The infected knee arthroplasty

A 6-year follow-up of 357 cases

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The incidence of deep infection after 12,118 primary knee arthroplasties performed in Sweden from October 1, 1975 through 1985 with a median follow-up of 6 years was 1.7 percent for arthrosis and 4.4 percent for rheumatoid arthritis. Risk factors for infection were large prostheses, postoperative wound-healing complications, rheumatoid arthritis, a prior deep infection, and skin infections. We have analyzed the treatment of 357 knee arthroplasties with a deep infection. Systemic antibiotics alone were primarily used in 225 knees, with healing of the infection in 44 knees, 20 of which had a functioning prosthesis at the final follow-up; the treatment did not compromise later revision surgery. Soft-tissue surgery was used in 154 knees—37 healed, 15 of which had a functioning prosthesis. Resection arthroplasty resulted in healing of the infection in 11 of 22 knees. Revision arthroplasty was performed in 107 knees, with eventual healing of the infection in 81 knees, 36 of which had a functioning prosthesis; there were no differences in the outcome of one-stage and two-stage procedures. Arthrodesis was attempted in 135 knees, with eventual healing of the infection in 120 knees and fusion in 105. Twenty-two patients were amputated. Thus, the infection healed in 315 knees (88 percent), but only 71 (20 percent) recovered with a functioning prosthesis, and 8 patients died of the infection. Attention should therefore focus on prophylactic measures directed towards the soft-tissue problems—by avoiding conflicting skin incisions, by gentle handling of the periarticular soft tissues, by avoiding the use of constrained prostheses and oversized compartmental prostheses, by letting wound healing take priority over motion in knees with compromised soft tissues, and by using prophylactic antibiotic treatment for skin ulcers until these have healed.

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Submitted 90–12–08. Accepted 90–04–05

We presented the results of treatment of 51 infected knee arthroplasties at our department in an earlier report (Bengtson et al. 1989a) and concluded that infected compartmental prostheses with good bone stock could be treated with an exchange arthroplasty using a similar type of prosthesis in a two-stage procedure. If the bone stock is poor, an arthrodesis using a two-stage procedure was recommended. However, a number of questions remained unanswered, had conflicting answers, or needed more probing as regards risk factors for infection and the treatment of infection:

1. Do postoperative wound-healing complications predispose to deep infection (Johnson and Bannister 1986)?
2. Should the treatment be based on the result of bacteriologic culture (Miley et al. 1982, Insall and Thompson 1984, Poss et al. 1984)?
3. Can prolonged systemic antibiotic treatment suppress or even heal the infection, or will it compromise later revision, or even be dangerous to the patient (Lidgren et al 1977, Insall and Thompson 1984, Thornhill and Maguire 1987)?
4. Should surgery be instituted promptly once the diagnosis of infection has been established (Marsh and Cotler 1981, Poss et al. 1984)?
5. Can debridement heal the infection (Johnson and Bannister 1986, Borden and Gearen 1987)?
6. Will staging of the surgery improve the results (Insall et al. 1983, Freeman et al. 1985)?

We have analyzed patient-, implant-, and treatment-related factors in 357 cases of infected knee arthroplasties identified through the Swedish Knee Arthroplasty Project (Knutson et al. 1986) in an attempt to answer these questions.

Definitions

Index operation: the operation that is followed by infection.

Index prosthesis: the prosthesis present in the knee at the time of infection.

Definite deep infection required one of the following four criteria: a sinus from the joint or adjacent bone; three or more positive cultures from

Table 1. Clinical data on 357 infected cases (344 patients) following 12,118 primary knee arthroplasties and 1,518 revisions for noninfectious complications (series 1)

Arthroplasty	Primary (n 12,118)	Infection following Primary (n 309)	Infection following Revision (n 48)
Sex			
Female	8,715	209	35
Male	3,403	100	13
Diagnosis			
Rheumatoid arthritis	4,534	186	26
Arthrosis	7,534	121	22
Other	50	2	0
Age at the index operation			
Median	69	67	70
Range	17-91	32–83	45–82
Type of prosthesis*			
Hinge	464	58	13
Stabilized	447	23	11
Bi-/tricompartmental	5,816	179	21
Bilateral unicomp.	1,125	19	1
Unicompartmental	4,266	30	2

*All the prostheses were fixed with bone cement.

tissue biopsies taken at the time of the operation; septicemia with isolation of the same bacteria in the blood and in the knee aspirate; growth of the same bacteria in two or more knee aspirates. *Probable deep infection:* one or two positive biopsy cultures or growth in only one knee aspirate (Knutson et al. 1984a).

The infection was classified as *early* if it was diagnosed within 3 months of the index operation; otherwise, it was classified as *late* (Insall et al. 1983).

The infection was considered *hematogenous* if the same pathogen grew both in the knee and at a distant focus, or if there was primary wound healing of the index operation with no clinical signs of infection for 2 years—even in the absence of a known distant focus.

