From the Department of Orthopedics
Lund University Hospital, SE-221 85 Lund, Sweden

The Swedish Knee Arthroplasty Register
Validity and Outcome

Otto Robertsson

Thesis

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Paper I–VI

List of papers

This thesis is based on the following papers:

I. **Robertsson O, Dunbar MJ, Knutson K, Lewold L, Lidgren L.** Validation of the Swedish Knee Arthroplasty Register. A postal survey regarding 30,376 knees operated on between 1975 and 1995. *Acta Orthop Scand* 1999; 70(5): 467-72.

II. **Robertsson O, Dunbar MJ, Pehrsson T, Knutson K, Lidgren L.** Patient satisfaction after knee arthroplasty. A report on 27,372 knees operated on between 1981 and 1995 in Sweden. *Acta Orthop Scand* 2000; 71(3): 262-7.

III. **Robertsson O, Borgquist L, Knutson K, Lewold S, Lidgren L.** Use of unicompartmental instead of tricompartmental prostheses for unicompartmental arthrosis in the knee is a cost-effective alternative. *Acta Orthop Scand* 1999; 70(2): 170-75.

IV. **Robertsson O, Knutson K, Lewold S, Lidgren L.** Surgical routine reduces failure after unicompartmental arthroplasty. *J Bone Joint Surg (Br)* (Accepted).

V. **Robertsson O, Dunbar MJ, Knutson K, Lidgren L.** Past incidence and future demand for knee arthroplasty in Sweden. A report from the Swedish Knee Arthroplasty Register regarding the effect of past and future population changes on the number of arthroplasties performed. *Acta Orthop Scand* 2000; 71(4): 376–80.

VI. **Robertsson O, Knutson K, Lewold S, Lidgren L.** The Swedish Knee Arthroplasty Register 1975–1997 with special emphasis on 41,223 knees operated on 1988–1997. Submitted 2000.

Abbreviations and definitions

CRR Cumulative revision rate

CRRR Cumulative re-revision rate

HDPE High density polyethylene

OA Arthrosis, equivalent to osteoarthritis

PAS Patient Administrative System. A database run by Swedish health authorities that registers hospital admissions

PMMA Polymethyl methacrylate (bone cement)

Primary arthroplasty
The first time one or more joint surfaces are resurfaced with prosthetic implant(s)

RA Rheumatoid arthritis

Revision arthroplasty
A reoperation during which prosthetic component(s) are either exchanged, removed or added

RR Risk ratio

RSA Radiostereometric analysis

SKAR The Swedish Knee Arthroplasty Register

TKA Tricompartmental knee arthroplasty

UHMWPE
Ultra high molecular weight polyethylene

UKA Unicompartmental arthroplasty

Introduction

Historical background

Arthroplasty was initially a term used for a variety of procedures aimed at reducing pain and increasing function of a joint, such as joint resection, arthrolysis and interposition. As a term for endoprosthetic joint replacements, it is claimed to have been introduced by Themistocles Gluck, a German surgeon who used prostheses made of ivory for joint replacement, both in the hip and knee, as early as 1890 (Gluck 1890). Gluck's patients had joint tuberculosis, and despite encouraging initial results, problems with continued infections made him soon caution against this type of surgery. Infections remained the main obstacle to the further development of endoprosthetic arthroplasty and during the next 50 years, the surgical treatment consisted mainly of knee arthrodesis or operations with interposition of organic or inorganic materials. It was only after antiseptic and aseptic routines were introduced that real progress was made regarding joint replacement. In his classic article, Walldius was one of the first to report encouraging results of total joint replacement of the knee with his hinge prosthesis, originally made of acrylate (Walldius 1957, reprinted 1996). Other surgeons were also experimenting with hinged knee prostheses in the 1950s, among others, Shiers who published a preliminary report in 1954. Along with the development of hinges, interposition arthroplasties with inorganic materials further developed into hemicompartmental procedures with metal spacer blocks that could be used to replace the tibial joint surface.

The real advance came in the 1970s, with the principle of low-friction arthroplasty, initially developed for the hip joint. Ultra high molecular weight polyethylene (UHMWPE) parts were made to articulate against polished metal parts, fixed to bone with polymethyl methacrylate (PMMA), for distribution of load.

The hemiprostheses evolved into resurfacing unicompartmental prostheses, commonly used in both the femoral and tibial compartments (Gunston 1971, Marmor 1988). By connecting two unicompartmental components, first on the femoral side and later on the tibial side, bicompartmental prosthesis was created (Freeman and Lewack 1986), which was transformed into a tricompartmental design by adding a patellar flange. In 1974, Insall and Walker successfully introduced the unconstrained total condylar prosthesis with a metal femoral and UHMWPE tibial component used with PMMA cement (Insall et al. 1976). Hinge prostheses were also redesigned allowing bi/multiaxial rotation (linked) and adapted the principle of low friction arthroplasty with UHMWPE bearings.

Göran Bauer (1923–1995), professor of orthopedics in Lund and later editor of the Acta Orthopaedica Scandinavica, realized in the early seventies, that in this environment it would be impossible for an individual surgeon to base his choice of optimal operative treatment on his own experience. The literature at the time gave little guidance, since it mainly dealt with descriptions of specific methods or implants used for various conditions instead of comparing methods or implants with respect to specific conditions. He thus became the major promoter of initiating the Swedish knee arthroplasty project in 1975, at the time of rapid development of this new type of surgery. The aim was to give early warning of inferior designs and present average results based on the experience of a whole nation instead of that of highly specialized units. For this purpose a nationwide prospective register of knee arthroplasties–the Swedish Knee Arthroplasty Register–was started in Lund.

Evaluation of failures

Initially, the disability indicating endoprosthetic surgery was so severe—with no suitable alternative treatment—that any short-term benefit was regarded as a success, if it did not cause later complications for the patients. It is therefore understandable that the main interest focused on failures and complications, rather than the degree of benefit.

Early arthroplasty studies were mainly descriptive where the number of complications or failures was related to the number of implants. The problem with these types of studies was that in order to increase sample size, the operations were included during several years. This, in combination with the death of some patients during the study period, resulted in variable lengths of follow-up, unclear sample sizes and misleading failure rates that could not be compared to that of other studies. Therefore, other methods for analysis were required.

Survival methods

The use of survival (actuarial) methods to produce life tables began in the 17th century. These methods allowed for varying periods of follow-up and permitted calculation of cumulative failure rates over time that could be presented in a graph. Subjects to be studied were included at different points in time and were then followed at regular intervals to investigate if a defined event (terminal event) occurred or not. In the medical field, survival methods were initially used for following cancer patients after treatment, recording the time interval between the treatment and death (terminal event) in failed cases or to the end of the study period in successful cases. However, not all patients can be followed until the terminal event or to the end of the study period as some do not show up at controls, can not be located or decline to participate. These become classified as censored cases. The survival methods make use of the information available for these patients by recording the time from treatment until the case was censored (lost to follow-up). Another mechanism of premature withdrawal occurs when patients die of reasons completely unrelated to that being investigated (e.g., traffic accident). When evaluating a treatment, such patients are censored at the time of death, in the same manner as if they had been lost to follow-up. Thus, for cases that are lost to follow-up or die of causes unrelated to that being investigated, the treatment is recorded as a success for the time period available. The statistics used are normally based on the assumption that if followed, the censored cases would have behaved in the same way as those not withdrawn from the study.

The final result of the life table analysis is an evaluation of risk, that can be expressed as the cumulative probability of experiencing the terminal event with time, or as hazard, which is the risk of experiencing the terminal event during a fixed time interval, conditional on being at risk at start of the interval.

The end-point

In 1980, Dobbs was the first to use survivorship methods for arthroplasties when analyzing failures after hip arthroplasty. Later Tew and Waugh (1982) used it for knee arthroplasty and so did the SKAR (Knutson et al. 1985, 1986). When used for arthroplasty, the terminal event is changed from death to some defined failure.

Although commonly used, the terms success and failure are difficult to define in the context of surgical intervention, where the primary objectives of a treatment can vary. Thus, a postoperative result for a given patient might be called a success, while for another it would be a failure. Even seemingly obvious failures (e.g., pain, loosening, instability, wear) may be low grade and not easily distinguished from normal postoperative conditions. Thus, depending on the definition of failure and the interval of follow-up, it can be difficult to decide if and when the end-point has been reached. The reason why revision arthroplasty has become the most widely used end-point is that unlike pain, radiological signs and range of motion or health scores it can hardly be disputed if and when the revision occurred.

In spite of being easy to define, using revision as an end-point is not without problems, as not all patients with clinical failure need to be offered surgery or can sustain surgery, and the timing of surgery may be influenced by external causes. Further, even when revision is used as an end-point indicating failure, there is a variation in the literature regarding if all or only specific revisions should be used as the end-point. Some authors do not include revisions for infections in results (Faris et al. 1991, Ritter et al. 1995), claiming that they are not related to the durability of the implant. Similarly, revisions for other than plain mechanical reasons are sometimes excluded (Jordan et al. 1997) and when a component is added to a previously unrevised compartment (e.g. addition of a patellar component), this can be regarded more as a failure of the original procedure than that of the implant per se (Murray et al. 1998a).

In an effort to include some clinical parameters in the definition of failure, some authors have used revision in combination with some other measure of failure as an end-point. Thus, revision or planned revision (Font-Rodriguez et al. 1997), revision or loosening (Ranawat et al. 1989), revision and pain (Mackinnon et al. 1988, Nelissen et al. 1992) have all be used as a definition of failure.

Patients lost to follow-up

Patients prematurely withdrawn from the study have been matter of debate (Murray et al. 1998b). While it is obvious that patients that die without experiencing a revision have no chance of experiencing it later, it is possible that patients lost to follow-up have been revised. It is indeed plausible that patients become lost when seeking an alternative treatment elsewhere. Therefore it is important, irrespective of the end-point used, that the number of patients lost to follow-up is kept to a minimum and it has even been suggested that they should all be treated as failures in a "worst case" scenario (Carr 1993).

Patient related factors

Several studies that have addressed the effect of diagnosis and age of patients on results have concluded that these factors do influence the results (Rand et al. 1991, Knutson et al. 1994, Coyte et al. 1999). However, in the majority of published studies in which survival rates are disclosed, the calculations are performed on all diagnoses and age groups combined, which makes interpretation difficult because of differences and case-mix.

Evaluation of success

Independent of the definition of failure, survival studies only register withdrawal, failure or success. While a strict definition of failure allows for a wider variation in success and vice versa, survival studies give no information on the degree of failure or success, respectively. Thus, the major disadvantage of a project such as the SKAR that uses a strict definition of failure, is that besides missing some true clinical failures not coming to revision, it gives no clue regarding if, or to what extent, the patients that do not fail have benefited from the operation. In order to evaluate health, numerous scoring systems have been devised, regarding general health as well as disease or site-specific conditions. Many of these have been used on patients undergoing endoprosthetic surgery. However, there has been no consensus on which scoring system was the most appropriate, probably because that there is no "gold standard" for arthroplasty outcome that scoring systems can be judged by (Dunbar et al. 1999). Further, the success of an operation must bee seen in context with the aims of the surgery. For joint arthroplasty in general, the indications for surgery have been non-specific (Gartland 1988) with disabling pain or functional disability with evidence of an intra-articular disease being the most common (Mancuso et al. 1996). Ideally, a knee arthroplasty should reduce pain and deformity as well as improve mobility and walking ability. However, depending on the preoperative status of the patient, a varying change in these factors can be expected (Brinker et al. 1997, Fortin et al. 1999). Further, it is not granted that the operation was meant to resituate the knee to that of a completely "healthy" individual, not to mention the general health.

The complexity and workload associated with the use of health questionnaires has hitherto hindered their large-scale use by the SKAR.

Revision rate and cost

The general assumption has been that the majority of knee-replaced patients fare well, with exemption of the failures (Callahan et al. 1994). Thus, the main focus of improvement has been to reduce the number of failures by introducing new designs, new materials and new fixation techniques. However, newer, technically more advanced implants have the tendency of becoming more expensive than the ones they are to replace (Healy et al. 1994). With the increasingly large number of elderly patients and the relatively low failure rate of many implants, it becomes questionable if it is always economically sound to replace a current implant with a newer more expensive one, even if it may be assumed to have a slightly lower failure rate that most often is hypothetical but not documented. Health economic calculations are not part of the introduction of knee implants today.

