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Research Article

Retrospective Analysis of Failure Causes and Microbiologic Features of Periprosthetic Joint Infection in Hip and Knee Arthroplasty Cases

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Abstract:

Background: Failures of bipolar hip hemiarthroplasty (BHA) and total knee arthroplasty (TKA) lead to time- or energy-consuming revision arthroplasty, which is considered as a big challenge to arthroplasty surgeons and patients. Periprosthetic joint infection (PJI) has been identified as one of the most difficult causes to treat. This study aims to examine the potential causes of failure following BHA/TKA and microbiological testing results with antibiotic susceptibility in PJI cases.

Materials and Method: We retrospectively reviewed the causes of failures after BHA in 92 patients and after TKA in 48 patients admitted to Pyongyang University of Medical Sciences Hospital. Then we investigated the microbiological etiology of 53 hip and 26 knee periprosthetic joint infections that were treated with the two-staged revision and analyzed the antibiotic susceptibility of causative bacteria.

Results: The main reasons for failures of primary BHA were aseptic loosening (43/92) and periprosthetic joint infection (34/92), whereas in revision BHA they were infection (8/14) and dislocation of the inner head (3/14). The main reasons for failures of primary TKA were infection (25/48) and aseptic loosening (8/48), whereas in revision TKA they were infection (9/13) and flexion contracture (2/13). Staphylococcus aureus and E. coli were the most common causative microorganisms in hip and knee PJI cases. Gram-positive bacteria were sensitive to ceftriaxone + gentamicin +rifampicin and levofloxacin/cefotaxime was susceptible to gram-negative bacteria.

Conclusion: The present study might be helpful to expand our knowledge about the failure modes of BHA and TKA and to establish the antibiogram for empiric regimens based on the antibiotic susceptibility results.

Keywords: bipolar hip hemiarthroplasty; total knee arthroplasty; periprosthetic joint infection; antibiotic susceptibility; failure cause

1.Introduction

Hip and knee arthroplasties are the most successful orthopedic procedures that have relieved pain and improved joint function in millions of patients worldwide. Despite the success of modern prosthetic designs and bearing surfaces, a considerable amount of hip and knee prostheses still fail within 15 years [1]. Improved surgical technique and prosthesis design have decreased the incidence of deep infection, dislocation, and fracture, however aseptic loosening, periprosthetic joint infection (PJI) and the clinical endpoint of osteolysis remain as the most frequent complications and in the UK account for 63% of all revision surgery [1].

In literature, potential causes involved in the failure of bipolar hip hemiarthroplasty (BHA) have been reported as the following: aseptic loosening, periprosthetic infection, liner wear, periprosthetic fracture, implant breakage, heterotopic ossification, and unexplained pain [2-6]. The failure causes of total knee arthroplasty (TKA) are categorized into 3 groups: (1) extra-articular causes of failure including heterotopic ossification; (2) intra-articular mechanical causes including poor sizing, component breakage due to wear and poor stress distribution, impaired extensor mechanism, aseptic loosening, periprosthetic osteolysis, and instability; (3) intra-articular biological causes including infection, metal hypersensitivity, ankylosis, arthrofibrosis, and recurrent hemarthrosis. [7-10]. Osteolysis and resulting prosthesis loosening have been major complications after BHA and TKA, in which wear debris could account for their development [11, 12]. Implant-related failures have been known to be caused by poor tribological characteristics and designs of prostheses [13-15].

Among the aforementioned causes of failure following BHA and TKA, periprosthetic joint infection is considered as one of the most catastrophic and frequent causes [16]. Due to high cost and time-consuming of management in the revision setting for failure cases [17-19], there have been increasing researches on its early diagnosis, evaluation and management over the whole world [20-25]. Different microbiological profiles have been reported not only between hip and knee but also between different authors, indicating that bacterial species and antibiotic susceptibility could be various in different arthroplasties and regions [21]. Although proper identification of the offending organism with antibiotic susceptibility obtained from microbiological results is pivotal for guiding long-term antibiotic selection, empiric antibiotic therapy is often utilized while antibiotic susceptibility is

pending or negative [26, 27]. In this setting, many institutions and regions have cumulative antibiograms created by testing antibiotic sensitivities of previously infecting organisms that have been treated in the institution or region [28]. These antibiograms represent the general sensitivity of antibiotics to commonly infecting organisms and can be an invaluable resource when determining what antibiotics to use for empiric therapy in many clinical scenarios with pending sensitivities [29]. The microbiological testing results are essential in setting up the database for the management guideline of periprosthetic joint infection [30].