The infection was considered *eradicated* at the final follow-up if there were no clinical signs of infection of the knee (no effusion, redness, warmth, or fistulation) and if no systemic antibiotics had been used during the previous year. The deep infection was considered *suppressed* if there were no clinical signs of infection of the knee and if systemic antibiotics were still used or had been used during the previous year. Both eradication and suppression of the infection were grouped as a clinically *healed* infection.

Functioning prosthesis: a healed, stable, painless knee with at least 5°–80° of motion.

Primary treatment referred to the initial treatment of the deep infection regardless of mode of treatment.

Primary surgical treatment referred to the initial surgical treatment of the infection.

Primary soft-tissue surgery, resection arthroplasty, revision arthroplasty, arthrodesis, and *amputation* referred to the first attempt with each particular mode of treatment.

Material and methods

From October 1, 1975 through 1985, the Swedish Knee Arthroplasty Project received reports of 12,118 primary knee arthroplasties (7,534 for arthrosis and 4,534 for rheumatoid arthritis)—1,214 of which were revised 1,518 times during the same period because of aseptic loosening or instability. On January 1, 1986, a deep infection had been reported after primary arthroplasty in 309 knees and after a noninfected revision arthroplasty in 48 knees (Table 1). These 357 knees were all followed until June 30, 1989, and were used to analyze the treatment of infection (Series 1). By June 1989, a deep infection had been reported after primary arthroplasty in 332 knees, and these knees were used for calculations of incidences (Series 2). Details about the infected cases were obtained from the patients' records from different hospitals, nursing homes, etc. Telephone calls to the patients were made to update the information.

A deep infection prior to the primary arthroplasty had been reported in 31 of the 12,118 knees.

Systemic antibiotic prophylaxis had been used alone in 229 cases and with addition of antibiotic-mixed cement in 63 cases. Antibiotic-mixed cement alone had been used in 12 cases. In 42 cases, antibiotic prophylaxis had not been used. Information could not be obtained as regards antibiotic prophylaxis in 11 cases. (In the knee arthroplasties that were not infected, information could not be obtained in one fourth of the cases).

A radiographic examination at the onset of infection was done in 303 cases. In 50 cases the prosthetic components were radiographically loose, in 243 cases fixed, and in 10 cases inconclusive. Radiographs had not been taken in 54 cases. In 65 radiographically examined cases, major surgery had been undertaken within 1 month of the onset of infection. Only two radiographically fixed prostheses were found to be loose; and in 8 inconclusive cases, three prostheses were found to be loose and five prostheses fixed at the operation.

A definite deep infection was diagnosed in 289 cases, whereas a probable deep infection was diagnosed in 68 cases.

Table 2. Early and late infection in relation to onset and origin (Series 1)

Type of infection	Postoperative infection		Hematogenous infection[a]	
	Early	Late	Early	Late
Acute septic arthritis	35	62	1	57
Chronic arthritis	1	14	0	9
Fistulation or abscess	128	28[b]	1	21[b]
Total	164	104	2	87

[a]Eighty-nine hematogenous infections (83 patients).
[b]Nine postoperative and eight hematogenous knees developed fistulation after incision of an abscess.

Table 3. Distant infectious foci in 89 hematogenously infected knee arthroplasties (Series 1)

Distant focus	N
Cutaneous lesion	28
Respiratory tract	10
Urinary tract	7
Fracture surgery	4
Septic arthritis/bursitis	3
Spondylitis	2
Prosthetic infection of other knee	2
Gastrointestinal tract	1
Oral cavity	1
Endocarditis	1
Unknown	30
Total	89

A hematogenous infection occurred in 89 cases (83 patients) with skin infections as the most common source (Tables 2–3).

Methods for the treatment of infection

Systemic antibiotics were used together with all the types of surgical treatment. To be regarded as a separate mode of treatment, systemic antibiotics should have been employed alone, with or without drainage, for at least 2 weeks after the debut of the infection (225 knees).

Soft-tissue surgery (154 knees) was divided into: a) minor debridement (82 knees)—e.g., superficial wound toilette and excision of a sinus; b) debridement (32 knees)—thorough synovectomy and excision of all the visibly infected soft tissues; c) plastic surgery (20 knees)—split-skin graft, musculocutaneous gastrocnemius flap, local skin flaps; d) other (20 knees)—e.g., secondary suture (Table 4).

Resection arthroplasty (22 knees).

Revision arthroplasty (107 knees) was performed as a one-stage or a two-stage procedure. *One-stage* (69 knees) implied direct exchange of the prosthesis. *Two-stage* (38 knees) meant that the prosthesis and bone cement were removed and that antibiotic-loaded cement beads were inserted into a primary procedure. After a median interval of 30 (14–225) days, a new prosthesis was inserted with gentamicin cement.

