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KNEE ARTHROPLASTY

The outcome of infected total knee arthroplasty: culture-positive versus culture-negative

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Abstract
Purpose We studied the outcome in culture-positive and culture-negative infected total knee arthroplasty (TKA).
Methods We retrospectively reviewed 140 patients with culture-positive and 102 patients with culture-negative infected TKAs. We determined the infection control rate and clinical outcome after repeated debridement, and repeated 2-stage TKA in the culture-positive and culture-negative groups. The mean follow-up was 9.3 years (range 5–14 years) in the culture-positive group and 10.6 years (5–22) in the culture-negative group.
Results The overall infection control rate was 56 % in both groups after the first treatment. The overall infection control rate was 90 % in the culture-positive group and 95 % in the culture-negative group. A functional knee was obtained in 90 % in the culture-positive group and 95 % in the culture-negative group.
Conclusions The data suggest that treatment according to the types of infection in both culture-positive and culture-negative groups after TKA controlled infection and maintained functional TKA with a firm level of fixation for most patients. Repeated debridement and repeated two-stage exchange TKA further improved infection control rates after the initial treatment and increased the likelihood of maintaining a functional TKA.

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Keywords Infection control rate · Culture-positive · Culture-negative · TKA

Introduction

Periprosthetic joint infection is one of the most challenging complications after total knee arthroplasty (TKA) with an incidence of 1 to 4 % after primary TKA [9–11, 29, 30]. Accurate diagnosis of periprosthetic joint infection is essential and often involves withholding antibiotic therapy in hopes of isolating an organism from a preoperative joint aspiration or intraoperative tissue cultures. Determining the causative organism then allows tailored local and systemic antibiotic therapy. Despite extensive efforts, the cultures often have a high false-negative rate despite adequate clinical, radiographic, and surgical suspicion for periprosthetic joint infection. Incidence of negative cultures in most infection series ranged from 0 to 25 % [1, 5, 7, 21, 23, 24, 38].

The reported control rates of treating deep infection of TKA have ranged from 20 to 68 % for surgical debridement with retention of the prosthesis, 50–87 % for one-stage exchange, and 56–100 % for two-stage exchange [2–4, 8, 13, 17, 18, 25, 27, 32, 33, 36, 39, 40]. However, in a culture-negative periprosthetic joint infection, choosing the appropriate antibiotic therapy is difficult.

To confirm previous reports, we (1) compared each type of infected TKA that did not yield positive cultures at the time of treatment with those that had positive cultures to determine the control rates of infection, and (2) determined whether repeated debridement and repeated two-stage exchange arthroplasty would improve further the control rate of infection after failed first treatment in culture-positive and culture-negative cases.

Materials and methods

We retrospectively reviewed data for 209 patients with 209 infected total knee arthroplasties from January 1991 to March 2008. Of the 209 patients, 11 were lost to follow-up before 2 years, and 7 died, leaving 191 patients (191 knees) for review. The records of the 191 patients had been entered into an ongoing computerized database that was updated continuously. The study was approved by the institutional review board, and patients provided written informed consent. The primary diagnosis for the indication for TKA was osteoarthritis in all patients. There were 44 men and 147 women with a mean age index TKA of 66.3 ± 8.65 years (range 40–90 years). Their mean body mass index was 28.29 ± 4.31 kg/m^2 (range 20.1–41.3 kg/m^2). The minimum duration of follow-up monitoring was 5 years (mean 10 ± 0.92 years, range 5–22 years) (Table 1).