There has been little literature on failure causes and microbiological characteristics of cemented BHA and cemented TKA among the Korean population. Therefore, this study is designed to analyze the failure causes, microbiological testing results including antibiotic susceptibility and optimal combination of antibiotics through the retrospective survey of BHA and TKA cases.

Materials and Methods

We retrospectively reviewed failure causes in the medical records of 92 BHA cases and 48 TKA cases who underwent revision in the clinical orthopedic institute of Pyongyang University of Medical Sciences Hospital between 1st February 2015 and 30th April 2021. An Institutional Review/Ethics Board approval was obtained for the present study. In BHA failure cases, all BHAs were performed by H. U. Pak and H. J. Li using a kind of bipolar head and two kinds of cemented, double-tapered, polished femoral stems. Knee prosthesis used in primary and revision TKA cases was the total-condylar, PCL-sparing, patellar resurfacing knee prosthesis, and all of them were implanted by two surgeons. All components were implanted using a three-generation cementing technique and all the patients were placed on the same pre- and postoperative management. The demographic data of the BHA and TKA failure cases is summarized in Table 1.

	Hip		Knee	P
Number of failure cases	92(100)		48(100)	
after primary arthroplasty	78(84.8)		35(72.9)	0.09
after first revision	14(15.2)		13(27.1)	
Gender				
Male	71(77.2)		9(18.8)	<0.01
Female	21(22.8)		39(81.2)	
Age				
Mean	59.3		57.8	0.08
SD	7.2		8.4	
Range(min-max)	51-67		50-65	
Primary diagnosis	ONFH	28(30.4)	PA	6(12.5)
	OA	6(6.6)	OA	26(54.2)
	Nonunion of FN	58(63.0)	RA	16(33.3)

Table 1: Demographic data of failed BHA and TKA cases

BHA: Bipolar Hip Hemiarthroplasty, TKA: Total Knee Arthroplasty, ONFH: Osteonecrosis of the femoral head, OA: Osteoarthritis, FN: Femoral neck, PA: Posttraumatic ankylosis, RA: Rheumatoid arthritis, SD: Standard deviation. The numbers in brackets show percentages.

Major causes of cemented BHA failure used in this analysis were the following: aseptic loosening (AL), periprosthetic joint infection (PJI), liner wear (LW), periprosthetic fracture (PF), breakage of component (stem or bipolar head), heterotopic ossification (HO) and ankylosis [31, 32]. The percentage of failure causes was evaluated in every parameter among failure cases and also was assessed according to the time point of revision: early failure with <5 years, delayed failure with 5 to 10 years, and late failure with >10 years. Analysis of failure causes in revision cases was identical to primary cases and revision included entire exchange of either bipolar head or liner, partial exchange of components, and one- or two-stage revision [3].

Major causes of cemented TKA in this study were chosen as the following: periprosthetic joint infection (PJI), aseptic loosening (AL), ankylosis/flexion contracture (FC), instability, impaired extensor mechanism (impaired EM), tibial insert wear (TIW), periprosthetic fracture (PF), dislocation and implant breakage [33]. Like failed BHA cases, the percentage of TKA failure causes was assessed by time point of revision: early failure with <2 years, delayed failure with 2 to 5 years, and late failure with >5 years [2,3].

Inclusion criteria for failure analysis

The patients were included when they followed the regular visit protocol after arthroplasty and they were still alive during follow-up.

Exclusion criteria for failure analysis

We excluded patients missed from follow-up due to the death or revision performed by the other hospital's surgeons after primary arthroplasty in Pyonyang University of Medical Sciences Hospital.

We performed a retrospective review of 53 hips and 26 knees with PJI that were managed with two-staged revision in our institution between 1st March 2019 and 25th May 2024, through the screening of medical records.