Arthrodesis (135 knees). External fixation (111 knees) was used applying a Charnley frame, an Audrey-Vidal frame, or a biplanar frame in 39, 49, and 23 cases, respectively. Internal fixation (24 knees) was used, with insertion of a Küntscher nail in 20 cases, staples in 2 cases, and a Rush pin or Steinmann's pins in 1 case each. *One-stage* (93 knees) implied direct external (89 knees) or internal fixation (four knees) after removal of the prosthesis, bone cement and infected tissues, and in 27 knees also insertion of antibiotic-loaded cement beads, which were extracted within 2 weeks. *Two-stage* (42 knees) meant that the prosthesis and bone cement were removed in a primary procedure and the knee was supported in a plaster cast. In 36 knees, antibiotic-loaded cement beads were used. After a median of 30 (10–300) days, intramedullary nailing (20 knees) or external fixation (22 knees) was performed.

Amputation (22 knees).

Follow-up

The median time interval between onset of signs of infection and surgical treatment was 1 (0–64) month. The median follow-up time from the onset of infection was 67 (0–147) months and from the latest surgical treatment 51 (0–141) months. Totally, 114 patients (122 knees) had died of unrelated causes at the time of the final follow-up.

Statistics

Multiple logistic regression was used to estimate the independent effects on healing of age, sex, diagnosis, previous knee operations, type of prosthesis, year of infection, onset of infection (early or late), fistulation, microorganisms (gram-positive or gram-negative/mixed flora), loose prosthetic components (loose or with radiolucent zones larger than 2 mm as judged by radiographs or loose at operations performed within a month of the onset of infection), no drainage treatment during systemic antibiotic treatment, time

Table 4. Results of surgical treatment of 301 infected knee arthroplasties (Series 1)

	A			B			C			D			E			F			G	H	J	
Surgery	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III		I	II	III
Soft-tissue s.	138	30	13	69*	8	2	1+1*	0	0	10+23*	4	1	5+10*	6	0	154	30	13	1	257	37	15
Resection a.	14	7	–	6	4	–	0	–	–	2	0	–	0	–	–	22	11	–		22	11	
Revision a.	72	54	28	32	20	6	0	–	–	5*	4	2	3	1	0	107	75	34	2	112	81	36
Arthrodesis	68	57	44	51	44	35	1	1	1	15	11	9	8*	3	5	135	113	89	2	143	120	94
Amputation	9	9	–	1	1	–	5	5	–	3	3	–	4	4	–	22	22	–		22	22	
Total	301	157			77			6			22			14			251		5	556	271	

A Primary surgical treatment
B Additional attempts after failed soft-tissue surgery with the index prosthesis in situ
C Additional attempts after failed resection arthroplasty
D Additional attempts after failed revision arthroplasty
E Additional attempts after failed arthrodesis
F Summary of primary attempts with each mode of surgery
G Number of reinfections
H Total number of attempts with each mode of surgery
J Status at final follow-up
* Secondary or later attempts
I Total number of knees
II Number of healed infections
III Number of functioning prosthesis for soft-tissue surgery and revision arthroplasty; number of fusions for arthrodesis

interval between infection and surgery (within 2 days or later), previous antibiotic treatment, type of soft-tissue surgery, type of revision prostheses (compartmental or constrained), staging (one- or two-stage), and fusion. Because of the large number of investigated factors, forward stepwise analyses were performed. Multiple logistic regression was used for primary treatment with systemic antibiotics alone (225 knees), and for primary surgical treatment with soft-tissue surgery (138 knees), arthrodesis (68 knees), and revision arthroplasty (72 knees; Table 4).

Survival curves were constructed using the lifetable technique. Differences in survival were investigated using the chi-square test.

All the tests were two-sided, and a significance level of 0.05 was used.

Results

At the final follow-up, the deep infection was considered clinically healed in 315 knees (88 percent), 271 after surgery and 44 after systemic antibiotics alone. There was no difference in the final results for definite and probable infections.