The UKA is an example of an implant that in Sweden has a documented higher revision rate than the more expensive TKA (Knutson et al. 1994). As both types of implants can be used for unicompartmental disease there are authors that recommend only the TKA, even in unicompartmental disease (Laskin 1978, Sculco 1994). Other have been more in favor of using the UKA, arguing that the surgical procedure is less extensive (Rougraff et al. 1991), bone stock is better preserved (Engelbrecht et al. 1976, Goodfellow et al. 1988, Marmor 1988, Bert 1991), recovery is faster (Cameron et al. 1988), the risk of infections is lower (Bengtson et al. 1991) and patient satisfaction after UKA is greater than after TKA (Laurencin et al. 1991, Rougraff et al. 1991).

Using available Swedish data for these types of implants, a comparison can be made with respect to implant cost, hospital stay and rate of revision to estimate the economical consequence had the cheaper UKA implant been replaced with the more expensive TKA, in an effort to reduce the overall revision rate.

Volume of surgery

The survivorship of joint arthroplasties depends on a number of factors. Results may be related to the materials used, such as design of implants and method of fixation, to patient factors such as age, grade and type of disease or to the experience and skill of the operating surgeon. Of these factors, it is especially difficult to take into account the surgeons skill. Although not addressing the skill of individual physicians, the volume of treated patients at institutions can be used as an indicator of the routine when treating a particular disease. After first having been used in the evaluation of treatment for cardiac diseases, volume studies have been used in orthopedics (Lavernia et al. 1995, Kreder et al. 1998, Espehaug et al. 1999).

To be able to estimate the effect of volume on CRR in a non-randomized study, the material observed needs to be as homogenous as possible and there has to be a sufficient number of failures to make statistically valid comparisons. Patients operated on with UKA, due to osteoarthrosis in the medial knee compartment, are probably the most homogenous group that can be selected from the SKAR with respect to the grade of disease. Further, the UKA has been claimed to be technically demanding (Sculco 1994) and has a relatively high number of revisions. Thus, by classifying units by the number of UKA operations performed, it is possible to evaluate the effect of volume on the CRR after medial UKA. An implant of special interest is the Oxford UKA which due to a mobile meniscal bearing is technically demanding and which at certain centers in the U.K. has had a considerably lower CRR (Murray et al. 1998b) than in Sweden (Lewold et al. 1995) where the results, in contrast to the U.K., were nationwide, involving surgeons and centers with varying degree of experience.

Incidence

The incidence of a procedure (i.e. number/ 100,000 inhabitants) indicates the volume performed in a society. However, as arthroplasty often is more common in certain age groups, the total incidence does not necessarily represent the relevant volume of procedures being offered to the population as it is influenced by the disease pattern and age profile of the population. Thus, when countries are compared regarding frequency of a procedure, the age specific incidence and the age profile of populations have to be taken into account (Ingvarsson et al. 1999).

In the last decades, new forms of medical and surgical treatment have become available and in combination with increased general welfare, life expectancy has increased. This has created, or will create a shift in the age profile of most countries, leading to an increase in the number of elderly with a subsequent increase in musculo-skeletal disorders such as joint diseases, fragility fractures

Table 1. Literature review of knee prosthetic survival studies

Author	Origin	Year of operation	Diagnosis (%) OA	RA	Other	Model [a]	Type	n	Female (%)	Age
Tew et al 1985	UK	1970–83				Various models [b]	MIxed [c]	673		
Thacker & Fulford 1986	UK	1976–85				Denham	TKA	335		elderly
Morrey et al. 1987	USA	1977–81	Mixed			Total Condylar	TKA	1,253	66	³ 63
Scuderi et al. 1989	USA		78	13	9			1,430	69	67
		1974–78				T. C. all PE tibia	TKA	224		
		1978–81				T. C. PS all PE tibia	TKA	289		67
		1981–86				T. C. PS MB tibia	TKA	917		
Gill & Mills 1991	USA	1976–89	86	9	5	Various models	TKA	1,000		W 69 M 70
Rand & Ilstrup 1991	USA	1971-87	Mixed [d]			Various models [e]	Mixed [f]	9,200	51–71	56–7
			100	–	–			6,269 [g]		
			–	100	–			2,876 [g]		
			Traumatic					55 [g]		
Lindstrand et al. 1992	SE	1983-90	100	–	–			3,777	Eq. [h]	68 [h]
						PCA	UKA	772		
						Marmor	UKA	1,562		
						St Georg	UKA	1,441		
Knutson et al. 1994	SE	1976-92	Mixed [d]			Various models		10,228	74–78 [i]	68–70 [k]
		1976-82	100	–	–		TKA	1,360		
		1983-87	100	–	–		TKA	2,827		
		1988-92	100	–	–		TKA	6,041		
Ritter et al. 1995	USA	1983-91	91	6	3	AGC all PE tibia	TKA	2,001	65	69
Abernethy et al. 1996	UK	1980-83	Mixed			T. C. PE tibia	TKA	550	54	67
		1983-90	Mixed			Kinematic MB	TKA	1017	52	65
Ansari et al. 1997	UK	1974-93	100	–	–	St Georg	UKA	461	68	70
Jordan et al. 1997	USA	1985-91	90	10	–	LCS uncemented	TKA	473	70	68
Font-Rodriguez 1997	USA	1974-94	78	15	7			2,629		
		1974-78				T. C. PE tibia cement	TKA	215	70	67
		1978-81				T. C. PS PE tibia cem.	TKA	265		
		1981-94				T. C. PS MB tibia cem.	TKA	2,036		
		1974-94				T. C. PS modul. cem.	TKA	49		
		1974-94				T. C. Constr. cement.	TKA	64		
Basset 1998	USA	1988-93	88	6	6	Performance	TKA	1,000	60	69
Murray & Frost 1998	UK	1987-93	82	18	–	AGC, Nuffield, IB2	TKA	1,429		71
Coyte et al. 1999	CAN	1984-91	85	12	3	Mixed		17,229	63	69

[a] T. C. = Total Condylar, PE = polyethylene, PS = posterior stabilized, MB = metal backed
[b] 9 models including 87 revisions
[c] Hinges and TKA
[d] Selected diagnoses shown
[e] 9 groups of implants including 1,131 revisions
[f] Hinges, TKA, BKA and UKA
[g] Including revisions
[h] Equal in compared groups
[i] OA, decreasing with time
[k] OA, increasing with time

and direct medical costs. These circumstances led to the declaration of the Bone and Joint Decade 2000–2010 by the United Nations in November 1999. One of the goals is that the member countries are to show the current prevalence, incidence and burden of musculo-skeletal disorders (Lidgren 2000). Such knowledge is at present scarcely available but by using the SKAR and the Swedish Census Register, data may be extracted that enables comparison, planning and estimations of actual and future demand and cost.

Literature review

While there is a large amount of studies that in some way disclose results calculated by survival methods, the number of large studies is rather

Dead (n)	Lost to FU (%)	At risk last interval (%)	Reached endpoint	Cum survival (100–CRR)	Comments
	9	6	186	85% at 10 Y	End-point: revision or severe pain
36	4	25	8	95% at 5Y	
			9	99% at 5 Y	End-point: only loosening
					End-point: revision or planned revision
		53	10	93% at 7 Y	
		37	6	97% at 7 Y	
		8	7	99% at 7 Y	
69	8	< 3	6	94% at 13 Y	End-point: revisions, nonrevised infection and patellar dislocation
				Primaries (all models)	CRR range for different implant groups
			582	91% at 5 Y – 80% at 10 Y	78–98% at 5 Y
			325	92% at 5 Y – 83% at 10 Y	64–98% at 5 Y
				83% at 5 Y – 69% at 10 Y	Traumatic cases also included in OA
			65	84% at 6 Y	
			52	95% at 6 Y	
			55	93% at 6 Y	
				89% at 5 Y	
				95% at 5 Y	
				97% at 5 Y	
39	< 6		8	98% (CI 96–100) at 10 Y	Infected excluded (n 15)
58			17	97% at 5 Y – 92% at 10 Y	130 excluded (dead or inadequate radiographs)
62			48	94% at 5 Y – 88% at 10 Y	164 excluded (dead or inadequate radiographs)
	5	29	18	88% (CI 81–93) at 10 Y [m]	
39			17	95% at 8 Y (CI 91–98)	End-point: mechanical failures
					End-point: revision or planned revision
0	2		13	91% at 21 Y	Worst case 85% at 21 Y
85	4		14	94% at 16 Y	Worst case 90% at 16 Y
95	2		26	98% at 14 Y	Worst case 93% at 14 Y
0	6		3	94% at 10 Y	Worst case 89% at 10 Y
2	3		1	98% at 7 Y	Worst case 95% at 7 Y
31	4.5		10	99% at 5 Y	
	4		23	94.3% (CI 88–100) at 7 Y	Including patellar additions as revisions
				97.5% (CI 94–100) at 7 Y	Excluding patellar additions as revisions
				92–96% at 7 Y	Approximations based on ICD9 classifications

FU = follow-up
Y = years
[m] 74% if pain and revision is end-point

scarce. Further, comparisons between studies are difficult because of differences regarding the types of implants used, period of surgery, number of cases included, case mix, number of cases lost to follow-up and even definition of end-points. In Table 1 selected results of some larger studies are listed along with some other relevant information when available.

Although seemingly simple to understand, the results of survival studies can be difficult to interpret. Several of the mentioned factors can have an effect on results. While the results can displayed in graphs and simple numbers, information (if available) regarding design and confounding factors is to be sought in the less glossy material and methods sections. It is my hope that the study will shed some light on the different aspects of outcome evaluation in the SKAR.

Aims of the study

The aims of the study were as follows:

to validate the SKAR with respect to revisions recorded, and evaluate if the Swedish Patient Administrative System (PAS) could be used for improving the registration.

to inquire on a large scale, how satisfied Swedish patients were with their knee after having a knee arthroplasty and if revision can be justified as a measure of outcome.

to evaluate the relationship between revision rate and economical burden by comparing UKA and TKA used for osteoarthrosis, knowing that the former had a higher CRR but were less expensive.

to investigate the relationship between the numbers of procedures performed per unit and the risk of later revisions by analyzing UKA performed for medial OA.

to describe the age specific incidence of knee arthroplasty in the Swedish population and to investigate if past changes in the age profile are linked to the observed increase in surgery as well as to evaluate how predicted changes in the age profile might affect future demand.

to describe the Swedish Knee Arthroplasty Register regarding demography, epidemiology, comprehensiveness and general prosthetic survival.

Patients and methods

Items recorded in the SKAR

Patient identity

Unique in the Nordic countries is the extensive use of a social security number for all inhabitants, available through a national census register. It includes information on the date of birth and gender and is used by everyone in their contact with authorities, hospitals and most private companies, when identification is required. It is readily available, is printed on ID cards and passports, and permits life-long tracing of patients including date of death. This is in sharp contrast to the situation in most other countries, where such tracing is an immense, if not impossible, task.

Side operated on, date of operation and operating unit

These variables are distinct, and besides mix-up and typing errors cause no problem regarding registration. By adding to the social security number a letter, representing the side operated on, every knee gets its own unique ID. The registration of the operating unit was not originally intended to evaluate results of individual units, but was to allow for inquiries about patients at a later date.

Primary diagnosis

Although the diagnosis is clear for the majority of patients that are treated for osteoarthrosis (OA) or rheumatoid arthritis (RA), some cases are difficult to classify under a single diagnosis, especially as a patient can suffer from more than one condition. Although it is possible to record several diagnoses, inevitably a single diagnosis becomes the primary one. In cases where more than one diagnosis has been given by the operating surgeon as being the cause for operation, the most specific has usually been recorded as the main one (e.g., osteonecrosis is preferred to OA, fracture to disease, malignancy (local) to fracture). Being a systemic disease, RA is classified as the main cause of operation, regardless of local specific diagnoses, such as gonarthrosis or osteonecrosis. It may however be superseded by more severe diagnoses, such as infection, fracture or malignancy. Further, when recorded in one knee, RA can change a more nonspecific diagnosis in the other knee (sooner or later).

Type of arthroplasty and endoprosthesis

The definitions used by SKAR for the various types of knee prostheses bear the mark of their evolution, and sometimes may seem a little odd to the uninitiated. However, most of these concepts are still used today, with some modifications.

Prostheses without mechanical links between the components (resurfacing prostheses)

Femoropatellar prostheses are used only in the patellar joint (Figure 1).

Unicompartmental prostheses (Figures 2 and 3) are used for replacing the medial and/or the lateral tibiofemoral compartment. In unicompartmental arthroplasty (UKA) only one compartment is replaced. A bicompartmental arthroplasty can be achieved using two unicompartmental prostheses, both medially and laterally but these are rarely performed nowadays.