Infection after TKA was diagnosed if the patient fulfilled any one of the following criteria: (1) an abscess or sinus tract communicating with the joint space; (2) positive preoperative aspiration culture findings on solid media; (3) positive cultures on 2 or more intraoperative cultures; or (4) one positive culture on solid media in conjunction with the presence of pus. In patients with negative cultures, infection was diagnosed when there were the following findings: elevated erythrocyte sedimentation rate ([ESR] >20 mm/h, C-reactive protein [CRP] level >0.5 mg/dL), elevated synovial WBC count ≥2000/μL, and synovial neutrophil percentage [PMN %] ≥65 %, presence of pus in the affected joint, and more than 5 neutrophils per high-power field on histologic examination [9, 12, 28, 31, 35]. In the 45 patients who underwent total knee arthroplasty for infection from 1999 to 2004, serologic counts in the aspirated synovial fluid were not available and there was no threshold value of serologic counts available. Infection in these patients was diagnosed by the findings of serum serology and joint fluid culture. Each infection was classified as early postoperative deep, late chronic, and acute hematogenous infection according to Tsukayama et al. [36, 37] Clinical host condition was classified as uncompromised, compromised, and significantly compromised based on the classification of McPherson et al. [26] in 146 patients. For the remaining 45 of 146 patients who underwent total knee arthroplasty from 1999 to 2004, the classification for clinical host condition was not used.

Study patients were divided into 2 groups based on culture results from both preoperative joint aspirate and intraoperative periprosthetic tissues from the affected joint at the time of initial surgical treatment at our institution, which totaled 140 patients with positive-culture results (culture-positive group), and 51 patients with negative-culture results (culture-negative group). All of the patients with culture-negative had PCR analysis. Gram-positive cocci were isolated from 84 knees, and gram-negative bacilli were cultured from 38 knees. The fungal (*candida albicans*) isolates in 8 knees and mycobacterium (mycobacterium tuberculosis) isolates in 10 knees came from late chronic infections (Table 2). Twenty-one of 140 patients had culture-negative initially and turned culture-positive later. Patients' demographics, clinical characteristics, and treatment results were compared between the 2 study groups. The history of previous antibiotic treatment for infected TKA of the same joints and follow-up cultures of the same joints after failure of our initial surgical treatment were also documented to outline the pattern of 51 patients with negative-culture results (Table 1).

Early deep postoperative infections were treated with debridement, replacement of the polyethylene insert of the tibial component, retention of the prosthesis, and intravenous administration of antibiotics for 6 weeks (Fig. 1). The patients with culture-negative were treated empirically as patients with culture-positive. If the infection recurred, repeated debridement and replacement of the polyethylene insert of the tibial component, retention of the prosthesis, and intravenous antibiotics for 6 weeks followed. If the infection recurred again, 2-stage exchange arthroplasty was performed as for the recurrent early deep postoperative infection. First, we performed debridement, removal of all of the prosthetic components and bone cement, and placement of a vancomycin and gentamycin-impregnated (2.0 g and 80 mg per 40-g batch, respectively, of bone cement) mobile cement spacer. Antibiotics were administered intravenously for 6 weeks (Table 3). After completion of antibiotic therapy, ESR, CRP levels, and total WBC count and differential in the joint aspirates were obtained, and the patient was observed for 2 more weeks. If results of these tests showed no evidence of infection, we performed TKA. Multiple cultures of specimens obtained during revision operations were performed to confirm infection eradication. If the infection recurred once again, repeated 2-stage exchange arthroplasty was performed. Arthrodesis was performed if the infection recurred again. In selective cases, fusion-taken-down and TKA were performed after infection was controlled completely. Late chronic infection was treated with 2-stage revision, as for the recurrent early deep postoperative infection. If the infection recurred, repeated 2-stage exchange arthroplasty was performed. If the infection recurred again, arthrodesis was performed. Also, in selective cases, fusion-taken-down and TKA were performed. Acute hematogenous infections were treated with debridement, replacement of the polyethylene insert, retention of the prosthesis if it was not loose, and intravenous administration of antibiotics for 6 weeks. If the

Table 1 Comparison of demographics and variables between culture-positive and culture-negative patients