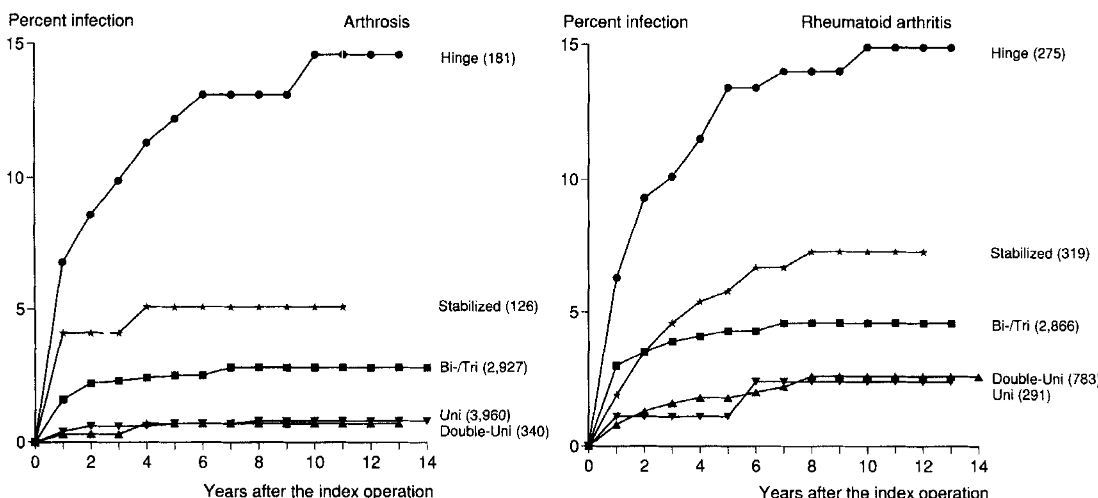

Figure 1. Cumulative risk of infection after primary knee arthroplasty in relation to type of prosthesis and diagnosis (series 2). For rheumatoid arthritis, there were significant differences between hinge and bi-/tri prostheses ($P < 0.0001$). For arthrosis, there were significant differences between hinge and bi-/tri prostheses and between bi-/tri and uni prostheses ($P < 0.0001$). None of the curves was continued when less than 20 knees remained for a specific type of prosthesis because of the risk of misleading interpretation of the right-hand tails of these curves (Dorey and Amstutz 1986). Initial number of prostheses within brackets after type of prosthesis.

Table 5. Incidence of postoperative wound-healing complications (PWHC) after primary knee arthroplasty (Series 2)

Type of prosthesis	N	PWHC n1	PWHC % of N	Deep infection after PWHC n2	Deep infection after PWHC % of PWHC	Total no. of deep infections
Arthrosis						
Hinged/stabilized	307	33	11	14	42	28
Bi-/tricompartmental	3,267	172	5.3	33	19	75
Unicompartmental	3,960	137	3.5	9	6.6	28
Total	7,534	342	4.5	56	16	131
Rheumatoid arthritis						
Hinged/stabilized	594	49	8.2	19	39	56
Bi-/tricompartmental	3,649	193	5.3	63	33	138
Unicompartmental	291	10	3.4	2	20	5
Total	4,534	252	5.6	84	33	199
Chi-square test:						
Bi-/tricompartmental prostheses, rheumatoid arthritis vs arthrosis		NS		$P = 0.004$		
Arthrosis, bi-/tricompartmental vs unicompartmental prostheses		$P = 0.0002$		$P = 0.001$		

Table 6. Incidence of hematogenous infection after primary knee arthroplasty 1975–1985 (Series 2)

Type of prosthesis	Arthrosis Infection	Arthrosis n	Arthrosis %	Arthrosis P-value	Rheumatoid arthritis Infection	Rheumatoid arthritis n	Rheumatoid arthritis %	Rheumatoid arthritis P-value	P-value
Hinge/stabilized	7	307	2.3	0.0001	27	594	4.5	0.0001	NS
Compartmental	21	7,227	0.3		36	3,940	0.9		0.0001
Bi-/tricompartmental	15	3,267	0.5	0.02					
Unicompartmental	6	3,960	0.2						

Incidences of infection (series 2)

The incidence of infection after primary arthroplasty was 1.7 percent for arthrosis and 4.4 percent for rheumatoid arthritis, with a median follow-up of 70 and 76 months, respectively (range 0–167 months; $P = 0.0001$). The incidence of infection after revision arthroplasty was 2.5 percent for arthrosis (primary vs revision arthroplasty; NS) and 4.1 percent for rheumatoid arthritis.

The 10-year cumulative risk of infection after primary arthroplasty for *arthrosis* was 15 percent for 181 hinge prostheses, 5.1 percent for 126 stabilized prostheses, 2.8 percent for 2,927 bi-/tricompartmental prostheses, 0.7 percent for 340 bilateral unicompartmental prostheses, and 0.8 percent for 3,960 unicompartmental prostheses (Figure 1). The corresponding numbers for *rheumatoid arthritis* were 15 percent for 275 hinge prostheses, 7.9 percent for 319 stabilized prostheses, 4.6 percent for 2,866 bi-/tricompartmental prostheses, 2.6 percent for 783 bilateral unicompartmental prostheses, and 2.4 percent for 291 unicompartmental prostheses.

The number of postoperative wound-healing complications (PWHC) after 12,118 primary arthroplasties was 600 (5 percent). Totally, 142 wound-healing complications (23 percent)—wound drainage in 61 knees, skin necrosis in 32 knees, hematoma in 33 knees, and superficial dehiscence in 16 knees—developed into a deep infection (PWHC vs no PWHC; $P = 0.0001$). Large prostheses increased the risk of wound-healing complications; rheumatoid arthritis, as well as large prostheses, increased the risk of an ensuing deep infection (Table 5).

Nine of the 31 knees with deep infection prior to the primary arthroplasty developed a deep infection after the index operation after an average of 5 (1–13) years. The microorganisms identified in three of these nine knees were identical to the preoperative findings.

Four of 86 patients (91 knees) died of sepsis following hematogenous infections after primary arthroplasty. The risk of hematogenous infection was increased for rheumatoid arthritis and for large prostheses (Table 6).

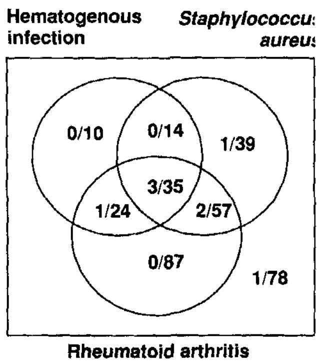

Figure 2. Death due to sepsis in 344 patients with an infected knee arthroplasty with respect to diagnosis, type of infection, and bacteriologic finding (Series 1).

