	62			
UC: Design I prosthesis (%)				12	48	28
Lateral approach (%)	82	76	86	9.9	84	86
Trochanteric osteotomy (%)	0.7	14	23	0.4	1.0	8.8
Systemic antibiotic (%)	82	99	99	99	100	100
Perioperative complication (%)	2.0	2.0	17	0.8	3.5	25

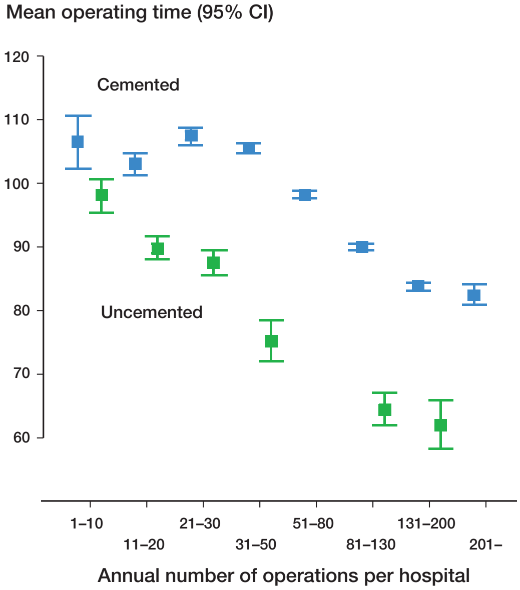
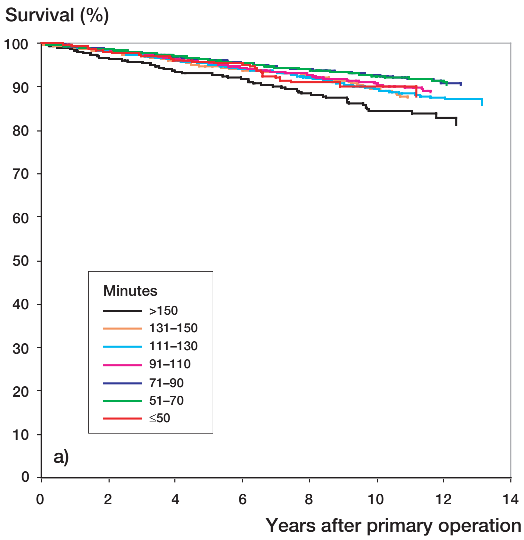


Figure 2. Mean operating times of 28 890 cemented and 2 855 uncemented primary total hip replacements performed at local hospitals in Norway between 1987 and 2001, by annual number of operations per hospital.

For both cemented and uncemented implants, the highest probability of revision was observed for operations with the longest duration (Figure 3). Although the distribution of some patient and procedure characteristics was associated with operating time, unadjusted and adjusted regression results were similar (Table 3). We observed a 2-fold (95% CI: 1.6–2.6, $p < 0.001$) higher revision rate for operations lasting longer than 150 min (as compared to those lasting 71–90 min) among cemented implants, and 1.3 times higher (95% CI: 0.8-2.2, $p = 0.3$) among uncemented implants. Findings based on Cox regression analysis were supported by results based on the generalized additive modeling of survival data (Figure 5).

We further analysed 9 886 Charnley implants fixed with Palacos or Simplex cement, where a lateral surgical approach without trochanteric osteotomy had been used on patients operated on due to primary coxarthrosis. The results obtained were similar to those already described (Figure 4), with an adjusted 2.0 times higher (95% CI: 1.2–3.2) revision rate among operations lasting longer than 150 min, as compared to those lasting 71–90 min. For uncemented prostheses in patients with primary coxarthrosis ($n = 1\,562$), the analogous risk ratio was 1.4 (95% CI: 0.5–4.1). Restricting the material to operations without perioperative complications or to hips without prior surgery gave only small changes compared to the figures given in Table 3. Analyses performed for high-volume hospitals gave more pronounced differences in revision risk estimates.