Variable	Culture-positive ($N = 140$)	Culture-negative ($N = 51$)	P value (Chi-square test)
Age (years)	65.2 ± 8.4 (range 57–79)	67.4 ± 8.9 (range 40–90)	0.36
Gender			0.41
Male	30	14	
Female	110	37	
Host condition			0.59
Uncompromised	98 (70 %)	34 (67 %)	
Compromised	42(30 %)	17(33 %)	
Implant			
Primary	140 (100 %	51 (100 %)	
Type of infection			0.63
Early deep	75 (54 %)	26(51 %)	
Late chronic	59 (42 %)	23 (45 %)	
Acute hematogenous	6 (4 %)	2(4 %)	
Draining sinus			0.16
Yes	10 (7 %)	0 (0 %)	
No	130 (93 %)	51 (100 %)	
Preoperative antibiotic treatment			0.003
Yes	97 (69 %)	21 (41 %)	
No	43 (31 %)	30 (59 %)	
IV antibiotics (postoperative)			0.001
Vancomycin	91 (65 %)	43 (84 %)	
Others	49 (35 %)	8 (16 %)	
Oral antibiotics(postoperative)			0.001
Yes	28 (20 %)	31 (61 %)	
No	112 (80 %)	20 (39 %)	
Laboratory data			
WBC (/mL)	9287 ± 3895	8081 ± 2809	0.049
ESR (mm/h)	98.1 ± 38.7	79.8 ± 29.1	0.003
CRP (mg/L)	25.1 (10.1–58.8)	15.5 (9–48.9)	0.003
Aspirates WBC (/mm^3)	46,750 (20,500–98,500)	36,501 (19,500–72,762)	0.004
Aspirate			
Neutrophil (%)	93 (78–96)	91 (85–93)	0.131
Follow-up (years)	9.3 (5–14)	10.6 (5–22)	0.323

infection recurred, 2-stage exchange arthroplasty and repeated two-stage arthroplasty and arthrodesis were performed (Fig. 1). A Legacy Constrained-Condylar Knee prosthesis (LCCK; Zimmer, Warsaw, Indiana) was used in all knees with antibiotic-impregnated bone cement. On the second day after surgery, a continuous passive motion machine was used for passive range-of-motion exercise twice daily for 30 min each time. The machine settings were advanced incrementally under the supervision of a physical therapist. On the second postoperative day, patients began standing at the bedside or walking with crutches or a walker twice daily for 30 min, each time under the supervision of a physical therapist. Patients used crutches or a walker with full weight bearing for 6 weeks and then a cane as needed thereafter. No patient received physiotherapy after discharge from the hospital.

Routine follow-up evaluation was scheduled at postoperative intervals of 3 months, 1 year, and yearly thereafter. At these intervals, we evaluated the patients and obtained radiographs. Preoperative and postoperative review data were recorded according to the system of the Knee Society [15]. All of the knees were evaluated by one observer (DRK) who was not connected with the original surgery, and the data were entered into a computerized record. The criteria for infection control were: no pain or swelling; no wound drainage; normal serology (ESR <20 mm/h, CRP level <0.5 mg/dL); a synovial fluid leukocyte differential of less than 65 % neutrophils

Table 2 Bacterial isolates in 140 infections in positive-culture results

Pathogen	Group		
	Early deep (75)	Late chronic (59)	Acute hematogenous (6)
Gram-positive cocci (84)			
Coagulase-positive *Staphylococci* ($n = 30$)	10	16	4
Methicillin-susceptible	8	10	2
Methicillin-resistant	2	6	2
Coagulase-negative *staphylococci* ($n = 26$)			
Methicillin-susceptible	6	10	0
Methicillin-resistant	2	4	4
Streptococcus ($n = 14$)	6	8	–
Enterococcus ($n = 14$)	8	6	–
Gram-negative bacilli ($n = 38$)			
Enterobacter ($n = 22$)	10	10	2
Acinetobacter baumannii complex ($n = 16$)	8	8	–
Fungus *candida albicans* ($n = 8$)	–	8	–
Mycobacterium tuberculosis ($n = 10$)	–	10	–