Inclusion criteriafor PJI: ICM diagnostic criteria (2018)[21]

(1) Two major criteria including presence of sinus tract with the evidence of communication to the joint or visualization of the prosthesis and two positive growths of the same organism using standard culture methods

(2) 7 minor criteria with various scores including (a) elevated CRP (>10 mg/L for chronic infections) or D-Dimer (>860g/L for chronic infection) (score 2), (b) elevated ESR (>30 mm/h for chronic infections) (score 1), (c) elevated synovial WBC count (>3000 cells/mL for chronic infections) or Leukocyte esterase (++ for acute and chronic infections) (score 3) (d) elevated synovial PMN% (>70% for chronic infections) (score 2), (e) single positive culture (score 2), (f) positive histology (score 3) (g) positive intraoperative purulence (score 3).

When one of the 2 major criteria or minor criteria scoring≧6 was fulfilled, PJI was confirmed. In the case with minor criteria scoring of 3 to 5, it was evaluated as possibly infected, whereas with minor criteria scoring of <3, it was confirmed as the absence of infection.

Exclusion criteria for PJI

Excluded patients were the death cases during the follow-up period and HIV (Human Immunodeficiency Virus) cases.

Demographic data of hip and knee PJI cases was summarized in Table 2.

	Hip	Knee	P

Number of infected cases	53(100)		26(100)	
after primary arthroplasty	45(84.9)		15(57.7)	<0.01
after first revision	8(15.1)		11(42.3)	
Gender				
Male	36(67.9)		4(15.4)	<0.01
Female	17(32.1)		22(84.6)	
Age				
Mean	56.3		57.8	0.09
SD	6.2		7.4	
Range(min-max)	50-64		49-66	
Past history of surgery/therapy	22(41.5)		4(15.2)	<0.01
Surgery	15(28.3)		1(3.8)	
Steroid	6(11.3)		2(7.6)	
Immunosuppressant	1(1.9)		1(3.8)	
Comorbidity Diabetes	13(24.5) 6(11.3)		5(19.0) 2(7.6)	0.59
Hypertension	5(9.4)		2(7.6)	
Coronary disease	1(1.9)		-	
Rheumatism	1(1.9)		1(3.8)	
Primary diagnosis	ONFH	23(43.4)	OA	18(69.2)
	OA	3(5.6)	RA	3(11.6)
	AS	1(1.9)	AS	1(3.8)
	RA	1(1.9)	TBA-related contracture	1(3.8)
	Fracture	25(50.9)	PA	3(11.6)

Table 2: Demographic data of infected BHA and TKA cases

BHA: Bipolar Hip Hemiarthroplasty, TKA: Total Knee Arthroplasty, ONFH: Osteonecrosis of the femoral head, OA: Osteoarthritis, AS: Ankylosing spondylitis, PA: Posttraumatic ankylosis, RA: Rheumatoid arthritis, TBA: Tuberculous arthritis, SD: Standard deviation. The numbers in parentheses show percentages.

Evaluation

According to every failure cause, failure time (time interval between arthroplasty date and the onset of first sign) was yielded as Mean±SD with 95% confidence interval using SPSS 27.0 in BHA and TKA groups.

We evaluated the causative bacteria, antibiotic susceptibility, culture-negative rate, and the interval between the arthroplasty and the onset of infection signs in every medical record of hip and knee PJI cases. Medical records with culture test results based on non-standard guidelines were excluded to minimize the deviation of analysis. Through microbiological tests, the bacterial species were identified and categorized into three groups: gram-negative, -positive, and mixed infection. The case number and percentage of each causative microorganism were recorded in the hip and knee PJI cases. According to three categories, the susceptible case numbers and the percentage were recorded with regard to 12 antibiotics including Penicillin, Streptomycin, Ciprofloxacin, Cefotaxime, Ceftriaxone, Tetracycline, Gentamicin, Ampicillin, Rifampicin, Chloramphenicol, Amikacin, and Levofloxacin in hip and knee PJI cases.

Statistical analysis

In analyzing demographic data of failed cases and PJI cases, we used chi-test to determine the statistical difference of composition according to number, gender, and age between hip and knee cases. We also evaluated the differences between three infections (Gram-negative: Gram-positive: Mixed infection) between hip and knee cases by chi-test. Composition differences of bacterial species were assessed by chi-test in each infection group.

Results

Analysis of the failure causes in primary and revision BHA. Compositions of failure causes in primary and revision BHA cases are presented in Figure 1. Immunology reports. The most common causes were aseptic loosening (43/92) and PJI (34/92), followed by dislocation (5/92), liner wear (4/92), periprosthetic fracture (2/92) and heterotopic ossification (2/92) in primary BHA cases, whereas in revision BHA, the PJI (8/14) and dislocation (3/14) were the most frequent causes, followed by aseptic loosening (1/14), periprosthetic fracture (1/14) and liner wear/breakage (1/14, respectively). Breakage of prosthetic components and hip ankylosis are less common in primary cases (1/92, respectively).