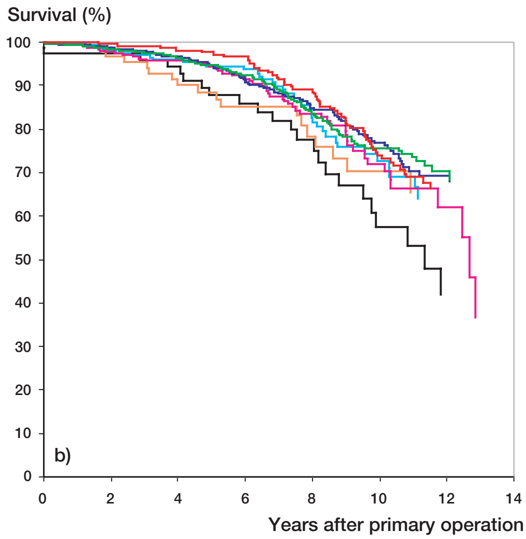


Figure 3. Kaplan-Meier survival curves (by operating time) for 28 890 cemented (a) and 2 855 uncemented (b) primary total hip replacements performed at local hospitals in Norway between 1987 and 2001.

Table 3. Relative risk estimates and 10–year revision percentages based on Cox regression analyses among 28 020 [a] cemented and 2 773 [a] uncemented primary total hip replacements performed at local hospitals in Norway between 1987 and 2001

Operating time for the primary operation (min)	No. THRs	No. revised	10-year %	95% CI	Unadjusted RR	95% CI	P-value	Adjusted RR	95% CI	P-value
Cemented implants										
< 51	453	29	9.9	6.1–14	1.3	0.9–2.0	0.1	1.3	0.9–1.9	0.2
51–70	4548	195	7.7	6.5–9.0	1.0	0.9–1.2	0.9	1.0	0.8–1.2	1.0
71–90	9844	399	7.4	6.5–8.2	1			1		
91–110	6461	317	9.2	8.1–10	1.2	1.1–1.4	0.01	1.2	1.1–1.4	0.01
111–130	4180	252	11	9.1–12	1.4	1.2–1.6	<0.001	1.4	1.2–1.6	<0.001
131–150	1584	101	11	8.4–13	1.4	1.1–1.7	0.004	1.4	1.1–1.7	0.01
> 150	950	88	16	12–19	2.1	1.6–2.6	<0.001	2.0	1.6–2.6	<0.001
Uncemented implants										
< 51	245	55	26	20–33	1.0	0.7–1.4	1.0	0.9	0.6–1.3	0.6
51–70	746	83	24	19–29	1.0	0.7–1.3	1.0	1.0	0.8–1.4	0.9
71–90	929	97	23	18–28	1			1		
91–110	406	55	28	20–36	1.3	0.9–1.8	0.2	1.2	0.9–1.7	0.2
111–130	272	38	27	19–36	1.1	0.8–1.7	0.5	1.0	0.7–1.4	0.8
131–150	99	18	30	17–42	1.4	0.8–2.3	0.2	1.2	0.7–2.1	0.4
> 150	76	23	42	27–57	1.9	1.2–3.0	0.01	1.3	0.8–2.2	0.3

[a] Numbers reduced due to missing values in covariates

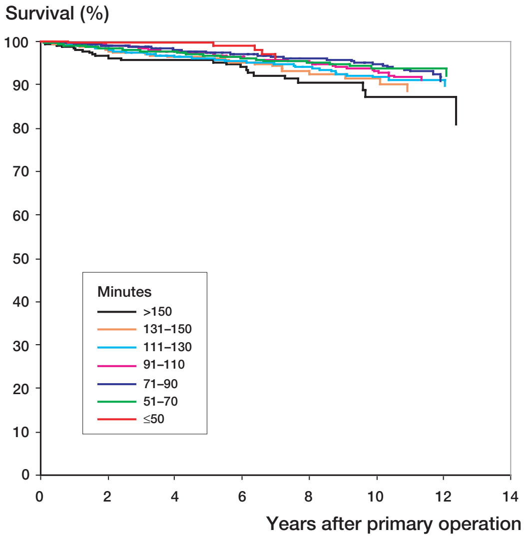


Figure 4. Kaplan-Meier survival curves (by operating time) for 9 886 Charnley implants fixed with Palacos or Simplex cement with a lateral surgical approach without trochanteric osteotomy, on patients with primary coxarthrosis operated at local hospitals in Norway between 1987 and 2001.

Among cemented implants, 13% of the revisions were performed due to deep infection when the primary operation lasted longer than 150 min, as compared to 8.3% for operating times from 71–90 min (adjusted RR = 3.5, 95% CI: 1.7–7.4). With revisions due to dislocation as endpoint, the analogous revision rate ratio was 1.7 (95% CI: 0.8–3.4). With revision due to aseptic loosening as endpoint, an operating time below 51 min was associated with a 1.6 times (95% CI: 1.0–2.4) increased revision rate compared to those lasting 71–90 min (Table 4).