Mortality

Eight patients died of sepsis (Figure 2). Six had a *Staphylococcus aureus* sepsis, 1 a *Clostridium perfringens* sepsis, and 1 a *Staphylococcus epidermidis*. sepsis. All but 2 patients had rheumatoid arthritis. There were five hematogenous infections (4 patients): three early and one late. Two patients died within a week, before surgical intervention took place. Three patients died after additional soft-tissue surgery; 1 died 11 months after debridement of a nonhealed revision arthroplasty, 1 died 1 month after excision of a sinus following primary soft-tissue surgery, and the third patient died 2 weeks after excision of an abscess following two failed excisions of sinuses. Two patients (three knees) died 2 days after removal of the prostheses. One patient died 6 months after an attempted arthrodesis.

Organisms

Gram-positive cocci dominated (68 percent)—notably *Staphylococcus aureus*, especially in late and hematogenous infections (Table 7). *Staphylococcus epidermidis* and a mixed flora were common in early infections. The proportion of the different organisms did not change between 1975–80 and 1981–85.

Table 7. Type of bacteria in 357 infected knee arthroplasties with regard to early, late, and hematogenous (hem) infection (Series 1)

Microorganism	Early	Late	Hem	Total
Aerobic gram-positive				
Staphylococcus aureus	50	47	52	149
Staphylococcus epidermidis	29	23	7	59
Streptococcus sp.	2	8	7	17
Enterococcus	10	0	0	10
Difteroids *(Corynebacterium)*	1	3	1	5
Pneumococcus	0	4	0	4
Total	92	85	67	244
Aerobic gram-negative				
Escherichia coli	3	2	1	6
Pseudomonas	3	0	2	5
Proteus sp.	0	1	3	4
Serratia	0	1	0	1
Klebsiella	1	0	0	1
Acinetobacter	0	0	1	1
Enterobacter	1	0	0	1
Total	8	4	7	19
Anaerobes				
Clostridium sp.	1	0	2	3
Bacteroides	0	0	2	2
Anaerobic cocci	2	0	0	2
Peptococcus	1	0	0	1
Propionibacterium acnes	0	0	1	1
Total	4	0	5	9
Mixed flora	38	9	8	55
Mycobacterium tuberculosis	1	0	0	1
Unknown	21	6	2	29
Grand total	164	104	89	357

Treatment (series 1)

Systemic antibiotics—alone or in conjunction with suction drainage, multiple aspirations, or irrigations—were employed as the primary treatment in 225 cases. The deep infection was successfully suppressed in 25 knees and eradicated in 22. Twenty knees had functioning prostheses. Three knees became reinfected after 2–6.5 years, and all of them healed after surgery. The deep infection remained in 178 cases. Ten patients declined surgical treatment and were put on lifelong systemic antibiotic treatment. The remaining 168 cases underwent surgical treatment after a median of 5 months (0.5–64 months) of antibiotic treatment. Based on radiographic evaluations, 129 patients had fixed prostheses at the beginning of the antibiotic treatment. At the time of the operation, there were 76 cases with reported loose prosthetic components, but only 40 cases with fixed components. Regardless of the duration of antibiotic treatment (more or less than the median of 5 months), the majority of the cases eventually healed after surgical treatment. Fistulation, loose prosthetic components, and gram-negative and mixed pathogens were risk factors for nonhealing (Table 8).

Surgical treatment was undertaken in 301 cases, with a total number of 556 attempts at surgery, resulting in 271 clinically healed infections (Table 4).

Primary *soft-tissue surgery* was performed in 154 knees—in 138 as the primary surgical treatment. Thirty knees healed, 13 of which had a functioning prosthesis. One patient had become reinfected after 6 years following a fall resulting in a tibial fracture below a hinge prosthesis. Additional attempts with the

Table 8. Bivariate and multivariate analyses of the relative risk (RR) of nonhealing after primary treatment of infected knee arthroplasty in the nationwide multicenter study

Risk factor	Bivariate		Multivariate	
Primary treatment	RR	*P*-value	RR	*P*-value
Early infection				
Revision arthroplasty	3.1	0.005	4.5	0.02
Fistulation				
Antibiotics alone	1.4	< 0.001	5.0	< 0.001
Soft-tissue surgery	1.3	0.006	3.3	0.003
Early period (1975–80)				
Arthrodesis	4.2	0.03	40.0	0.004
Gram-negative or mixed bacteria				
Antibiotics alone	1.3	< 0.001	5.0	0.009
Loose prosthesis				
Antibiotics alone	1.2	0.03	4.6	0.02
Revision arthroplasty	0.1	0.006	< 0.1	0.005
Arthrodesis	0.1	0.06	< 0.1	0.005

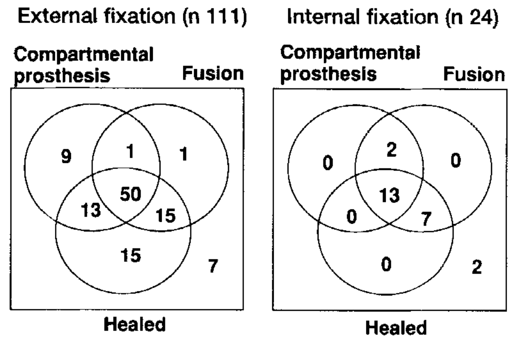

Figure 3. Distribution of 135 knees with primary arthrodesis relating type of fixation to type of prosthesis removed, fusion, and healing of infection.

index prosthesis in situ resulted in eight healed knees with two functioning prostheses. Fistulation was a risk factor.