Bicompartmental prostheses (Figures 4 and 5) are used to replace both the lateral and medial compartments with a single component (on the

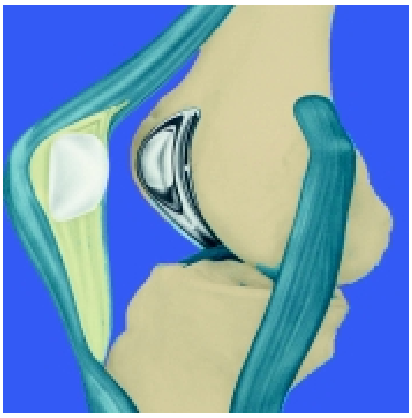

Figure 1. A femoropatellar prosthesis (Lubinus) with a PE patellar component and an isolated metal femoral groove.

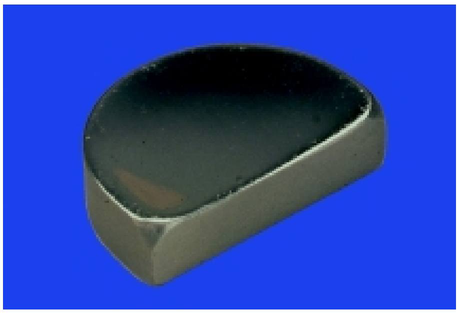

Figure 2. A nowadays obsolete Macintosh hemiprosthesis, which was used as an onlay prosthesis on the articular surface of the tibial plateau.

Figure 3. A modern unicompartmental prosthesis (Duracon) with a PE tibial component. The metal femoral component is inserted after resection of the femoral condyle.

Figure 4. One of the earliest bicompartmental prostheses (Geometric) with bridges between the two unicompartmental parts, which ensured parallell placement of the components.

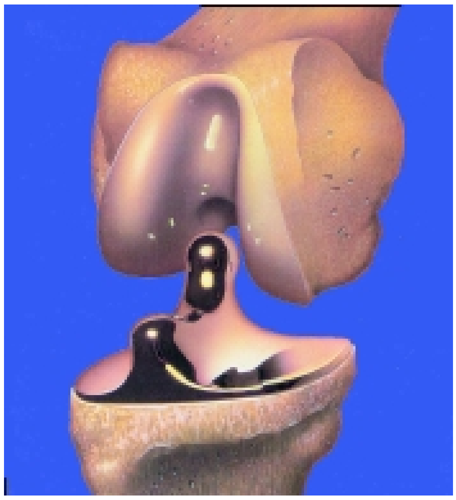

Figure 5. A bicompartmental prosthesis (Deane) of unusual design with a ball and socket articulation, which has been abandoned because of mechanical problems and femoral loosening.

Figure 6. A tricompartmental prosthesis (Kinemax) with a modular tibial part, a femoral component with a patellar flange and an optional PE patellar component.

tibial and femoral sides), but the femoral side has no patellar flange (thus the patellar joint is not affected). Nowadays these are not commercially available as unlinked prostheses.

Tricompartmental prostheses (Figure 6) are used to replace all 3 joint compartments of the knee, affecting both the femoro-tibial compartments (medial and lateral) and the femoro-patellar compartment (with or without a separate patellar button). Thus, the coverage of the femoral component distinguishes it from the bicompartmental prosthesis. Modern designs are either uncon-

Figure 7. A hinge prosthesis (GSB) with a patellar flange and long stems for intramedullary fixation. Half the femoral component is removed to display the inner design with a PE liner to avoid direct metal to metal articulation.

Figure 8. A linked prosthesis (Rotalink) without patellar flange. The femoral housing contains a PE lined hinge. The tibial metal protrusion articulates against a PE lined tube connected to the hinge thus allowing axial rotation.

strained (posterior cruciate retaining) or constrained by highly conforming components or a cam axis design that forces a roll back of the femur on the tibia (posterior stabilized). The latter are used after removal of the posterior cruciate ligament.

Prostheses with mechanical links between the components

Hinged prostheses (Figure 7) are fixed axis total knee designs with stem fixation.

Linked prostheses (Figure 8) are mechanically coupled prostheses that permit more than fixed axis rotation. They are either modified (i.e., rotating) hinges or reinforced cam axis designs that also control varus–valgus stability (i.e., superstabilized). Both are available with or without a patellar flange.

Endoprosthetic model

When recordings started, each type of prosthesis had relatively few models, often named after their designers. The name of the implant was like that of the model. This classification of models by their names has since led to various problems, of which a few examples can be given.

Implants have been changed regarding design and material, but not the name. As a unit often used a particular model during a certain time period, this model became well known to the local surgeons who often referred to it by a generic name, instead of a more specific one, and even kept using the same generic name when a new variety was introduced (e.g., St. George when EndoLink was introduced). Thus, implants by the same name might be different varieties of the implant (e.g., PCA was used for different variations of the Porous-coated Anatomic prosthesis). Similarly, changes in surface properties (metal backing, coating) were introduced that did not affect naming. Interchangeability permitted use of different models on the femoral and tibial sides (hybrids), and there are examples where the popularity of a hybrid became so great that after a while it was introduced as a standard. This has severely reduced the possibility of analyzing the effect of mechanical properties of implants on results.

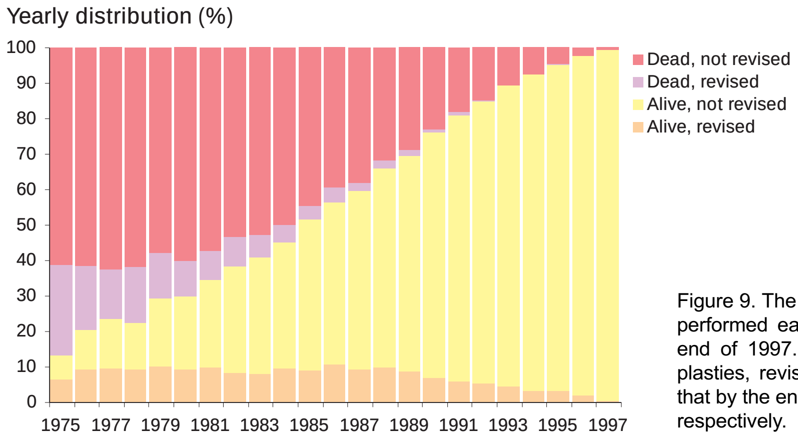

Figure 9. The fate of primary arthroplasties performed each year as recorded by the end of 1997. The bars represent arthroplasties, revised or unrevised, in patients that by the end of 1997 were alive or dead, respectively.

Method of fixation

The use of bone cement was recorded separately for each component. In the beginning, this information was relatively self-evident and based on the implant model used, but with increasing popularity of implants with surface coatings, intended for use both with or without cement, the availability of this information became crucial. Because of the delay in realizing this, during a few years in the mid-1980s, the records regarding the cementing of components were sometimes incomplete.

Recording of postoperative results

For reasons mentioned in the introduction, initially the main interest focused on failures and complications, rather than the degree of benefit. The first data-forms, regarding the primary operation, thus included data on immediate general complications (during the hospital stay), but specific problems were rarely reported and recording of such data was abandoned in 1990.

As knee arthroplasty became accepted as a safe and reliable treatment (even for patients with less disability), the degree of success became an issue. Back in 1979, a clinical evaluation was included at the 3-year follow-up, using the British Orthopaedic Association (BOA) Assessment Chart. This failed, because the clinicians found the extra workload unacceptable. The longevity of the procedure thus became measured by the absence of failure, which became defined as the need for an additional operation: the revision. The inquiry regarding patient satisfaction in 1997 (Paper II) was the first major attempt by the registry to gain large-scale information regarding the majority of arthroplasties, not classified as failures.

Reason for revision

The main reason for revision has been recorded. The operation reports regarding revisions have been gathered and reviewed at the project center at the Department of Orthopedics in Lund. In case the operating surgeon stated several reasons as having caused the revision, one became selected as the main reason. As for the primary diagnoses, the most specific (most serious) reason was normally chosen, but unlike the diagnoses, the different reasons for revision were common and often interconnected in various ways. In an end-stage of malalignment, wear, instability, loosening and prosthetic fracture, it could be difficult to decide what was the first or primary reason for failure. To amend the registration, during a recent change in routines, the SKAR has begun recording the state of individual components as well as one main reason.

Date of death

The SKAR has been regularly crossed checked against the National Census register to gather information on patients that have deceased and their exact date of death. At the end of a study period, all living patients not reported as revised became defined as success with the prosthesis in situ.

It is obvious that during a period of 23 years many of the patients operated on early in the period are deceased. Figure 9 describes the fate of the knees operated on each year as of the end of

1997 and the percentage of primary arthroplasties remaining at risk for revision.

How the SKAR has evaluated failures

Survival

Since 1985, survivorship methods have been used for description of outcome in the SKAR. Initially, results were described with life table curves using the Wilcoxon (Gehan), the log-rank and other similar tests to test crude (empirical) survival between groups. As these methods have the disadvantage that when comparing groups (e.g., implant type), the effect of other factors (e.g., age, gender) is not taken into account, Cox's regression later was used to estimate differences in survival, allowing adjustment for external factors

As the survival method initially had been used to show the proportion of patients surviving a disease, the graphical results were expressed as a curve that started high on the left axis with all patients surviving (100%), falling to the right as patients died. This was also how the register initially showed the curves, but for semantic reasons this was later changed. Instead of showing the percentage surviving arthroplasty (by not being revised or reaching another end-point), by subtracting the survival percentage from 100% the curves express the cumulative rate (percentage) of revisions (CRR) (or other defined end-point) occurring after the index arthroplasty, starting at zero and gradually increasing. Thus, the term used for the analysis (CRR) also clarifies the end-point used (revision).

The end-point

In view of the workload with clinical follow-up examinations and lack of definitions for clinical failure, the SKAR needed simpler indicators of failure. It had been noted that grossly unsuccessful cases were often caused by implant and fixation problems, or wound complications, frequently requiring surgical intervention. An additional operation, a revision, therefore indicated that both the patient and surgeon had agreed upon that the original problem had not been solved, indicating failure of the primary operation. Any later operation after primary knee arthroplasty could be called a revision, including soft tissue operations, transpositions, extraction of bone or cement fragments and arthroscopy. As some of these could be of minor nature and were not necessarily related to the primary procedure, it could be debated if they always represented failure. It was therefore decided to use a stricter definition of revision that included only re-operations during which prosthetic components had been added, exchanged or removed (including amputations and arthrodeses). The SKAR has not considered using revision in combination with other measures of failures such as loosening, planned revisions or pain, because of the difficulties with the definitions and the logistic problems when using potentially reversible conditions as an end-point.

Patients lost to follow-up

The SKAR has relied on the participating units to provide information regarding revisions of included patients. Until 1989, a follow-up form at 1, 3, 6 and 10 years postoperatively was sent to the participating units to inquire if a patient had experienced a re-operation or complications. These forms were later abandoned in favor of yearly lists of all revisions. The combination of high quality national census registers, free health service and few private alternatives for revision surgery meant that the majority of patients could be traced until death, and did not become lost to follow-up in the traditional meaning. However, if a revision was not reported to the register by a participating unit, the patient became lost to follow-up in a true worst-case scenario (Carr 1993) where a lost case is indeed a revised case.

Patient related factors

With the large number of operations reported to the SKAR it has been possible to provide separate outcome results for OA and RA, which were the main indications for surgery. The numbers of operations for other diseases has been low and have hitherto not been evaluated in detail. Results were adjusted for differences in age and gender using Cox's regression analysis.

Statistics

When probability levels (p-values) are used, a value of - 0.05 has been considered significant. Confidence intervals, describing the uncertainty in estimates with a range of plausible values, have been calculated using 95% confidence.

The end-points used for survival statistics after primary arthroplasty were as follows: 1) When analyzing overall revision rate the end-point was the first true revision done for any reason. 2) When analyzing the revision rate for loosening, it was also the first true revision, but only if loosening had been registered as the indication for revision. 3) When analyzing infection, the end-point was defined as revision for infection, irrespectively of if this was the first revision or revision at a later time. At the end of a study period, those patients alive, not registered as having reached the terminal end-point (revision 1-3), were classified as successful cases while deceased unrevised cases were classified as withdrawals at the date of death.

When analyzing the secondary revision rate after a primary revision, the end-point was the first re-revision for any reason.

When Cox's regression was used, the regression model included, besides the variable to be studied, the calendar year of operation and age of the patients as numerical variables and the gender of patients as a categorical variable.