All four operating time categories over 90 min were associated with an increased risk of revision due to aseptic loosening, as compared to the 71–90 min category. Among uncemented implants, 10 revisions were performed due to deep infection and there was 1 revision among operations lasting longer than 110 min. Furthermore, 29 uncemented prostheses were revised due to dislocation, 4 of these among operations lasting longer than 110 min and all 4 belonging to the longest operating time category. This gave a 2.8 times (95% CI: 0.6–12) increased adjusted revision rate due to dislocation when operations lasting longer than 150 min were compared with operations lasting 71–90 min (Table 4).

Table 4. Relative risk estimates based on multiple Cox regression analyses with specific revision causes as endpoint among 28 020 [a] cemented and 2 773 [a] uncemented primary total hip replacements performed at local hospitals in Norway between 1987 and 2001

Operating time for the primary operation (min)	No. THRs [a]	Revision due to aseptic loosening				Revision due to infection				Revision due to luxation			
		n	$RR_{Adj.}$	95% CI	P	n	$RR_{Adj.}$	95% CI	P	n	$RR_{Adj.}$	95% CI	P
Cemented implants													
< 51	453	26	1.6	1.0–2.4	0.03	1	0.5	0.1–4.0	0.6	2	0.9	0.2–3.6	0.9
51–70	4548	147	1.1	0.9–1.3	0.5	17	1.0	0.6–1.9	0.9	26	0.8	0.5–1.3	0.5
71–90	9844	285	1			33	1					60	1
91–110	6461	242	1.3	1.1–1.5	0.01	32	1.5	0.9–2.5	0.09	33	0.9	0.6–1.4	0.6
111–130	4180	201	1.5	1.2–1.8	<0.001	16	1.2	0.6–2.2	0.6	31	1.3	0.9–2.1	0.2
131–150	1584	82	1.5	1.2–1.9	0.002	7	1.4	0.6–3.1	0.5	7	0.7	0.3–1.7	0.5
> 150	950	62	2.0	1.5–2.6	<0.001	11	3.5	1.7–7.4	0.001	12	1.7	0.8–3.4	0.1
Uncemented implants													
< 51	245	38	0.8	0.5–1.3	0.3	0	–	–	–	2	1.5	0.2–8.8	0.7
51–70	746	52	0.8	0.6–1.2	0.4	2	1.2	0.2–8.7	0.9	7	1.4	0.5–4.0	0.6
71–90	929	75	1			2	1			7	1		
91–110	406	29	0.8	0.5–1.2	0.3	4	5.3	0.9–30	0.06	9	2.5	0.9–6.8	0.08
111–130	272	30	0.9	0.6–1.3	0.5	0	–	–	–	0	–	–	–
131–150	99	15	1.2	0.7–2.1	0.6	1	7.2	0.6–95	0.1	0	–	–	–
> 150	76	18	1.3	0.7–2.2	0.4	0	–	–	–	4	2.8	0.6–12	0.2

[a] Numbers reduced due to missing values in covariates

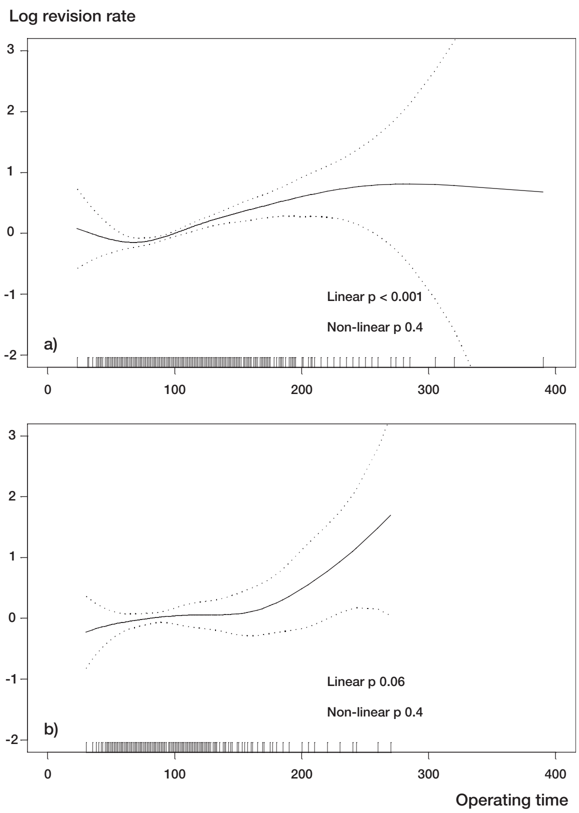


Figure 5. Graphic display of the relationship between operating time and the log revision rate for 28 890 cemented (a) and 2 855 uncemented (b) primary total hip replacements performed at local hospitals in Norway between 1987 and 2001. The curves, shown with 95% confidence intervals, were based on generalized additive Cox regression models with adjustment for confounders. The linear p refers to a linear trend test and the non-linear p to a test of non-linearity in effects.