Primary *resection arthroplasty* was performed in 22 knees. In 11 knees the preoperative planning had been resection as the first step in a staged procedure aiming at arthrodesis or revision arthroplasty. However, four of these 11 knees were amputated, and the remaining seven knees had no further surgery, as the patients were satisfied. A total of 11 knees healed, three with fibrous ankylosis. Eight patients could walk short distances with an orthosis with or without crutches or canes.

Primary *revision arthroplasty* was performed in 107 knees, in 72 of which as the primary surgical treatment. Seventy-five knees healed and 34 had a functioning prosthesis. The deep infection remained in 32 knees, 29 of which had additional surgery. Two knees became reinfected and had additional surgery. There was a total of five secondary revision arthroplasties, four of which healed—two with functioning prosthesis. Another four knees healed after soft-tissue surgery, giving a total of 81 healed knees. An early infection and fixed prosthetic components were risk factors.

Primary *arthrodesis* was performed in 135 knees, in 68 of which as the primary surgical treatment. The infection healed in 113 knees, and fusion was obtained in 89 knees (Figure 3). A deep infection remained in 22 knees. Sixteen of these patients had undergone additional attempts, which resulted in nine healed and five fused knees. Thirteen patients with healed, but nonfused, knees were subject to additional attempts at arthrodesis, and 11 knees fused. Two knees became reinfected and were amputated. Thus, the deep infection eventually healed in 120 of 135 knees with fusion in 105. Arthrodesis before 1981 and fixed prosthetic components were risk factors.

An above-the-knee *amputation* was performed in 22 patients. The indication for amputation was uncontrollable sepsis in 2 patients and nonhealing of the infection without sepsis in 19 patients. Information concerning prosthetic limbs and walking abilities could not be obtained in 6 patients.

Discussion

A deep infection after knee arthroplasty is a serious complication. Units that have specialized in joint prosthetic surgery have presented their results of treatment of infections, but the number of cases has often been small and selected, and the number of variables that might have affected the results of different modes of treatment has been large (Insall et al. 1983, Rand and Bryan 1983, Freeman et al. 1985, Knutson et al. 1985, Rosenberg et al. 1988). A multicenter collaboration, however, would have a better opportunity to collect a large number of cases to improve the evaluation of risk factors and of treatment. The Swedish Knee Arthroplasty Project is prospective in that it has had a continuous registration of infections (Knutson et al. 1986). However, the retrieval of relevant information about the infected knee arthroplasties has taken place after treatment has commenced. Further, the patients did not receive a standardized treatment, for it was up to the participating orthopedic surgeons to decide what treatment to choose and when. Thus, this is, to a large

extent, a retrospective multicenter study of the treatment of deep infection showing community-based results.

Multivariate analyses were performed to estimate the relative effect of one factor on healing while taking into account the effects of other factors. These analyses were not used for secondary treatments because of the ensuing difficulty in evaluating the influence of earlier treatment. Although the total number of patients was large, some of the statistical analyses were based on small sets of data and on highly disproportionate numbers of healed and nonhealed infections. This posed a special problem in the multivariate analyses; and to obtain more valid estimates, stepwise approaches were tried. However, even this technique presented difficulties in some instances.

Improvements in prosthetic design, in aseptic and antiseptic perioperative routines, in patient selection, and in surgical techniques have reduced the overall incidence of infection to 1–2 percent (Rand et al. 1986). To further reduce the infection rate, the problems of postoperative wound-healing complications and hematogenous infection must be addressed. One fourth of the postoperative wound-healing complications progressed to deep infection in our series, as well as in those of Johnson and Bannister (1986). Johnson and Bannister (1986) also found, as we did, that superficial wound infection was a greater risk for rheumatoids than for arthrotic patients as regards the development of a deep infection. Conflicting skin incisions predispose to tissue breakdown (Bengtson et al. 1987b). Therefore, for knee surgery, we recommend a skin incision compatible with later knee arthroplasty procedures. Further, oversized components (a risk with tricompartmental prostheses) should be avoided. Wound healing when disturbed should take priority over early postoperative exercises.