The relative risk of a significant variable is expressed after adjusting for the effect of other explanatory variables in the model. For categorical variables the reference category has been defined as having a relative risk of 1; the risk for other categories was measured relative to the reference category, expressed as a risk ratio (RR). For numerical variables, the RR relates to the change in risk if the variable increases by one unit (i.e. 1 year increase in age or calendar year of operation).

For graphic presentation, the cumulative revision rate (CRR) was calculated with the life table method using one month intervals and plotted with confidence intervals calculated using the Wilson quadratic equation with Greenwood and Peto effective sample-size estimates (Dorey et al. 1993). Curves were cut-off when 40 knees remained at risk.

SPSS software was used for all statistical calculations.

Overview of patient allocation

Paper I

Period 1975–1995

Total 45,195 knee arthroplasties in 36,901 patients. Alive 30,376 knee arthroplasties in 25,761 patients.

Paper II

Period 1981–1995

Answers regarding patient satisfaction with 27,372 knees in 23,239 patients.

Paper III

Period 1985–1995

15,437 TKA and 10,624 UKA performed for OA where patients could be located in both the SKAR and the PAS.

Paper IV

Period 1986–1995

10,474 medial UKA for osteoarthrosis, including 874 PCA, 905 Oxford and 4,307 St. Georg/Link prostheses.

Paper V

Period 1976–1997

57,201 knee arthroplasties in 46,659 patients.

Paper VI

Period 1975–1997

57,533 primary arthroplasties in 46,893 patients with special emphasis on the period 1988–1997 with 41,223 arthroplasties in 34,877 patients.

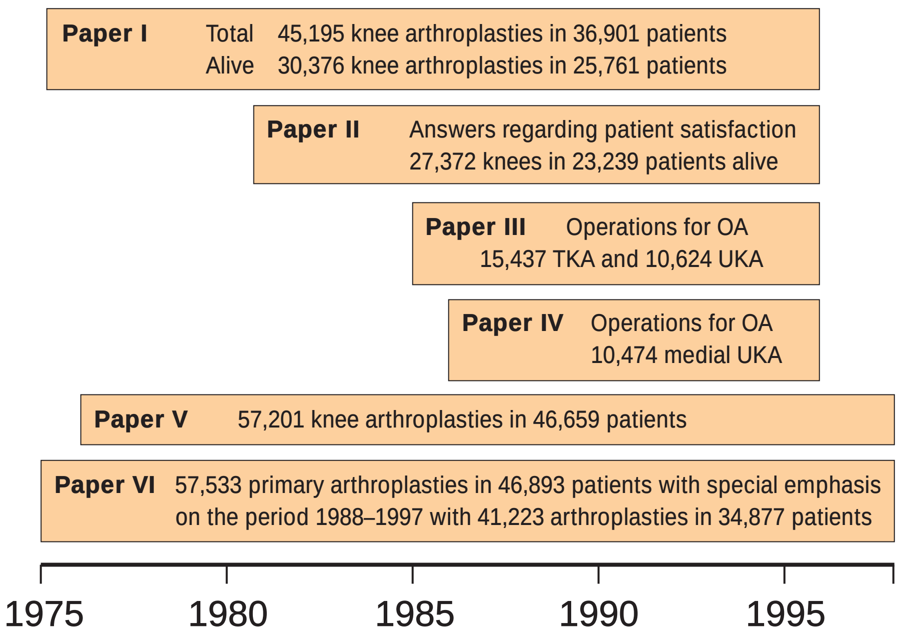

Figure 10. Patient allocation.

Summary of papers

Paper I: Validation of the Swedish Knee Arthroplasty Register. A postal survey regarding 30,376 knees operated on between 1975 and 1995

The SKAR was started as a voluntary register, prospectively following included patients with respect to complications and failures. A previous study (Knutson et al. 1994) had shown that between 1985 and 1992 the number of arthroplasties registered in the SKAR was about 85% of the number registered by the health authorities in the PAS database. Because of the vast number of primary operations, an unbiased loss in reports of primary arthroplasties was not regarded as a problem. However, as the register is prospective, with revisions utilized as the end-point in survival analyses, it was of importance that revisions of included patients were reported.

To validate the register, a questionnaire was sent to all living patients with 30,796 knees registered as having been operated on from 1975-1995 to inquire if they had been reoperated without this being reported to the register. 93% of the patients responded, resulting in the finding that 1.7% of the knees, previously registered as unrevised, had in fact been revised but not reported. Thus, one fifth of all revisions had been missed. The reports of the participating units were more accurate during the first 10 years, but after that accuracy declined. The university hospitals were better than the smaller units at reporting revisions. The types of revision most often unreported were partial revisions or procedures such as amputations, extraction of the prosthesis and arthrodesis.

We further investigated if the missing revisions could have been localized by comparison of the SKAR and PAS databases, and found that 84% would have been revealed. This lead to a subsequent update of the SKAR incorporating all deceased and non-responding patients.

Paper II: Patient satisfaction after knee arthroplasty. A report on 27,372 knees operated on between 1981 and 1995 in Sweden

The validation process of the SKAR (Paper I), gave an opportunity for an inquiry regarding patient satisfaction. However, to avoid a reduction in response rate, such inquiry needed to be short and simple. We decided to ask the patients to mark one of four alternatives, indicating how satisfied they were with the operated knee: A) very satisfied B) satisfied C) uncertain or D) unsatisfied. With an average 6 (2–17) years after primary arthroplasty, 95% of the 28,962 patients operated on between 1981 and 1995 responded. Of those responding, 81% were satisfied or very satisfied, 11% uncertain and 8% were unsatisfied. The proportion of satisfied patients was affected by the preoperative diagnosis, with patients with RA being the most satisfied, followed by patients operated for OA, posttraumatic conditions and osteonecrosis. There was no difference in proportions of satisfied patients, depending on if they had primarily been operated on with a total knee arthroplasty (TKA) or a medial unicompartmental arthroplasty (UKA). For TKA's performed with patellar resurfacing, there was a higher ratio of satisfied patients than for TKA's not resurfaced, but this increased ratio diminished slightly with time passed since the primary operation. In unrevised cases the overall satisfaction rate was unchanged regardless of the time passed since the primary operation and the proportion of satisfied patients was higher than in revised knees, in which 22% of patients were unsatisfied after a mean follow-up of 5 (0–16) years. Revised UKA had a higher proportion of satisfied patients than a revised TKA.

Paper III: Use of unicompartmental instead of tricompartmental prostheses for unicompartmental arthrosis in the knee is a cost-effective alternative

UKA is known to have a higher CRR than TKA while the UKA implants generally are less expensive. For the two procedures, we estimated the cost of implants and hospital stay and related the cost difference at primary operation to the difference in number of revisions to be expected. 15,437 primary TKA's and 10,624 primary medial or lateral UKA's were compared. The operations were all done for OA during 1985–1995. By matching patients in the PAS database with the SKAR, information on hospital stay could be gained. The CRR and the relative risk of becoming revised were calculated, as well as the risk of a second revision and the risk of infection. The weighted mean cost of the most common implants in each group was used as an estimate of the implant cost.

We found that the TKA patients were, on average, 1.9 years older at operation and had a lower CRR than the UKA patients – i.e. 10-year CRR of 11.5 % and 15.8 %, respectively. After adjusting for age, sex and year of operation, UKA patients were found to have a 2-day shorter hospital stay and fewer serious complications than TKA patients. The mean estimated cost of a unicompartmental implant was 57% that of a tricompartmental implant. Compared to performing primary TKA in all the patients, we found that the use of UKA had saved more money than the cost generated by the increased number of revisions.

Paper IV: Surgical routine reduces failure after unicompartmental arthroplasty

To investigate if the number of operations performed at surgical units affected the risk of later revision, 10,474 UKA performed for medial OA in Sweden during 1986-1995 were analyzed. 3 types of implants were the focus of interest: an implant with a high revision rate that has been proven to have unfavorable mechanical and design properties; a technically demanding implant with a mobile meniscal bearing, which in Sweden has had an increased revision rate; and finally, the most commonly used unicompartmental implant in Sweden.

The majority of units were found to perform relatively few UKA's per year. However, there was a correlation between the mean number performed and the risk of later revision. The 3 implant types were differently affected. The implant with inferior mechanical and design properties was not affected by the number of operations performed, while the technically demanding implant was highly affected and the most common implant less affected. We concluded that the effect of operative volume on the prognosis of UKA, probably expressed differences in experience in selecting the appropriate patients for surgery and in performing the procedure.

Paper V: Past incidence and future demand for knee arthroplasty in Sweden. A report from the Swedish Knee Arthroplasty Register regarding the effect of past and future population changes on the number of arthroplasties performed

By combining data from the SKAR and Swedish Census Registers it was possible to calculate the past age specific incidence of primary knee arthroplasties and, based on predicted Swedish population changes, estimate the future demand.

Since the start of the SKAR in 1975, OA has accounted for the largest increase in number of knee arthroplasties while operations for RA have remained constant. The mean yearly number of operations between the periods 1976–1980 and 1996–1997 increased more than five-fold while only 6% of that increase could be explained by changes in the age profile of the population. The majority of operations were performed on senior citizens 65 years and older who also have experienced the largest increase in incidence. By using the yearly incidence for 1996 and 1997 and taking into account the expected future changes in the age profile of the Swedish population we estimated that, in absence of an effective preventive treatment, the number of knee arthroplasties will increase by at least 36% until 2030.

Paper VI: The Swedish Knee Arthroplasty Register 1975–1997 with special emphasis on 41,223 knees operated on 1988–1997

General demographic and epidemiological outcome, with special emphasis on results for the most recent 10-year period, was analyzed with the data in the SKAR updated until the end of 1997.

From 1975 till 1997, the mean age of patients at surgery increased from 65 to 70 years. Women accounted for 2/3 of the operations with an unchanged sex ratio over the years. With increasing age, the risk of revision became less; hence age was one of the factors taken into account when estimating the risk of revision. The overall risk of revision was found similar for both sexes if the diagnosis was OA but in RA men with TKA had a higher risk of revision than women.

For TKA, patients with OA were generally older at surgery than those with RA. Although the overall CRR was similar for both groups, when adjusted for differences in age, gender and time of operation, the risk of revision was higher for OA than RA. The opposite was true for the risk of becoming revised for infection where patients with RA had higher risk.

In UKA the risk of revision did not change with the time of surgery, while for TKA the risk significantly diminished with time, even after taking into account the increased age of patients at surgery. During 1988–1997 for OA, primary UKA had a higher risk of revision than TKA while the risk of revision for infection was lower after UKA than TKA. Using uncemented fixation of the tibial plateau in TKA was associated with an increased risk of revision. Resurfacing of the patella during TKA was not found to significantly affect the revision rate. When analyzing different brands of implants, we found that newer TKA implants by the same manufacturer often had better results than the ones they replaced, at least in a short-term. The most commonly used TKA and UKA implants were also among those with the lowest risk of revision. Half of the revisions performed during 1988-1997 were performed within 45 months after the primary operation. Loosening was the most commonly stated cause of the first revision, being reported in 44% of the cases. Both failed UKA and TKA were most commonly revised to a TKA. However, partial revisions were also common in TKA, especially if the diagnosis was OA. When the results after non-infected revisions were analyzed, we found that partial revisions (excluding patellar additions or removal) of failed TKA and UKA had a higher rate of re-revision than revisions with a new TKA. Failed UKA revised with a new UKA similarly had higher risk of re-revision than revisions to a TKA.

Besides a higher CRR than previously reported, our findings after update of the register have not affected conclusions drawn from the register in recent years.

Discussion

Validity

When the failure rate is low or when few patients remain at risk (many deceased), relatively few failures can have a profound effect on revision rate. Therefore, it is of importance to take into account patients lost to follow-up when using survival curves for statistical evaluation (Carr 1993, Dorey et al. 1993). This was also pointed out by Murray and coworkers (1993). They found when reviewing 35 papers that only half of them included figures on patients lost to follow-up and those that did had a mean loss of 5% (inter-quartile range of 4% to 10%). The authors thus recommended the plotting of worst-case curves, based on failure of all patients lost to follow-up.

The SKAR has relied on a voluntary contribution from the orthopedic community, unrelated to monetary reimbursement. With the free healthcare system and the ease of which patients are tracked, few patients are really lost to follow-up in the traditional meaning. However, the participating units can neglect reporting of revisions, which has the same implications as the patients being lost to follow-up in a worst-case scenario.