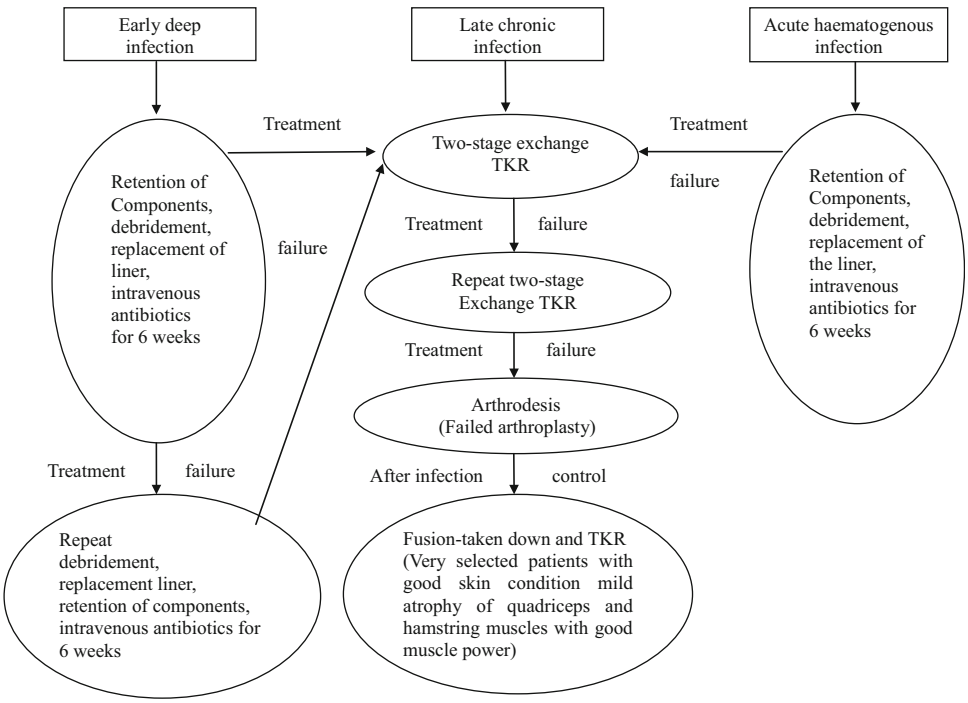

Fig. 1 Diagram of the treatment pathway for an infected total knee arthroplasty

(or a leukocyte count $<1.7 \times 10^3/\mu L$); and a normal radiographic finding for at least 2 years after the end of antibiotic therapy [34]. For a knee to be considered functional, there had to be no or only slight pain upon walking (with or without the use of a cane) and no radiographic findings, such as progressive osteolysis or loosening of the prosthetic components that indicated a need for immediate or impending surgical intervention. If the initial treatment failed, we recorded the number and type of subsequent courses of treatment that were attempted. In some instances, infection eradication was achieved only after multiple courses of treatment.

One of the study's authors (YHK) evaluated the final radiographs. We defined radiographic loosening as a complete radiolucent line of ≥ 2 mm in width at the bone cement of the prosthesis-cement interface or shift in position of a component or components on serial radiographic examination [16].

Table 3 Treatment of infection with antibiotics

Microorganism	Antimicrobial agent	Dosage	Route
Staphylococcus aureus coagulate-positive or -negative			
Methicillin-susceptible	Nafcillin or floxacillin plus	2 g every 6 h	IV
	Rifampin for 2 weeks followed by	450 mg every 12 h	PO
	Rifampin plus	450 mg every 12 h	PO
	Ciprofloxacin or	750 mg every 12 h	PO
	Levofloxacin	750 mg every 24 h	PO
Methicillin-resistant	Vancomycin plus	1 g every 12 h	IV
	Rifampin for 2 weeks	450 mg every 12 h	PO
	Rifampin plus	450 mg every 12 h	PO
	Ciprofloxacin or	750 mg every 12 h	PO
	Levofloxacin or	750 mg every 24 h	PO
	Teicoplanin or	400 mg every 24 h	IV
	Fusidic acid	500 mg every 8 h	PO
Streptococcus and enterococcus	Penicillin G or	5 million units every 6 h	IV
	Ampicillin or amoxicillin	2 g every 4-6 h	IV
Enterobacter and acinetobacter	Ceftazidime or cefepime plus	2 g every 8 h	IV
	Aminoglycoside for 2 weeks followed by ciprofloxacin	750 mg every 12 h	PO
Culture-negative	Vancomycin plus	1 g every 12 h	IV
	Ciprofloxacin or	750 mg every 12 h	PO
	Levofloxacin or	750 mg every 24 h	PO
	Teicoplanin or	400 mg every 24 h	IV
	Fusidic acid	500 mg every 8 h	PO
Fungus	Fluconazole	400 mg every 24 h	IV
	or Caspofungin	50 mg every 24 h	IV
Tubercle bacilli	Isoniazid	300 mg every 24 h	PO
	Ethambutol	800 mg every 24 h	PO
	Rifampin	600 mg every 24 h	PO
	Pyridoxine	50 mg every 24 h	PO