One third of the hip and knee prosthetic infections are hematogenous (Ritter and Sieber 1983, Grogan et al. 1986). Some of the patients with hematogenously infected total hip and knee replacements have shown an acute and dramatic course, with a high mortality rate (Wilson et al. 1975, D'Ambrosia et al. 1976, Salvati 1976, Dhala et al. 1985). In our study, hematogenous infection with *Staphylococcus aureus* in rheumatoid arthritis was dangerous regardless of treatment, as 3 of 35 patients died of sepsis. Measures for preventing hematogenous infections should focus on eradication of portals of entry. Because skin infections are the most common source of infection, it is necessary to heal skin ulcers, especially those distal to a joint with a prosthesis (Thomas et al. 1983). Antibiotic prophylaxis is recommended until the wound is healed. This has also been proven to be economically efficient (Bengtson et al. 1989b). Respiratory-tract, urinary-tract, and other infections should be vigorously treated in patients with a knee arthroplasty (Bengtson et al. 1987a). Tooth extraction always causes bacteremia (Lindqvist and Slätis 1985). We found no definite hematogenous infection after dental surgery. Antibiotic prophylaxis in dental procedures is, however, still being debated, and prospective studies have shown a low risk of bacterial nidation around prosthetic joints in otherwise healthy patients (Ainscow and Denham 1984). Antibiotic prophylaxis for dental surgical procedures may be considered—especially in high risk groups, such as patients with rheumatoid arthritis.

In agreement with the results of Jerry et al. (1988), we found that a prior deep infection results in a high rate of infection following knee arthroplasty.

The design of our study did not permit an analysis of other proposed risk factors for infection, such as diabetes mellitus, obesity, steroid therapy, previous knee surgery, bone cement, etc. (Rand et al. 1986).

The larger the prosthesis, the higher is the risk of infection. The results from Lund (Bengtson et al. 1989a) and our present study clearly show that it is less risky to use unicompartmental than bicompartmental or tricompartmental prostheses as regards infection. Thus, in cases with unicompartmental gonarthrosis where tibial osteotomy is ruled out, a unicompartmental prosthesis should to be considered—preserving the uninvolved compartment—rather than a larger prosthesis replacing the entire joint.

In a review of reports of the treatment of infected knee arthroplasty from centers in the United States and in England (124 cases), it was shown that 71 percent of organisms isolated were gram-positive cocci, with *Staphylococcus aureus* comprising 41 percent; mixed cultures and gram-negative organism occurred in 18 and 11 percent, respectively (Bannister 1989). This accords with our study. On the other hand, Sanzén (1989) found a shift over the years from mainly *Staphylococcus aureus* and gram-negative bacteria to *Staphylococcus epidermidis* and anaerobes in a study of the bacteriology in infected hip arthroplasties. A preponderance for *Staphylococcus epidermidis* was found in infected knee arthroplasty (Rosenberg et al. 1988, Wilde and Ruth 1988); the material, however, was highly selected, as it only concerned patients treated with revision arthroplasty. There was no significant bacteriologic shift over the years in infected knee arthroplasties in our study. One might object that this could be due to insufficient bacteriologic technique, because more than a third of the infected cases in our study were diagnosed from knee aspirates, but only 3 cases were diagnosed from tissue biopsies, which give

more reliable cultures (Kamme and Lindberg 1981). The bacteriologic results in Lund (Bengtson et al. 1989a), with tissue biopsies in most cases and anaerobic cultures routinely performed, were the same as in our study—except for anaerobes, which comprised 12 percent (6/51) of the organisms in Lund, but only 2.5 percent (9/357) in our study.

Our study confirmed previous reports of the low success rate of systemic antibiotics alone in the treatment of an infected knee arthroplasty (Insall et al. 1983, Johnson and Bannister 1986). It has been proposed that the use of prolonged systemic antibiotic treatment may compromise later surgical treatment (Thornhill and Maguire 1987). Well over half of our cases thus treated developed progressive bone resorption with prosthetic loosening, which is in contrast to the findings of Lidgren et al. (1977). However, regardless of the duration of antibiotic treatment, 90 percent of the infected cases that were later reoperated on eventually healed. Thus, we could not show that a period of systemic antibiotics did affect the result of the surgical treatment.

The difficulty in eradicating the infection with antibiotics alone raises the question of how dangerous this method is. The question is difficult to answer, because there was a continuous selection for operative treatment of patients failing to respond to antibiotic treatment. Moreover, we chose as inclusion criterion for our study that systemic antibiotic treatment must have been employed for at least 2 weeks after the debut of the infection. The overall picture of the infection should, at that time, be clear enough for a decision for definite treatment. This excluded 2 patients who, while on systemic antibiotics, died of sepsis within 5 days of the debut of the infection, and before a decision on surgery had been made.

Although the systemic antibiotic treatment of infection had a low success rate, it had a low mortality, and did not compromise later surgical intervention. It might therefore, combined with repeated aspirations, be tried in sedentary patients carrying a high operative risk.

Debridement has been proposed for infections with acute onset and fixed prosthetic components (Bliss and McBride 1985). Debridement and other types of soft-tissue surgery in our series had a low success rate. The explanations for this were certainly that the surgical debridement had been incomplete, that the frequency of skin problems was high, and/or that bacteria were growing in the bone-cement interface (Gristina and Costerton 1984). Our results accord more with those of Woods et al. (1983) and Johnson and Bannister (1986), who found surgical debridement and excision of a sinus track to be unsuccessful. In a previous study from our institution of 10 knees with early tissue breakdown resulting in exposed prostheses and treated with different plastic surgical techniques, we found, however, that a gastrocnemius musculocutaneous flap provided a reliable coverage (Bengtson et al. 1987b).