While the SKAR has been voluntary, the PAS is a mandatory administrative system, which during recent years has been related to monetary reimbursement through ICD diagnosis and procedure registration. It seems that in recent years the PAS has captured a larger number of primary knee arthroplasties and revisions than the SKAR. Ideally, the PAS could be expanded to include the information contained in different specialty registers. However, the complexity of such a database is prohibitive because of the different needs of the specialties, changes in medical treatment and changes in focus of interest. It has, however, been discussed (Werkmeister et al. 1995) whether reimbursement in some way should be linked to delivery of a minimal data set of information for implants regarding type of implant, treatment and complications.

During validation of the SKAR one fifth of revisions had not been reported to the register. The types of revisions that were forgotten most often concerned amputations, extractions and arthrodeses or relatively minor revisions such as partial or patella revisions. The reasons may be that the former are often caused by infections and the patients therefore were not admitted to orthopedic wards, and the minor revisions may have been forgotten or not recognized as true revisions.

87% of missing revisions in previously unrevised patients could be located with help of the PAS database. As the information to the SKAR and PAS is provided at different levels, on the one hand by administrative departments and on the other by health care staff, a systematic error where no information is provided to both registers is unlikely. Thus, comparison of the registers at regular intervals in the future will minimize the chance of revisions not becoming registered.

As the conclusions from the SKAR in the past have not been based on comparisons of results to that of other studies, they have not been affected by the general increase in CRR that was caused by the validation and subsequent update of the register.

Patient satisfaction

The SKAR has measured the effectiveness of knee replacement by the patient's risk of becoming revised. However, in case of complications, not all patients may be offered revision surgery and the decision to revise depends on factors that can be related to the patient, the surgeon and available resources. Further, although avoiding failure and complications is of primary importance, analyses of failures do not tell anything about the majority of patients that never come to revision. Because of practical limitations, we were not able to use comprehensive evaluations or questionnaires to gather information on the patients in the SKAR, but instead used a short question on the patient satisfaction with the operated knee. Our 95% response rate (Paper II) is high for a postal survey (Asch et al. 1994, McHorney et al. 1994, Plant et al. 1996) and suggests that patients with knee arthroplasty are positive to inquiries regarding the operation and that the procedure has been a major event in their lives.

Patient satisfaction has by others (Anderson et al. 1996, Heck et al. 1998b) as well as by our selves in an ongoing parallel study, been found to have a significant correlation to pain and somewhat less to physical function. However, it may be claimed that satisfaction can be affected by factors that seem unrelated to the surgical intervention (e.g., patient–surgeon relationship, attitude of staff, availability of hospital parking spots etc.). The fact that patient satisfaction is a complex concept was illustrated by our findings that primary disease and gender had an effect and that similar discrepancies have even been found in other studies using standardized generic health or disease-specific instruments, between men and women (Katz et al. 1994) and between those having unilateral knee disease and those having a contra-lateral knee problem (Hawker et al. 1998, Dunbar et al. 2000). These findings illustrate that a variety of factors, including the preoperative condition of patients, have to be taken into account when evaluating clinical results.

In our study of all living patients that in 1997 responded regarding their knee(s), primarily operated between 1981 and 1995 (follow-up time mean 6 years), the answer was very satisfied in 49%, satisfied in 32%, uncertain in 11% and dissatisfied in 8% of the knees (51%, 32%, 10% and 7% respectively for those unrevised). This can be compared to two 1998 reports from the USA. Hawker and coworkers (1998) found that after knee replacement that 85% of the patients were satisfied, 4% neutral and 11% dissatisfied (469 patients operated 1985-1989, follow-up time 3–7 years, 77% response rate), while Heck and coworkers (1998b) found 88% satisfied, 3% neutral and 9% dissatisfied (291 patients operated 1992–1993, follow-up time 2 years, 92% participation). Thus, all surveys showed more than 80% of patients were satisfied. The consistency we found in satisfaction over the 15 years, supported by the findings of Hawker and coworkers (1998), indicates that there was no relationship between pain and length of time since knee replacement. This shows that a successful knee arthroplasty can be expected to give a lasting acceptable clinical result.

For revised knees in the SKAR, 27% were very satisfied, 33% satisfied, 18% uncertain and 22% unsatisfied. Thus, in 60% of revisions the patients were satisfied with their knees (83% of unrevised), which is similar to what Espehaug and coworkers (1998) found for hip arthroplasty patients, operated during 1987–1993 in Norway, of which 61% were satisfied (84% of unrevised). That only 22% of the revised knee arthroplasties were dissatisfied must be considered an indicator of the benefit of revision surgery.

The lack of correlation between age and satisfaction was somewhat unexpected as one could expect that older patients would have lower demands, and perhaps expectations, than younger patients. However, our findings are in line with those of Hawker and coworkers (1998).

We found that patient satisfaction after TKA and UKA was similar. In the case of a revision, revised UKA's were more often satisfied than revised TKA's. This can be partly explained by the fact that TKA is more prone to infections and related to severe complications (Paper III). However, the advantage of the higher satisfaction rate in revised UKA is counteracted by the higher risk of revision.

The use of patellar components in TKA has long been a matter of debate (Bourne et al. 1995, Barrack et al. 1997, Schroeder-Boersch et al. 1998). We found the positive effect of patellar resurfacing on satisfaction somewhat diminishing with time. This can be interpreted as either the benefit diminished with time or the prosthetic designs gradually improved resulting in less complications/residual pain.

The present lack of a gold standard regarding postoperative results and how they should be measured, combined with the findings that less than 10% of patients were long-term dissatisfied with their knee arthroplasty, shows that it is not unreasonable to use failures and revisions as a measure of the effectiveness of the surgery.

Cost of implants

When choosing a knee implant for routine use, performance and cost are factors to be taken into account. CRR is often looked upon as an indicator of performance. However, with the relatively low CRR of modern implants it can be questioned if further reduction is reasonable at any cost. Further, it is also important to realize that the total CRR includes many different types of revisions and not all are equally as serious.

The clinical benefit of using UKA has been debated over the years. Some studies have shown very satisfactory results with UKA (Bae et al. 1983, Christensen 1991, Laurencin et al. 1991, Rougraff et al. 1991, Scott et al. 1991, Heck et al. 1993), while others have reported inferior clinical results and a high failure rate (Laskin 1978, Insall et al. 1980, Swank et al. 1993). Since it became known that that the indication for UKA should not include patients with multicompartmental diseases (Jonsson 1981, Knutson et al. 1986, Rand et al. 1991), its use for RA in Sweden gradually halted. Thus, our study (Paper III) was limited to patients with OA operated on with TKA or UKA of which the former had been shown to have a lower CRR (Knutson et al. 1994) but also a generally higher implant cost.

The period analyzed was limited by the availability of data regarding length of stay and thus the material allowed for a maximum follow-up of 11 years. The calculations were based on the CRR at 10 years and we did not assume any additional differences between the models at a later time. Although it is not possible to predict future revision rates, the assumption is based on our finding that the difference in revision rate between the two methods did not seem to increase after 10 years when operations performed during 1980–1984 were added to the analysis. Further, the high mean age at the primary operation with the estimated remaining life expectancy during 1989–1993 of 13.7 years for a 72-year-old woman and 11.4 years for a 71-year-old man (Statistics Sweden) would lessen the impact of later differences.

When estimating the effect of prosthetic type on length of stay, using a regression model to adjust for differences in age, gender and year of operation, we found that the UKA patients had mean 2-day shorter hospital stay. Considering the findings of Macario and coworkers in 1997, that the severity of illness or co-morbidity was not a consistent predictor of hospital costs or length of stay, we interpreted this as a result of a swifter surgical procedure and a faster recovery and rehabilitation.

We used the weighted mean price for the most commonly used implants in Sweden and found the implant cost to be a considerable part (20%) of the total cost for a TKA. This is supported by American studies estimating the implant cost being respectively 25% (Healy et al. 1994) and 37% (Lavernia et al. 1995) of the total cost.

Had all UKA patients been operated with a TKA instead, the lower expected revision rate would not have generated an economical benefit because of the more expensive initial procedure. That the long-term patient satisfaction was found to be similar for the two types of implants (Paper II), while serious complications were less frequent for the UKA indicated that using UKA had not significantly compromised the patient benefit. This illustrates that economic aspects, as well as clinical performance, should be considered when choosing implants.

Surgical routine

The type of joint disease, patient age at surgery and activity level are known to affect the revision rate after knee arthroplasty. An appropriate indication for surgery is also of importance, especially when all the joint surfaces of the knee are not resurfaced. In the literature, low surgical volume for arthroplasties has previously been associated with increased hospital stay and cost (Gutierrez et al. 1998, Kreder et al. 1998) and even increased mortality (Lavernia et al. 1995). For uncemented, but not for cemented hip arthroplasties, operating volume has been found to affect the risk of revision (Espehaug et al. 1999). The reason may be that the uncemented arthroplasty is more sensitive to surgical skill. For one of the implants in our study (Paper IV), the Oxford unicompartmental implant, there was a large variation in revision rate, depending on volume. This may explain why the general revision rate in Sweden (by many units) was higher (Lewold et al. 1995) than that reported from the originating centers in the U.K (Goodfellow et al. 1988, Murray et al. 1998b).

Because UKA has a higher CRR and is claimed to be more technically demanding than TKA (Sculco 1994), statistical associations are easier to find. Still, it is probable that our findings for the UKA also would be valid for the TKA, although to a lesser extent.

However, we do not know if there is a breaking point in mean number of operations/year, after which results do not improve or if the results gradually get better with increasing number of operations. Further, it is unclear exactly what factors caused the differences in results based on the mean number of operations. Factors such as differences in patients admitted to certain units, shelf life of implants (lower turnover / older polyethylene), availability of sizes (few operations / few implants available) or surgical skill may all be of importance. While unable to pin-point the exact reason(s) for the difference observed, we believe that a probable reason may be a difference in the surgical routine expressed in the combined skill in using proper indications for surgery, performing the surgery (especially in relation to position and alignment) and handling the postoperative rehabilitation, which can be claimed to be greater at a center where a procedure is performed frequently.

This is supported by our findings that the technically demanding implant was highly affected by the number of operations, while the implant with inferior mechanical properties was not affected

The conclusion that the operative volume can affect the surgical skill and thereby results raises the question whether the problem can be amended by increased training of surgeons or if technically demanding cases should be centralized to specialized units. If unattended, the problem might result in a chain reaction where inferior results would lead to still lower volume and worse results.

Incidence

The magnitude of arthroplasty surgery for countries is often expressed as the number of arthroplasties per 100,000 inhabitants. By this measure, there were 33 knee arthroplasties/100,000 inhabitants during 1990 in Sweden which had increased to 63/100,000 in 1996–1997 (Paper V) while in Norway the number in 1997 was 28/100,000 (Havelin 1999) and in the U.S.A. 92/100,000 (AAOS Bulletin 1999). For hip arthroplasty there were 108 hip arthroplasties/100,000 inhabitants in Sweden 1996–1997 (Malchau et al. 1999), while in Norway the number was 114/100,000 in 1997 (Havelin 1999) and 87/100,000 in UK 1996 (Birrell et al. 1999). To be able to compare the nations with respect to demand or offering of surgery the age and sex specific incidence has to be considered. However this information is at present not readily available for many countries.

Our finding for knee arthroplasties, that the incidence of operations for RA did not increase during the last 20 years while the increase was profound for the older age groups with OA, was somewhat unexpected. One might expect that previous insufficiency in operative capacity with a backlog of patients waiting for surgery would have resulted in an increase for most age groups and diseases. A possible reason for the findings may be that the RA patients already were treated within the Swedish hospital system with their physicians aware of the operative possibilities while the information spread more slowly to the general practitioners treating the majority of the older OA patients. Further, the indications for surgery may have widened with less disability required for treatment and with increasing safety of anesthetic methods, patients previously regarded as to old are now offered surgery.

During 1996-1997 the incidence of knee arthroplasty in Sweden was still increasing. We can only speculate if it is approaching a steady state. However, even if the incidence would not increase further, the Swedish population is getting older. Thus, with the age specific incidence from 1996–1997 and the expected age profile of the population, we can expect that the demand for knee arthroplasty surgery will increase by at least one third during 2000–2030.

On the other hand we found that there are no signs of a hidden demand of future revision surgery. The ratio of revisions/ primaries has been fairly constant, or even slightly diminishing over the years, and as the main increase in number of primary operations has been in the older age groups, it is unlikely that this will change.