In 47(51.1%) early failure cases, the most common causes are PJI (24/47) and AL (15/47), followed by dislocation (3/47), PF (2/47), LW (1/47), HO (1/47), and breakage (1/47, Figure 2). Figure.2. Composition of causes in early (A), delayed (B), and late failure causes (C) in BHA. AL-Aseptic loosening, PJI-Periprosthetic joint infection, LW-Liner wear, PF-periprosthetic fracture, HO-Heterotopic ossification, BHA-Bipolar Hip Hemiarthroplasty. The most frequent causes were AL (19/29) and PJI (6/29), followed by LW (2/29), PF (1/29) and dislocation (1/29) in 29(31.5%) delayed failure cases (Fig. 2). In 16(17.4%) late failure cases, the most common causes were AL (9/16), followed by LW (2/16), PJI (2/16), dislocation (1/16) breakage (1/16) and PF (1/16, Figure 2). The intervals between hip arthroplasty and the onset of every failure sign are presented in Table 3. The cause of the earliest failure was HO, followed by dislocation, PJI, PF, AL, and LW (Table 3).

Failure causes	Time interval (months, M±SD)	95% Confidence interval
Heterotopic ossification	10.7±4.5	6-17
Dislocation	24.5±8.9	14-35

Periprosthetic joint infection	40.3±8.4	31-50
Periprosthetic fracture	66.4±12.4	53-79
Aseptic loosening	92.9±15.2	76-109
Liner wear	109.9±14.9	94-126

Table 3: Time interval between BHA and onset of failure signs

BHA: Bipolar Hip Hemiarthroplasty, SD: Standard deviation

Analysis of the causes in the primary and revision TKA

The failure causes in the primary and revision TKA are summarized in Figure 3. Figure.3. Composition of failure causes in primary (A) and revision TKA (B)

AL-Aseptic loosening, PJI-Periprosthetic joint infection, FC-Flexion contracture, EM-Extensor mechanism, TIW-Tibial insert wear, TKA-Total Knee Arthroplasty PJI (25/48) and AL (8/48) were the most common causes, followed by flexion contracture (FC, 5/48), instability (4/48), impaired extensor mechanism (impaired EM, 3/48), tibial insert wear (TIW, 2/48) and PF (1/48) in primary TKA cases, whereas in revision TKA, the PJI (9/13) and FC (2/13) were the most frequent causes, followed by AL (1/13) and impaired EM (1/13). In 29(60.4%) early failure cases, the most common causes are PJI (17/29) and FC (4/29), followed by instability (3/29), AL (2/29), impaired EM (1/29), dislocation (1/29) and PF (1/29, Figure 4). The most frequent causes were AL (4/11) and PJI (3/11), followed by impaired EM (1/11), instability (1/11), dislocation (1/11) and PF (1/11) in 11(22.9%) delayed failure cases (Figure. 4). In 8(16.7%) late failure cases, the most common causes were PJI (3/8), followed by AL (2/8), TIW (1/8), implant breakage (1/11) and PF (1/11, Fig 4). Fig.4. Composition of causes in early (A), delayed (B), and late failure causes (C) in TKA. AL-Aseptic loosening, PJI-Periprosthetic joint infection, TIW-Tibial insert wear, PF-periprosthetic fracture, TKA-Total Knee Arthroplasty. The intervals between knee arthroplasty and the onset of every failure sign are presented in Table 4. The cause of the earliest failure was FC, followed by impaired EM, PJI, instability, PF, AL, and TIW (Table 4).