Resection arthroplasty has been presented as an alternative to arthrodesis in the treatment of infected patients with severe disability and limited demands (Kaufer and Matthews 1981). Centers with a special interest in resection arthroplasty have reported healing of the infection in 41 of 43 knees and the ability to walk with or without support in 30 patients (Falahee et al. 1987, Lettin et al. 1990). Only half of our resections healed; but among these 11 patients, 8 were walkers—using orthoses and crutches or canes. If the patient is dissatisfied with the resection arthroplasty, an arthrodesis or exchange arthroplasty can still be attempted.

A modified resection arthroplasty has recently been presented for problem cases with sepsis or excessive loss of bone stock in which exchange arthroplasty or arthrodesis are inadvisable or impossible (Jones and Wroblewski 1989). The space between the bone ends is filled with a bolus of antibiotic-loaded cement after implant removal. The bolus can improve stability and diminish shortening; moreover, it maintains a potential space for relatively easier revision arthroplasty (Cohen et al. 1988, Booth and Lotke 1989).

Prosthetic hip and knee joints with fistulation or infection with gram-negative bacteria have been regarded as unsuitable for reimplantation (Miley et al. 1982, Insall and Thompson 1984). However, in accord with the findings of Poss et al. (1984), we did not find gram-staining characteristics of the pathogen or fistulation to be predictors of the outcome of revision arthroplasty. Wilson et al. (1990) found reimplantation successful in two gram-negative infections; and with additional experience, Insall's group (Windsor et al. 1990) modified their view, finding reimplantation feasible if the gram-negative organism was sensitive to relatively nontoxic antibiotics.

Revision arthroplasty has been performed as a one-stage or two-stage procedure with success rates above 90 percent (Insall et al. 1983, Freeman et al. 1985, Borden and Gearen 1987, Rosenberg et al. 1988). The success rate in our study was lower (81/107); but this could have been due to differences in patient selection, type of revision, and criteria for infection. We found no differences in the outcome of one-stage and two-stage revision arthroplasties.

Arthrodesis has, in many centers, been the treatment of choice for the infected knee arthroplasty. We found that healing of the infection is important for fusion, because 85 of 113 of the healed knees fused,

while only four of 22 of the nonhealed knees fused after primary arthrodesis. We also found that the fusion rate after primary arthrodesis was 66/88 for compartmental prostheses and 23/47 for constrained prostheses, which is the same proportion as reported by Brodersen et al. (1979). Apart from persistent sepsis, Brodersen et al. (1979) identified bone loss and loss of bone contact as the major causes of nonunion. Bone loss may be treated with bone grafting, repeatedly if necessary (Knutson et al. 1985). Loss of bone contact is overcome by improved fixation methods (Knutson et al. 1984b). The improved results of arthrodesis after 1980 in our study might be due to the introduction of biplanar external fixation and of intramedullary nailing. Because most external fixations were one-stage procedures and most internal fixations were two-stage procedures, our study could not evaluate the merits of the different staging procedures.

In contrast to Poss et al. (1984), we found that early infections were a risk factor for nonhealing of revision arthroplasties. One explanation might be that most of the revised late infections had fewer skin problems and less bone involvement.

Fixed prosthetic components were found to be a risk factor for nonhealing of revision arthroplasties and arthrodeses. This might be due to the increased trauma of extracting fixed prosthetic components.

The outcome of 23 amputated patients were reported by Pring et al. (1988). After a follow-up of 4 years, only 7 patients were regular daily walkers; 20 of the 23 patients used a wheelchair during part of the day, and 12 patients were confined to a wheelchair. These results are difficult to compare with our results, as we could not obtain information about the use of prostheses and walking ability in 6 of our 22 amputated cases, and as Pring et al. (1988) only studied patients that were deemed suitable for a prosthetic fitting.

The treatment of infected knee arthroplasty is difficult. Although the infection healed in 315 knees (88 percent), only 71 patients (20 percent) recovered with a functioning prosthesis, and 8 patients died of the infection. Attention should therefore focus on prophylactic measures directed towards the soft-tissue problems—by avoiding conflicting skin incisions, by gentle handling of the periarticular soft tissues, by avoiding the use of constrained prostheses and oversized compartmental prostheses, by permitting wound healing to take priority over motion in knees with compromised soft tissues, and by using prophylactic antibiotic treatment for skin ulcers until these have healed.

Acknowledgement

The authors gratefully acknowledge the contribution of J. Ranstam, M.A., Department of Community Health Sciences, Malmö, in the statistical analyses.

This study was sponsored by the Swedish Medial Research Council (project 17X-09509), Stiftelsen för bistånd åt vanföra i Skåne, Riksförbundet mot reumatism, Signe och Reinhold Sunds Stiftelse, and Malmöhus läns landsting.

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