Statistical analysis

Chi-square, descriptive, and Student's *t* test analyses were used to compare demographics and comorbidities between the culture-negative and culture-positive groups. The differences among the 4 types of infection in culture-positive and culture-negative groups for discrete variables (including age, period of follow-up, CRP, ESR, leukocyte count, and leukocyte differential) were compared using Fisher's exact probability two-tailed *t* test. Logistic regression was used to assess the rate of failure associated with the different types of infection in both groups. One-way analysis of variance was used to confirm differences among the different types of infection with respect to the final clinical score. The level of significance was set at $P < 0.05$. All analyses were performed with use of SPSS software (version 18; SPSS, Chicago, Illinois).

Results

Overall rates of infection control, successful first treatment, and functional knee were not statistically different between the culture-positive and culture-negative groups ($P > 0.05$). Overall rates of infection control were not statistically different between the gram-positive and gram-negative groups ($P < 0.05$). Overall infection control rate was 90 % in the culture-positive group and 95 % in the culture-negative groups at means of 9.3 and 10.6 years follow-up, respectively. A functional knee was obtained 90 % in the culture-positive group and 95 % in the culture-negative group. In the culture-positive group, the initial course of treatment was successful for 41 of 75 knees (55 %) with early deep postoperative infection (Table 4), 47 of 59 knees (80 %) with late chronic infection (Table 5), and 2 of 6 knees with acute hematogenous

infection (Table 6). In the culture-negative group, the initial course of treatment was successful for 16 of 26 knees (62 %) (Table 4) with early deep postoperative infection (Table 4), 19 of 23 knees (83 %) with late chronic infection (Table 5), and 1 of 2 knees with acute hematogenous infection (Table 6). PCR results in all of the patients with culture-negative were negative.

Infection control and maintenance of functional TKA after first treatment were further improved by repeated débridement and repeated 2-stage exchange TKA (Table 7). The mean Knee Society knee and function scores in the culture-positive group were 87 and 77 points, respectively, and they were 89 and 75 points, respectively, in the culture-negative group (these score were not statistically different, $P > 0.05$) between the 2 groups.

In the culture-positive group, 7 knees (5 %) were revised for aseptic loosening of femoral and/or tibial components, and 2 knees were required above-knee amputation for persistent infection after 2 revisions. These 2 patients who underwent above-knee amputation were immuno-compromised by prolonged antibiotic therapy and superimposed MRSA with *candida albicans* infection. In the culture-negative group, 4 knees (8 %) were revised for aseptic loosening of the femoral and tibial components. Survivorship of total knee prosthesis at 9.3 years as the end point of revision, or arthrodesis, or amputation was 94 % (95 % confidence interval 0.91–0.97) in the culture-positive group, and it was 92 % (95 % confidence interval 0.89–0.98) in the culture-negative group.

Discussion

It is unclear whether patients with negative cultures presumed to have infected TKA achieve similar rates of infection-free survival as those with positive cultures. The current retrospective study compared each type of infected TKAs that did not yield positive cultures at the time of treatment with those that had positive cultures to determine the control rates of infection, and whether repeated debridement and repeated 2-stage revision would further improve the control rate of infection of the initial treatment in culture-positive and culture-negative cases.

There are a few limitations in our study. First, although all patients in this study were prospectively followed, the design of the study was to test retrospectively our classification-based treatment algorithm for infected TKA with the hypothesis that it would be successful. Second, owing to limited patient numbers, we were unable to analyze data for patients stratified according to infecting organism. It is possible that the infection control after infected TKA was influenced by the virulence of the infecting organism. Third, 11 of 209 patients (4 %) were lost to follow-up, and 7 (3 %) died. Nevertheless, the percentage of patients who died or were lost to follow-up was small and likely did not influence the findings of our study, unless the majority of these lost and died cases had become reinfected. Fourth, in patients with negative cultures, infection was diagnosed by the findings of serological markers. However, serological markers can lead to false negative diagnosis [19]. Finally, in the 45 patients who underwent total knee arthroplasty for infection from 1999 to 2004, serologic counts in the aspirated synovial fluid were not used and there was no threshold value of serologic count available. Infection in these patients was diagnosed by the findings of serum serology and joint fluid culture. This can lead to false negative diagnosis of infection.