Outcome

While encouraging results after total knee arthroplasty have been reported in patients younger than 56 years (Gill et al. 1997), with CRR as low as 1% at 10 years (CI 0–4%) (Duffy et al. 1998), we found (Paper VI) that knee arthroplasty in younger age groups was associated with an increased risk of revision. Our findings are consistent with previous reports from the register as well as with the Finnish Arthroplasty Register (Halonen et al. 1997) and among Medicare patients in the United States (Heck et al. 1998a).

The CRR at 10 years of 12% after TKA for OA (9% for RA) in patients younger than 65 years (1988–1997) was lower than the 26% (14% for RA) reported from the Finnish register for 1980–1995 but higher than that reported by Diduch and coworkers in 1997 for patients aged 55 years or less, operated during 1977–1992 because of OA and post traumatic conditions (13% at 18 years).

Of primary knee arthroplasties registered in Sweden 1975–1997, 78% were performed for OA and 17 % for RA. However, because of the increasing number of operations for OA the proportions were 85% and 11% respectively during 1988-1997 and 87% and 9% during 1993–1997. The proportion of RA patients is somewhat higher than reported for hip arthroplasties in Sweden from1992–1997 (OA 76%, RA 6%) (Malchau et al. 1998). In Ontario, Canada during 1984–1990, OA was diagnosed in 85% and RA in 12% of primary knee arthroplasties (Coyte et al. 1999), among Medicare patients in the U.S. during 1985-1990 in 89% and 6% respectively (Heck et al. 1998a), while in Finland in 1995, OA was the cause in 85% and RA in 13% of primary TKA (Halonen et al. 1997). In these studies, as well as that of a large series from the Mayo Clinic database (Rand et al. 1991), the RA patients were found to have lower revision rates while opposite results have also been reported (Kristensen et al. 1992). However, it should be noted that comparisons between groups could be elusive because of differences in case mix. This was illustrated in our study. Although OA and RA had a similar overall CRR, adjustment for differences in age, gender and time of operation had the effect that patients with RA had 0.75 times (CI 0.6–0.9) less risk of revision than those with OA.

That RA patients are more prone to infection after joint arthroplasties has previously been documented (Poss et al. 1984, Bengtson et al. 1987, Knutson et al. 1994). We found that the risk during 1988–1997 was 2 times (CI 1.5–2.6) that of patients with OA (1.4 times (CI 1.1–1.9) in TKA only).

Women accounted for 68% of the primary arthroplasties in the SKAR as well as among the Medicare patients, which was somewhat higher proportion than reported for hips in Sweden (60%) and for knees in Ontario (63%), but lower than for knee arthroplasties in Finland (78%). While women are reported to have lower risk of revision after hip arthroplasty (Malchau et al. 1998) and after knee arthroplasty in the Medicare and Mayo studies, the Canadian and Finnish studies did not find gender to affect the overall risk of revision after TKA. This was also the case in our material when all the diagnoses were analyzed together. However, when analyzed separately, we found that in RA men had a higher overall risk of revision, while in OA gender did not affect the revision rate.

Although gender did not affect the overall risk of revision it significantly affected the risk of revision for infection. In both RA and OA men had 1.6 times (CI 1.2–2.0) the risk of women of becoming revised for infection (all implants as well as TKA only), which is in accordance with what has been reported earlier for RA (Wilson et al. 1990).

In Sweden, overall revision rates after knee and hip arthroplasty have gradually diminished (Lewold et al. 1993, Knutson et al. 1994, Malchau et al. 1998). We found that the improvement was mainly seen after TKA but not after UKA, which might partly be caused by the higher failure rate of some recently introduced UKA implants (Lindstrand et al. 1992, Lewold et al. 1995). The improvement after TKA could not be explained by the increased number of operations in the elderly with lower revision rates.

That age, gender, and time of operation affect the revision rate illustrates the difficulty in comparing the results of studies that differ in this respect.

Although RSA studies have shown that uncemented implants have had a higher rate of early migration than cemented (Albrektsson et al. 1992), significant differences have not been found regarding the continuous migration that has been related to loosening (Grewal et al. 1992, Ryd et al. 1995). Our findings that during 1988–1997, the overall risk of revision was 1.4 times (CI 1.1–1.9) higher for TKA with uncemented tibial components indicates improved fixation for cemented implants. However, the majority of the uncemented implants in our study were porous coated, and more recent RSA studies have indicated that the newer hydroxyapatite-coated implants have no more micromotion than cemented implants (Nilsson et al. 1999).

As previously reported (Robertsson et al. 1997, Robertsson et al. 1999) we did not find that the risk of revision was significantly affected by the use of a patellar component. Unlike Petrie and coworkers in 1998, we did not find that patellar resurfacing affected the revision rate for infection. However, in Sweden the majority of the patellar components used have been all plastic while the reported increased rate of infections was related to metal backed components.

The CRR for UKA was higher than for TKA. However, the failure pattern was different. In accordance with previous reports (Bengtson et al. 1991, Knutson et al. 1994) the risk for UKA of becoming revised for infection is substantially lower than that for TKA, making UKA less susceptible than the TKA to ending in an arthrodesis or amputation. As previously stated (Lewold et al. 1998), a failed UKA is best revised to a TKA. Further, if revised to a TKA the risk for patients of re-revision was comparable to their risk of becoming revised had they been operated with a TKA in the first place.

The CRR does vary between implant models. However, the observed differences do not need to be solely caused by differences in implant durability. Other patient related factors, surgical routine and technique might affect the results, as well as the willingness of surgeons to revise (operative risk, difficulty of revision, bone stock, gain in quality of life). During the years, most implants have had at least some minor design changes (in some cases we have been able to distinguish between older and newer versions (PCA-Duracon) while in other it has been more difficult (Marmor/Richards)). Fortunately for TKA, the design changes seem to have generally resulted in an improvement of CRR. As reported from the Finnish Arthroplasty Register for TKA (Halonen et al. 1997), we found the most commonly used models (TKA and UKA) among those with the lowest risk for revision. This may of course be implant related, but may also be caused by other factors, such as better instruments used for aligning the implants and the increased surgical routine when the same implant is used often.

The future

For a patient with osteoarthritis of the knee, being offered a knee arthroplasty, it is relevant to know the risk for a complication or a revision. The CRR at 10 years estimates the risk, for patients that live 10 years, of experiencing a revision but the true proportion of TKA that come to revision is lower (as some patients decease before becoming revised). To calculate the risk for a longer period (15–20 years), all patients operated since 1976 need to be included in the evaluation. With a mean age at primary arthroplasty of 72 years, the mean life expectancy was 12 years. Thus, it is obvious that the long-term results are mainly based on younger patients. The observed lower CRR in older age groups is probably a result of less load on the joint because of a lower daily activity level, combined with reluctance in offering revision surgery to sedentary people with concomitant diseases. Predicting the future risk for a patient of becoming revised is difficult. Overall the CRR for the best performing TKA implants in patients with OA could be expected to be less than 5% at 10 years, increasing by 50% in the younger age groups and decreasing by 50% in the older ones. The CRR for the best UKA implants can be expected to be 50% higher than that for the best TKA. It has however, to be kept in mind that the most successful implants have had half of the overall average revision rate.

While knee arthroplasty surgery has improved considerably during the last decades, there is still room for improvement and new techniques are constantly evolving.

Better design and stricter testing of new implants has reduced the occurrence of material implant failures. However, HDPE wear is still a problem. While use of ceramic and metal-on-metal implants have mainly been limited to the hip, new types of cross-linked UHMWPE are now being introduced for use with knee arthroplasty.

Loosening has been related to migration of implants, wear and subsequent inflammation with an increase in joint fluid production and pressure. In an effort to improve implant fixation, biological stimulation of bone in-growth is being tested with local and systemic growth factors, with use of regulating factors such as bisphosphonates and with new implant coating materials such as phosphates/apatites.

In an effort to reduce tissue damage and shorten the rehabilitation period, some implants are being inserted with minimal invasive techniques and computer assisted surgery is being developed to improve accuracy. Although promising, the use of these new technologies is still rather uncommon in Sweden and the advantages are still to be proven.

Infections after knee arthroplasty have lessened during the years and seem to be reaching a plateau. Antiseptic and aseptic preventive procedures have become well established. The routines regarding the indications and use of antibiotic prophylaxis at a later time in life preventing haematogenous infections are less clear and will have to be developed and followed.

Problems related to the patella have become more prominent as a cause of complaints and revision surgery in recent years. The benefit of using asymmetrical femoral components and patellar buttons is still being debated and new designs are constantly being introduced. Widening of the indications for knee surgery to patients with fewer disabilities may further have increased the demand for an easy rehabilitation after surgery.

Surgical routine and skill has an effect on the outcome after arthroplasty. With the increase in number of operations to be expected and the complexity of implants available, some sub-specialization may appear. Instead of joint arthroplasty being the operation for every orthopedic surgeon, the more difficult operations will in the future be centralized to fewer surgeons and centers.

With the evolution in design, materials and methods, the hope is that complication and revision rates will be reduced. However, not all inventions studied in the SKAR proved beneficial and future monitoring of the results is important.

Thus, the importance of the SKAR will not lessen in the future. In Sweden, authorities have recently begun privatizing hospitals, which may increase the competition between units and call for accounting of results.

The register recently introduced the registration of the part numbers of implants inserted paving the way to more precise classification of implants and materials. This will allow for outcome evaluation with respect to factors such as type of coating, plastic thickness, asymmetry of components, stem length, etc. The recently introduced ICD10 coding by the PAS database will facilitate classification of diseases and procedures making it easier to investigate relevant hospital admissions after knee arthroplasty surgery. Further, by directly asking patients to fill out self administered questionnaires, more detailed information on health effects can be gathered, which in the long run may assist in judging procedures and substitute for scheduled postoperative outpatient visits.

After 25 years, the register has a future where its service to the participating units will diversify and improve.

Conclusions

- Of the revisions performed 1976–1995, one fifth were not reported to the SKAR. Comparison of the SKAR and the PAS database was found to be an effective method of improving the registration. With help of responding patients, and the PAS register regarding deceased and non-responding patients, the SKAR could be updated. The addition of unreported revisions led to a generally higher CRR than previously reported.

- In 1997, 6 (2–17) years after primary knee arthroplasty, 81% of all patients operated during 1981–1995 were satisfied or very satisfied with their knee while 11% were uncertain and 8% unsatisfied. The disease leading to surgery was found to affect satisfaction to a larger extent than the type of primary surgery. 22% of revised patients were unsatisfied with their knee 5 (0–16) years after revision. In light of the practical problems with extensive follow-up and the lack of a gold standard regarding postoperative results and how they should be measured it seems reasonable for the national register to continue to use failures and revisions as an outcome measure for knee arthroplasty.

- In patients with OA operated during 1985-1995, UKA had a higher rate of revision than TKA. However, after taking into account the cost of revisions, the economical cost of primarily using UKA was lower than if TKA had been used instead. This was because of a shorter hospital stay and less expensive implants that made the primary UKA procedure cheaper. Further, serious complications were not found as often after UKA as after TKA.

- During 1985–1995 the mean yearly number of medial UKA performed at the operating units affected the risk of revision. Generally the number of UKA performed at each unit was low. Patients operated at units performing less than one arthroplasty every other week had a higher risk of becoming revised than patients at units performing more. Three different types of implants analyzed separately showed a different sensitivity to operative volume. An implant with known design and mechanical deficiencies was not affected while a surgically demanding implant was highly affected and the most commonly used implant was affected to a lesser degree.

- During 1976–1997, there has been a surge in the number of knee arthroplasties performed for OA as opposed that for other diseases. The increase in number of operations for OA has mainly been caused by an increase in surgery of the elderly. Compared to the number of hip arthroplasties performed in Sweden, a further increase in number of knee arthroplasties may be expected. In the past, the increase in number of knee operations has only partly been caused by changes in the age profile of the population. However, future changes in the age profile can be expected to increase the demand by 1.1 % a year.

- With the data in the SKAR updated till the end of 1997, this study showed that survivorship was affected by patient-related (age, gender, diagnosis), time-related (year of operation), implant-related (type and brand) and technique-related (use of cement) factors. The update of the register resulted in an increase of CRR. However, general conclusions drawn from the register in recent years were not affected.