Discussion

We have found that an operating time longer than 150 min in primary cemented hips had a two-fold risk of revision compared to those with operating times of 71–90 min. Similar findings were obtained for uncemented implants, but with smaller risk ratios that were not statistically significant. A shorter operating time did not increase the risk of revisions, except for aseptic loosening in cemented implants with operating time below 51 min.

The increased risk of revision in cemented hips with operating time over 150 min was especially associated with an increased risk of reoperation due to infections. This is in accordance with the study of Archibeck and White Jr. (2002) who found that revisions and procedures in total knee arthroplasty that took more than 2.5 hours were associated with an increased risk of infection ($p < 0.001$).

A long operating time could indicate a difficult operation, an inexperienced surgeon, a generally slow-working surgeon, an inexperienced operating team or a combination of these factors. It is known that young, inexperienced surgeons produce more dislocations than the experienced ones (Hedlundh et al. 1996). Surgeons performing only a few THRs a year are also associated with a higher risk of revisions (Kreder et al. 1997). As our material does not allow us to analyze the importance of these factors, a cause-effect relationship between operating time and revision risk may be debated. However, exclusion of operations with perioperative complications or with previous surgery did not alter the results of this study.

We found that higher annual operating volumes in local hospitals were associated with a reduction in operating time of 25–35 min. An association between high-volume hospitals and low revision rates has not been established for cemented implants, but may be important for uncemented implants (Espehaug et al. 1999). In the present article, analyses restricted to operations performed at high-volume hospitals gave similar but more pronounced differences in revision risk estimates for operating time. The variations in mean operating time from 68 to 130 min between the different local hospitals indicate that some of the hospitals may be able to reduce the operating times. may Other studies have shown that this is possible (Patiala et al. 1984, Sommers et al. 1990). The experience of the surgeon has been associated with THR outcome (Buchholz et al. 1985, Courtois et al. 1985). A low number of THRs per surgeon has been identified as a risk factor for revision (Fowles et al. 1987, Kreder et al. 1997). Standardization programs reduce operating time (Patiala et al. 1984, Sommers et al. 1990). Therefore, higher annual operating volume per surgeon may be cost effective if the result is shorter operating time without an increased risk of revision. To achieve this, a standardization program that has included preoperative planning, selection of one implant for all cases, selection of surgical technique and instruments, positioning of the patient on the operating table and training of the assisting staff with one surgeon has been performed in the local hospital of Hammerfest, Norway since 1998 (the institution of the first author). The annual mean operating time was reduced from more than 3 hours at the beginning of the period (1987) to 60 min at the end of the period (2001).

We were not able to correct for annual number of operations per surgeon in this study, but this has been done in a previous study in which the lowest revision rates were found in local and central hospitals where the mean number of THRs per surgeon was high compared to university hospitals (Espehaug et al.1999). Another study has found that the risk of failure in patients operated on by a consultant whose firm carried out 60 or more THRs in 1990 was 25% of that of patients under the care of a consultant whose firm undertook less than 30 (Fender et al. 2003).

Several Norwegian orthopedic surgeons prefer to use uncemented implants in patients less than 60 years old. In our study 66% (1 868 hips) of the patients with uncemented implants were < 60 years of age at primary operation (Table 1). 54% (1 549 hips) of the uncemented implants in our study were operated in hospitals with an annual uncemented operating volume of less than 20 (Table 1). In several small, local hospitals, this strategy leads to only a few uncemented THRs/surgeon/year (Espehaug et al. 1999). It is obvious that these surgeons hardly get enough experience to perform the uncemented THR operation according to the learning curve (Salai et al. 1997).

In conclusion, hospitals with long operating times should consider the potential benefit of reducing these times, as this might lead to lower revision rates and increased operating volumes. Shorter operation times could be achived by standardization programs, but one should bear in mind that for cemented implants very short operating times also increased the risk of revision due to aseptic loosening.

No competing interests declared.

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