Although identification of a causative microorganisms from operative tissue samples or joint aspiration is the standard for diagnosis of periprosthetic joint infection, negative cultures are frequent in treatment of periprosthetic joint infections. In the present study, incidence of negative

Table 4 Treatment results of early postoperative deep infections

Treatment	Culture-positive ($N = 75$ knees)			Culture-negative ($N = 26$ knees)			P value
	Number of Infection	Results		Number of Infection	Results		
		Success	Failure		Success	Failure	
First treatment debridement	75 knees	41 knees (55 %)	34 knees (45 %)	26 knees	16 knees (62 %)	10 knees (38 %)	0.289
Second treatment debridement	34 knees (45 %)	5 knees (7 %)	29 knees (39 %)	10 knees (38 %)	2 knees (8 %)	8 knees (31 %)	0.571
Third treatment two-stage implantation	29 knees (39 %)	24 knees (32 %)	5 knees (7 %)	8 knees (31 %)	16 knees (23 %)	2 knees (8 %)	0.623
Fourth treatment arthrodesis (failed arthroplasty)	5 knees (7 %)	–	5 knees (7 %)	2 knees (8 %)	–	2 knees (8 %)	
Final results	75 knees	70 knees (93 %)	5 knees (7 %)	26 knees	24 knees (92 %)	2 knees (8 %)	0.359

Table 5 Treatment results of late chronic infection

Treatment	Culture-positive ($N = 59$ knees)			Culture-negative ($N = 23$ knees)			P value
	Number of infection	Results		Number of infection	Results		
		Success	Failure		Success	Failure	
First treatment two- stage implantation	59 knees	47 knees (80 %)	12 knees (20 %)	23 knees	19 knees (83 %)	4 knees (17 %)	0.145
Second treatment repeated two-stage implantation	12 knees (20 %)	8 knees (14 %)	4 knees (7 %)	4 knees (17 %)	3 knees (13 %)	1 knee (4 %)	0.139
Third treatment arthrodesis (failed arthroplasty)	4 knees (7 %)	–	4 knees (7 %)	1 knee (4 %)	–	1 knee (4 %)	
Final result	59 knees	55 knees (93 %)	4 knees (7 %)	23 knees	22 knees (96 %)	1 knee (4 %)	0.489

Table 6 Treatment results of acute hematogenous infection

Treatment	Culture-positive ($N = 6$ knees)			Culture-Negative ($N = 2$ knees)			P value
	Number of infection	Results		Number of Infection	Results		
		Success	Failure		Success	Failure	
First treatment debridement	6 knees	2 knees (33 %)	4 knees	2 knees	1 knee (50 %)	1 knee	–
Second treatment two-stage implantation	4 knees	3 knees	1 knee	1 knee	1 knee	–	–
Third treatment repeated two-stage total knee arthroplasty	1 knee	–	1 knee	–	–	–	–
Fourth treatment arthrodesis (failed arthroplasty)	1 knee	–	1 knee	–	–	–	
Final result	6 knees	5 knees	1 knee	2 knees	2 knees	–	–

Table 7 Summary of overall results for each group

Results	Culture-positive ($N = 140$)			Culture-negative ($N = 51$)		
	Early deep infection (75 knees)	Late chronic infection (59 knees)	Acute hematogenous infection (6 knees)	Early deep infection (26 knees)	Late chronic infection (23 knees)	Acute hematogenous infection (2 knees)
Successful first treatment	41 knees (55 %)	47 knees (80 %)	2 knees (33 %)	16 knees (62 %)	19 knees (83 %)	1 knee (50 %)
Infection eradicated	75 knees (100 %)	59 knees (100 %)	6 knees (100 %)	26 knees (100 %)	23 knees (100 %)	2 knees (100 %)
Functional knee	70 knees (93 %)	54 knees (92 %)	5 knees (83 %)	24 knees (92 %)	22 knees (96 %)	2 knees (100 %)
Amputation	–	2 knees (3 %)	–	–	–	–