Summary

The Swedish Knee Arthroplasty Register was initiated in 1975 on a national level to monitor and prospectively follow patients treated with knee arthroplasty. At the time, knee arthroplasty surgery was in rapid development, and the individual experience of surgeons was minimal. In the beginning, the registration was voluntary, but as the project was founded by the Swedish orthopedic community with surgeons excited about the prospects of this new type of surgery, the participation was good. Later on, the project was helped by central and local health authorities that realizing the benefits began expecting all operating units to participate in the registration. Because of the high number of primary operations, an unbiased loss in reports of primary arthroplasties has not been regarded as a problem. However, with revisions utilized as the end-point in survival analyses, it is important that revisions of included patients are reported. To validate if revision status was correctly recorded, a postal survey was made among all living patients, registered as operated during 1975–1995, to inquire if they had been re-operated without this being reported to the register. It was found that 1.7% of the responding knees, previously registered as unrevised, had in fact been revised but not reported to the register. This amounted to one fifth of all revisions. We further investigated if comparing of the SKAR with the PAS database, an administrative system run by the health authorities, was a feasible way of locating missing revisions. We found that of the lost revisions, revealed by the postal survey, 84% could be located. The method was thus used to search for lost revisions in the non-responding and deceased patients.

Although a revision is a well-defined event indicating that the original surgery has not, successfully or definitely, managed to solve the initial knee problem, it says nothing about the majority of operations that never come to revision. The postal survey performed to validate the register gave an opportunity for a short inquiry regarding patient satisfaction. 95% of patients operated during 1981–1995 responded, of which 81% were satisfied or very satisfied, 8% unsatisfied and 11% uncertain. The proportion of satisfied patients was affected by the preoperative diagnosis, while there was no difference in proportions of satisfied patients between those who had a TKA or a medial UKA. In unrevised cases the satisfaction rate was relatively constant regardless of the time passed since the primary operation. Although revised patients were not as satisfied with 22% being unsatisfied with their knee 5 (0–16) years after revision surgery, revision surgery must be considered effective.

While a TKA resurfaces both the tibio-femoral compartments of the knee, a UKA is normally used to resurface only one of the compartments. Therefore, a TKA is always an alternative that can be used instead of a UKA. With the TKA having a generally lower CRR than the UKA, it has been advocated that TKA should always be used, even in unicompartmental disease. On the other hand, supporters of the UKA have claimed it to have clinical benefits. To evaluate the economical effect of using a TKA instead of a UKA for unicompartmental arthrosis, we investigated the period 1985–1995. By using the PAS database, the hospital stay of patients when operated could be determined. 15,437 primary TKA and 10,624 primary UKA were compared regarding length of hospital stay, cost of implants and rate of revision. Age, gender and the year of operation were taken into account in calculations. As expected, the TKA had a lower CRR than UKA. We estimated that if all 10,324 UKA patients had been operated with a TKA instead, 537 fewer revisions could have been expected. However, as the primary TKA was more expensive, the initial cost had increased by USD 17.6 million (exchange rate in June 1995) which was considerably more than the estimated cost for the 537 revisions. Further the UKA had less risk for serious complications than the TKA. These findings illustrate that not only

the crude revision rate should be taken into account when choosing implants but also implant cost, the revision pattern and clinical results, when available.

It has been claimed that the UKA is technically demanding surgery. This may partly explain the relatively high CRR. To investigate if results were affected by the volume of surgery performed, we analyzed the mean number of UKA operations / year at each operating unit and correlated it with the CRR. We found that number of UKA performed at each unit was low and that performing less than one UKA every other week was associated with an increased risk of revision. However, implants behaved differently. For an implant with known inferior properties, the CRR was not affected by the operative volume while the CRR for a technically demanding implant was highly affected and the CRR for the most commonly used implant was affected to a lesser extent. Thus, not only implant related and patient related factors influence the rate of revision, which further illustrates the limitations in relying on the revision rates of occasional studies when selecting implants.

With the sharp rise in number of operations observed in recent years it becomes of interest to evaluate the causes and try to estimate the future trend. Combining data from the national census register (Statistics Sweden) with the information in the SKAR made it possible to determine the age specific incidences of knee arthroplasty and evaluate the effect of past changes as well as of predicted changes in the age profile of the population on the demand for surgery. We found that the past increase in number of operation mainly had been caused by inclusion of older age groups, probably because of widening in the indications for surgery. Past changes in the age profile of the population only explained a small part of the increase in surgery while future changes, with unchanged incidence, may increase the demand for knee arthroplasty by 1.1% /year. The incidence of knee arthroplasty is higher in the USA than Sweden and the incidence of hip arthroplasty in Sweden also is considerably higher than that of knee arthroplasty. Thus, it is probable that the incidence of knee arthroplasty may rise beyond that generated by the future changes in the age profile.

The previous major report from the SKAR, regarding demography and results, covered the years 1975–1992. After an additional 5 years the number of primary arthroplasties had almost doubled and was 57,533. With the register validated and updated with respect to revisions it became appropriate to analyze the data again with special respect to the last 10-year period. The results did not significantly affect the conclusions drawn in previous reports, although the update led to a general increase in CRR. In TKA, we found that high age, RA, recent operation and cementing of the tibia component were associated with reduced risk of revision while the risk of becoming revised for infection was increased for males and in RA. UKA had higher CRR than TKA but less risk of becoming revised for infection. Loosening was still the major cause of failure after both UKA and TKA. Revisions in which only some components were exchanged had an increased rate of re-revision. Failed UKA revised to a TKA had significantly less risk of re-revision than if the revision was a new UKA, additional UKA in the same knee or partial revision of the UKA.

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References

AAOS Bulletin June 1999. Future demand for orthopaedic skills to soar.

Abernethy P J, Robinson C M, Fowler R M. Fracture of the metal tibial tray after Kinematic total knee replacement. A common cause of early aseptic failure. J Bone Joint Surg Br 1996; 78 (2): 220-5.

Albrektsson B E, Carlsson L V, Freeman M A, Herberts P, Ryd L. Proximally cemented versus uncemented Freeman-Samuelson knee arthroplasty. A prospective randomised study. J Bone Joint Surg [Br] 1992; 74 (2): 233-8.

Anderson J G, Wixson R L, Tsai D, Stulberg S D, Chang R W. Functional outcome and patient satisfaction in total knee patients over the age of 75. J Arthroplasty 1996; 11 (7): 831-40.

Ansari S, Newman J H, Ackroyd C E. St. Georg sledge for medial compartment knee replacement. 461 arthroplasties followed for 4 (1-17) years. Acta Orthop Scand 1997; 68 (5): 430-4.

Asch D A, Christakis N A. Different response rates in a trial of two envelop styles in mail survey research. Epidemiology 1994; 5 (3): 364-5.

Bae D K, Guhl J F, Keane S P. Unicompartmental knee arthroplasty for single compartment disease. Clinical experience with an average four-year follow-up study. Clin Orthop 1983; (176): 233-8.

Barrack R L, Wolfe M W, Waldman D A, Milicic M, Bertot A J, Myers L. Resurfacing of the patella in total knee arthroplasty. A prospective, randomized, double-blind study [see comments]. J Bone Joint Surg Am 1997; 79 (8): 1121-31.

Bassett R W. Results of 1,000 Performance knees: cementless versus cemented fixation. J Arthroplasty 1998; 13 (4): 409-13.

Bengtson S, Blomgren G, Knutson K, Wigren A, Lidgren L. Hematogenous infection after knee arthroplasty. Acta Orthop Scand 1987; 58 (5): 529-34.

Bengtson S, Knutson K. The infected knee arthroplasty. A 6-year follow-up of 357 cases. Acta Orthop Scand 1991; 62 (4): 301-11.

Bert J M. Universal intramedullary instrumentation for unicompartmental total knee arthroplasty. Clin Orthop 1991; (271): 79-87.

Birrell F, Johnell O, Silman A. Projecting the need for hip replacement over the next three decades: influence of changing demography and threshold for surgery. Ann Rheum Dis 1999; 58 (9): 569-72.

Bourne R B, Rorabeck C H, Vaz M, Kramer J, Hardie R, Robertson D. Resurfacing versus not resurfacing the patella during total knee replacement. Clin Orthop 1995; (321): 156-61.

Brinker M R, Lund P J, Barrack R L. Demographic biases of scoring instruments for the results of total knee arthroplasty. J Bone Joint Surg Am 1997; 79 (6): 858-65.

Callahan C M, Drake B G, Heck D A, Dittus R S. Patient outcomes following tricompartmental total knee replacement. A meta-analysis. Jama 1994; 271 (17): 1349-57.

Cameron H U, Jung Y B. A comparison of unicompartmental knee replacement with total knee replacement. Orthop Rev 1988; 17 (10): 983-8.

Carr A J. The Oxford knee. Survival analysis of joint replacement. Int Orthop 1993; 17 (4 Suppl): 14-5.

Christensen N O. Unicompartmental prosthesis for gonarthrosis. A nine-year series of 575 knees from a Swedish hospital. Clin Orthop 1991; (273): 165-9.

Coyte P C, Hawker G, Croxford R, Wright J G. Rates of revision knee replacement in Ontario, Canada. J Bone Joint Surg [Am] 1999; 81 (6): 773-82.

Diduch D R, Insall J N, Scott W N, Scuderi G R, Font-Rodriguez D. Total knee replacement in young, active patients. Long-term follow-up and functional outcome. J Bone Joint Surg [Am] 1997; 79 (4): 575-82.

Dobbs H S. Survivorship of total hip replacements. J Bone Joint Surg [Br] 1980; 62-B (2): 168-73.

Dorey F, Nasser S, Amstutz H. The need for confidence intervals in the presentation of orthopaedic data. J Bone Joint Surg [Am] 1993; 75 (12): 1844-52.

Dunbar M J, Robertsson O, Ryd L, Lidgren L. Non-psychometric properties of seven outcome questionnaires as applied to 3600 patients from the National Swedish Knee Arthroplasty Registry. Free paper at the annual meeting of the American Orthopaedic Association, Anaheim 1999.

Dunbar M J, Robertsson O, Ryd L, Lidgren L. The knee bone is connected to the hip bone. Free paper at the annual meeting of the Candian Orthopaedic Association, Edmonton 2000.

Engelbrecht E, Siegel A, Rottger J, Buchholz H W. Statistics of total knee replacement: partial and total knee replacement, design St. Georg: a review of a 4-year observation. Clin Orthop 1976; 00 (120): 54-64.

Espehaug B, Havelin L I, Engesaeter L B, Langeland N, Vollset S E. Patient satisfaction and function after primary and revision total hip replacement. Clin Orthop 1998; (351): 135-48.

Espehaug B, Havelin L I, Engesaeter L B, Vollset S E. The effect of hospital-type and operating volume on the survival of hip replacements. A review of 39,505 primary total hip replacements reported to the Norwegian Arthroplasty Register, 1988-1996. Acta Orthop Scand 1999; 70 (1): 12-8.

Faris P M, Herbst S A, Keating E M, Ritter M A. Survival analysis of total condylar-type prostheses. Semin Arthroplasty 1991; 2 (1): 17-22.

Font-Rodriguez D E, Scuderi G R, Insall J N. Survivorship of cemented total knee arthroplasty. Clin Orthop 1997; (345): 79-86.

Fortin P R, Clarke A E, Joseph L, Liang M H, Tanzer M, Ferland D, Phillips C, Partridge A J, Belisle P, Fossel A H, Mahomed N, Sledge C B, Katz J N. Outcomes of total hip and knee replacement: preoperative functional status predicts outcomes at six months after surgery. Arthritis Rheum 1999; 42 (8): 1722-8.

Freeman M A, Lewack B. British contribution to knee arthroplasty. Clin Orthop 1986; (210) : 69-79.

Gartland J J. Orthopaedic clinical research. Deficiencies in experimental design and determinations of outcome. J Bone Joint Surg [Am] 1988; 70 (9): 1357-64.

Gill G S, Mills D M. Long-term follow-up evaluation of 1000 consecutive cemented total knee arthroplasties. Clin Orthop 1991; (273): 66-76.

Gluck T. Die Invaginationsmethode der Osteo- und Arthroplastik. Berl Klin Wschr 1890; 19: 732.

Goodfellow J W, Kershaw C J, Benson M K, O'Connor J J. The Oxford Knee for unicompartmental osteoarthritis. The first 103 cases. J Bone Joint Surg [Br] 1988; 70 (5): 692-701.

Grewal R, Rimmer M G, Freeman M A. Early migration of prostheses related to long-term survivorship. Comparison of tibial components in knee replacement. J Bone Joint Surg [Br] 1992; 74 (2): 239-42.

Gunston F H. Polycentric knee arthroplasty. Prosthetic simulation of normal knee movement. J Bone Joint Surg (Br) 1971; 53 : 272-77.

Gutierrez B, Culler S D, Freund D A. Does hospital procedure-specific volume affect treatment costs? A national study of knee replacement surgery. Health Serv Res 1998; 33 (3 Pt 1): 489-511.