culture result was 26.7 % (51 of 191), which was greater than other studies commonly reported as 20 % or less [1, 7, 14, 23]. We strongly believe this high incidence of negative culture results in our study is related to prolonged previous intravenous and oral antibiotic treatment, which was consistent with the previous reports [1, 22]. This suggests that a prolonged previous antibiotic treatment has led to the lower ESR and CRP values seen in the culture-negative group ($P = 0.03$).

Malekzadeh et al. [31] reported the largest series of culture-negative periprosthetic joint infection, which includes 135 cases (10.6 % incidence) within 16 years. They found no differences in treatment failure between the culture-negative and -positive cases. Huang et al. [14] also

found no differences in treatment failure between culture-negative and -positive cases. On the contrary, Choi et al. [6] reported that the culture-negative group showed significantly higher treatment success rates compared to the culture-positive group. They suggested that high usage of vancomycin and additional surgical treatment (reimplantation or arthrodesis) in culture-negative patients might have contributed to more favorable outcomes in their study. The findings of the current study showed no significant differences in the treatment failure between culture-negative and -positive groups. We believe that initial surgical treatment and subsequent aggressive additional treatments (repeated debridement, and repeated 2-stage exchange arthroplasty), led to improved eradication of infection in both culture-negative and -positive groups. Although repeated 2-stage exchange arthroplasty improved infection control rate, knee scores were worse than single 2-stage exchange arthroplasty.

In various series ranging in size from 5 to 116 infections, the overall infection control rate associated with the use of irrigation and debridement for the treatment of early deep postoperative infection ranged from 0 to 100 % [2, 19, 20, 27, 32, 33]. Mont et al. [27] reported that a protocol of multiple debridement was successful for the treatment of 10 of 10 early deep postoperative infections (defined as those that occurred less than 4 weeks after index arthroplasty). In our study, the success rate of initial treatment in early postoperative infection was 55 % in the culture-positive group and 60 % in the culture-negative group, which is similar to the 50 % reported for other series [33]. The infection control rate was improved to 93 % in culture-positive group and 92 % in culture-negative group after repeated debridement, and repeated 2-stage revision. The infection control rate of initial treatment in the late chronic infection in our series was 80 % in the culture-positive group and 83 % in the culture-negative group. These figures are similar to the 83 % reported for other series [33]. After repeated debridement and repeated 2-stage revision, the infection control rate was improved to 93 % in the culture-positive group and 96 % in the culture-negative group. The infection control rate of the first course of treatment (retention of the prosthesis, debridement, and intravenous antibiotics for 6 weeks) for acute hematogenous infection was similar (33 % versus 50 %) to the rates reported by others [27, 33]. After repeated debridement and repeated 2-stage revision, the infection was controlled in 5 of 6 knees in the culture-positive group and all knees (2 knees) in the culture-negative group.

Segawa et al. [33] reported that 5 of 10 patients with early deep postoperative infection, and 24 of 29 with late chronic postoperative infection were able to walk with no or only slight pain (some with the assistance of a cane). None of their patients had radiographic findings (such as evidence of implant migration or progressive osteolysis) that would have indicated a need for immediate or impending surgical intervention. In the current series, 7 knees (5 %) in the culture-positive group and 4 knees (8 %) in the culture-negative group were revised for aseptic loosening of femoral and/or tibial components. Two patients in the culture-positive group required above-knee amputation for persistent infection after 2 revisions.

In conclusion, the results of present study demonstrate that no significant differences exist in the infection control rate and clinical outcomes between culture-positive and culture-negative groups. The data suggest that treatment according to the types of infection in both culture-positive and culture-negative groups after TKA controlled infection and maintained functional TKA with a firm level of fixation for most patients. Repeated debridement and repeated two-stage exchange TKA further improved infection control rates after the initial treatment and increased the likelihood of maintaining a functional TKA.

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