Halonen P, Pulkkinen P, Nevalainen J. Knee Arthroplasty. Finnish Arthroplasty Register. Publications of the National Agency for Medicines. 1997; 2/1997: 1-40.

Havelin L I. The Norwegian Joint Registry. Bull Hosp Jt Dis 1999; 58 (3): 139-47.

Hawker G, Wright J, Coyte P, Paul J, Dittus R, Croxford R, Katz B, Bombardier C, Heck D, Freund D. Health-related quality of life after knee replacement. J Bone Joint Surg [Am] 1998; 80 (2): 163-73.

Healy W L, Finn D. The hospital cost and the cost of the implant for total knee arthroplasty. A comparison between 1983 and 1991 for one hospital. J Bone Joint Surg [Am] 1994; 76 (6): 801-6.

Heck D A, Marmor L, Gibson A, Rougraff B T. Unicompartmental knee arthroplasty. A multicenter investigation with long-term follow-up evaluation. Clin Orthop 1993; (286): 154-9.

Heck D A, Melfi C A, Mamlin L A, Katz B P, Arthur D S, Dittus R S, Freund D A. Revision rates after knee replacement in the United States. Med Care 1998a; 36 (5): 661-9.

Heck D A, Robinson R L, Partridge C M, Lubitz R M, Freund D A. Patient outcomes after knee replacement. Clin Orthop 1998b; (356): 93-110.

Ingvarsson T, Hagglund G, Lohmander L S. Prevalence of hip osteoarthritis in Iceland. Ann Rheum Dis 1999; 58 (4): 201-7.

Insall J, Aglietti P. A five to seven-year follow-up of unicondylar arthroplasty. J Bone Joint Surg [Am] 1980; 62 (8): 1329-37.

Insall J, Ranawat C S, Scott W N, Walker P. Total condylar knee replacment: preliminary report. Clin Orthop 1976; 00 (120): 149-54.

Jonsson G T. Compartmental arthroplasty for gonarthrosis. Acta Orthop Scand (Suppl 193) 1981; : 1-110.

Jordan L R, Olivo J L, Voorhorst P E. Survivorship analysis of cementless meniscal bearing total knee arthroplasty. Clin Orthop 1997; (338): 119-23.

Katz J N, Wright E A, Guadagnoli E, Liang M H, Karlson E W, Cleary P D. Differences between men and women undergoing major orthopedic surgery for degenerative arthritis [see comments]. Arthritis Rheum 1994; 37 (5): 687-94.

Knutson K, Lewold S, Robertsson O, Lidgren L. The Swedish knee arthroplasty register. A nation-wide study of 30,003 knees 1976-1992. Acta Orthop Scand 1994; 65 (4): 375-86.

Knutson K, Lindstrand A, Lidgren L. Survival of knee arthroplasties. A nation-wide multicentre investigation of 8000 cases. J Bone Joint Surg [Br] 1986; 68 (5): 795-803.

Knutson K, Tjornstrand B, Lidgren L. Survival of knee arthroplasties for rheumatoid arthritis. Acta Orthop Scand 1985; 56 (5): 422-5.

Kreder H J, Williams J I, Jaglal S, Hu R, Axcell T, Stephen D. Are complication rates for elective primary total hip arthroplasty in Ontario related to surgeon and hospital volumes? A preliminary investigation. Can J Surg 1998; 41 (6): 431-7.

Kristensen O, Nafei A, Kjaersgaard-Andersen P, Hvid I, Jensen J. Long-term results of total condylar knee arthroplasty in rheumatoid arthritis. J Bone Joint Surg [Br] 1992; 74 (6): 803-6.

Laskin R S. Unicompartmental tibiofemoral resurfacing arthroplasty. J Bone Joint Surg [Am] 1978; 60 (2): 182-5.

Laurencin C T, Zelicof S B, Scott R D, Ewald F C. Unicompartmental versus total knee arthroplasty in the same patient. A comparative study. Clin Orthop 1991; (273): 151-6.

Lavernia C J, Guzman J F. Relationship of surgical volume to short-term mortality, morbidity, and hospital charges in arthroplasty. J Arthroplasty 1995; 10 (2): 133-40.

Lewold S, Goodman S, Knutson K, Robertsson O, Lidgren L. Oxford meniscal bearing knee versus the Marmor knee in unicompartmental arthroplasty for arthrosis. A Swedish multicenter survival study. J Arthroplasty 1995; 10 (6): 722-31.

Lewold S, Knutson K, Lidgren L. Reduced failure rate in knee prosthetic surgery with improved implantation technique. Clin Orthop 1993; (287): 94-7.

Lewold S, Robertsson O, Knutson K, Lidgren L. Revision of unicompartmental knee arthroplasty: outcome in 1,135 cases from the Swedish Knee Arthroplasty study. Acta Orthop Scand 1998; 69 (5): 469-74.

Lidgren L. The Bone and Joint Decade 2000-2010: an update. Acta Orthop Scand 2000; 71 (1): 3-6.

Lindstrand A, Stenstrom A, Lewold S. Multicenter study of unicompartmental knee revision. PCA, Marmor, and St Georg compared in 3,777 cases of arthrosis. Acta Orthop Scand 1992; 63 (3): 256-9.

Macario A, Vitez T S, Dunn B, McDonald T, Brown B. Hospital costs and severity of illness in three types of elective surgery. Anesthesiology 1997; 86 (1): 92-100.

Mackinnon J, Young S, Baily R A. The St Georg sledge for unicompartmental replacement of the knee. A prospective study of 115 cases. J Bone Joint Surg [Br] 1988; 70 (2): 217-23.

Malchau H, Herberts P. Prognosis of total hip replacement. Revision and re-revision rate in THR: A revision-risk study of 148,359 primary operations. Presented as a scientific exhibit at the annual meeting of the American Association of Orthopaedic Surgeons, New Orleans. 1998.

Malchau H, Herberts P, Söderman P. The Swedish National Hip Arthroplasty Register. Annual report 1998. Dept of Orthopedics, University of Gothenburg 1999; : .

Mancuso C A, Ranawat C S, Esdaile J M, Johanson N A, Charlson M E. Indications for total hip and total knee arthroplasties. Results of orthopaedic surveys. J Arthroplasty 1996; 11 (1): 34-46.

Marmor L. Unicompartmental knee arthroplasty. Ten- to 13-year follow-up study. Clin Orthop 1988; (226): 14-20.

McHorney C A, Kosinski M, Ware J E, Jr. Comparisons of the costs and quality of norms for the SF-36 health survey collected by mail versus telephone interview: results from a national survey. Med Care 1994; 32 (6): 551-67.

Morrey B F, Adams R A, Ilstrup D M, Bryan R S. Complications and mortality associated with bilateral or unilateral total knee arthroplasty. J Bone Joint Surg [Am] 1987; 69 (4): 484-8.

Murray D W, Carr A J, Bulstrode C. Survival analysis of joint replacements. J Bone Joint Surg [Br] 1993; 75 (5): 697-704.

Murray D W, Frost S J. Pain in the assessment of total knee replacement. J Bone Joint Surg [Br] 1998a; 80 (3): 426-31.

Murray D W, Goodfellow J W, O'Connor J J. The Oxford medial unicompartmental arthroplasty: a ten-year survival study. J Bone Joint Surg [Br] 1998b; 80 (6): 983-9.

Nelissen R G, Brand R, Rozing P M. Survivorship analysis in total condylar knee arthroplasty. A statistical review [see comments]. J Bone Joint Surg [Am] 1992; 74 (3): 383-9.

Nilsson K G, Karrholm J, Carlsson L, Dalen T. Hydroxyapatite coating versus cemented fixation of the tibial component in total knee arthroplasty: prospective randomized comparison of hydroxyapatite-coated and cemented tibial components with 5-year follow-up using radiostereometry. J Arthroplasty 1999; 14 (1): 9-20.

Petrie R S, Hanssen A D, Osmon D R, Ilstrup D. Metal-backed patellar component failure in total knee arthroplasty: a possible risk for late infection. Am J Orthop 1998; 27 (3): 172-6.

Plant P, McEwen J, Prescott K. Use of the Nottingham Health Profile to test the validity of census variables to proxy the need for health care. J Public Health Med 1996; 18 (3): 313-20.

Poss R, Thornhill T S, Ewald F C, Thomas W H, Batte N J, Sledge C B. Factors influencing the incidence and outcome of infection following total joint arthroplasty. Clin Orthop 1984; (182): 117-26.

Ranawat C S, Hansraj K K. Effect of posterior cruciate sacrificing on durability of the cement- bone interface: a nine-year survivorship study of 100 total condylar knee arthroplasties. Clin Exp Rheumatol 1989; 7 Suppl 3: S149-52.

Rand J A, Ilstrup D M. Survivorship analysis of total knee arthroplasty. Cumulative rates of survival of 9200 total knee arthroplasties [see comments]. J Bone Joint Surg [Am] 1991; 73 (3): 397-409.

Ritter M A, Worland R, Saliski J, Helphenstine J V, Edmondson K L, Keating E M, Faris P M, Meding J B. Flat-on-flat, nonconstrained, compression molded polyethylene total knee replacement. Clin Orthop 1995; (321): 79-85.

Robertsson O, Knutson K, Lewold S, Goodman S, Lidgren L. Knee arthroplasty in rheumatoid arthritis. A report from the Swedish Knee Arthroplasty Register on 4,381 primary operations 1985-1995. Acta Orthop Scand 1997; 68 (6): 545-53.

Robertsson O, Knutson K, Lewold S, Lidgren L. Knee arthroplasty for osteoarthrosis and rheumatoid arthritis 1986-1995. Validation and outcome in the Swedish National Register. Presented as a scientific exhibit at the annual meeting of the American Association of Orthopaedic Surgeons, Anaheim. 1999.

Rougraff B T, Heck D A, Gibson A E. A comparison of tricompartmental and unicompartmental arthroplasty for the treatment of gonarthrosis. Clin Orthop 1991; (273): 157-64.

Ryd L, Albrektsson B E, Carlsson L, Dansgard F, Herberts P, Lindstrand A, Regner L, Toksvig-Larsen S. Roentgen stereophotogrammetric analysis as a predictor of mechanical loosening of knee prostheses. J Bone Joint Surg (Br) 1995; 77 (3): 377-83.

Schroeder-Boersch H, Scheller G, Fischer J, Jani L. Advantages of patellar resurfacing in total knee arthroplasty. Two-year results of a prospective randomized study. Arch Orthop Trauma Surg 1998; 117 (1-2): 73-8.

Scott R D, Cobb A G, McQueary F G, Thornhill T S. Unicompartmental knee arthroplasty. Eight- to 12-year follow-up evaluation with survivorship analysis. Clin Orthop 1991; (271): 96-100.

Scuderi G R, Insall J N, Windsor R E, Moran M C. Survivorship of cemented knee replacements. J Bone Joint Surg [Br] 1989; 71 (5): 798-803.

Sculco T P. The case for total knee replacement in unicompartmental knee arthritis. Orthopedics 1994; 17 (9): 857-8.

Shiers L G. Arthroplasty of the knee. Preliminary report of new method. J Bone Joint Surg [Br] 1954; 36 : 553-60.

Swank M, Stulberg S D, Jiganti J, Machairas S. The natural history of unicompartmental arthroplasty. An eight-year follow-up study with survivorship analysis. Clin Orthop 1993; (286): 130-42.

Tew M, Waugh W. Estimating the survival time of knee replacement. J Bone Joint Surg [Br] 1982; 64 (5): 579-82.

Tew M, Waugh W, Forster I W. Comparing the results of different types of knee replacement. A method proposed and applied. J Bone Joint Surg [Br] 1985; 67 (5): 775-9.

Thacker C, Fulford P. Assessment of the Denham knee replacement. Results after eight years. J Bone Joint Surg [Br] 1986; 68 (4): 600-7.

Walldius B. Arthroplasty of the knee using an endoprosthesis. Acta Orthop Scand (Suppl 24) 1957. Reprinted in Clin Orthop 1996; 331: 4-10.

Werkmeister J A, Ramshaw J A M. (Eds). Medical implant tracking. Discussion papers from a Symposium, “Towards an international implant and data system”. Australian Society for Biomaterials, Melbourne. 1995; ISBN: 0646 25520 7.

Wilson M G, Kelley K, Thornhill T S. Infection as a complication of total knee-replacement arthroplasty. Risk factors and treatment in sixty-seven cases. J Bone Joint Surg [Am] 1990; 72 (6): 878-83.