Failure causes	Time interval (months, M±SD)	95% Confidence interval
Flexion contracture	3.7±1.5	2-6
Impaired extensor mechanism	15.5±3.9	11-20
Periprosthetic joint infection	17.3±4.4	12-24
Instability	22.3±5.6	15-29
Periprosthetic fracture	38.9±9.4	29-48
Aseptic loosening	52.1±15.6	26-68
Tibial insert wear	91.6±15.9	75-108

Table 4: Time interval between TKA and onset of failure signs

TKA: Total Knee Arthroplasty, SD: Standard deviation

Microbiologicanalysis of periprosthetic joint infection

The mean time intervals between the arthroplasty and the onset of infection were 53.8±31.2 and 23.7±15.3 months, respectively, in hip and knee PJI cases. The culture-negative rates were 26.4% and 19.2%, respectively, in BHA and TKA. The composition of causative microorganisms is summarized in Table 5. The most predominant causative microorganisms were Staphylococcus aureus (64.2%, 61.6%) and E. coli (15.1%, 19.2%) in hip and knee PJI cases. The infection rate of gram-positive bacteria (71.7%) was significantly higher than gram-negative bacteria (28.3%). The mixed infection rate was 9.45 and 11.55% in hip and knee PJI cases, whereas it was the highest in the Staphylococcus aureus+ E. coli group (3.78% and 7.7% in hip and knee cases). Antibiotic susceptibility of the hip and knee PJI cases was presented in Tables 6 and 7. Based on the antibiotic susceptibility, recommended antibiotics were summarized in Table 8.

Microorganism		Hip		Knee		P
		N	Percentage (%)	N	Percentage (%)	
Gram-positive	*Staphylococcus aureus*	29	54.7	13	50.0	0.93
	Enterococcus spp	3	5.6	1	3.8	
	Streptococcus spp	1	1.9	1	3.8	
	Overall	33	62.2	15	57.6	
Gram-negative	*E. coli*	8	15.1	5	19.2	0.73
	Klebsiella pneumonia	6	11.3	3	11.6	
	Pseudomonas aeruginosa	1	1.9	0	0	
	Overall	15	28.3	8	30.8	
Mixed infection	*Staphylococcus+E. coli*	2	3.8	2	7.7	0.33
	Staphylococcus+Klebsiella	1	1.9	1	3.9	
	E. coli +Klebsiella	2	3.8	0	0	
	Overall	5	9.5	3	11.6	
0verall	Comparison between three infection groups (Gram-positive:Gram-negative:Mixed infection)					0.92

Table 5: Causative microorganisms in hip and knee PJI cases

PJI: Periprosthetic Joint Infection, E. coli: Escherichia coli

Species	Antibiotics											
	PE	SM	CIP	CTX	CRO	TC	GM	AMP	RIF	CP	AMK	LVX

Gram-positive	*Staphylococcus aureus*	5/34	3/34	1/34	19/34	20/34	0/34	3/34	8/34	12/34	1/34	10/34	10/34
	Enterococcus spp	0/3	0/3	0/3	2/3	2/3	0/3	3/3	1/3	2/3	0/3	0/3	1/3
	Streptococcus spp	0/1	0/1	0/1	0/1	0/1	0/1	1/1	0/1	1/1	0/1	1/1	1/1
Gram-negative	*E. coli*					4/8	1/8	0/8	0/8				7/8
		1/8	0/8	6/8	4/8					0/8	0/8	3/8	
	Klebsiella pneumonia	0/6	0/6	2/6	1/6	1/6	0/6	1/6	0/6	1/6	0/6	2/6	3/6
	Pseudomonas aeruginosa	0/1	0/1	0/1	0/1	1/1	0/1	0/1	0/1	0/1	0/1	0/1	1/1

Table 6: Percent susceptible in hip PJI cases

PE-Penicillin, SM-Streptomycin, CIP-Ciprofloxacin, CTX-Cefotaxime, CRO-Ceftriaxone, TC-Tetracyclin, GM-Gentamicin, AMP-Ampicillin, RIF-Rifampicin, CP-Chloramphenicol, AMK-Amikacin, LVX-Levofloxacin, E. coli-Escherichia coli, PJI: Periprosthetic Joint Infection

Species		Antibiotics											
		PE	SM	CIP	CTX	CRO	TC	GM	AMP	RIF	CP	AMK	LVX
Gram-negative	Staphylococcus aureus	4/16	2/16	0/16	1/16	5/16	0/16	4/16	4/16	7/16	1/16	0/16	10/16
	Enterococcus spp	1/1	0/1	0/1	1/1	1/1	0/1	1/1	1/1	1/1	0/1	0/1	0/1
	Streptococcus spp	0/1	0/1	0/1	1/1	1/1	0/1	0/1	0/1	0/1	0/1	1/1	0/1
Gram-positive	E. coli	1/5	0/5	2/5	2/5	3/5	0/5	0/5	0/5	0/5	0/5	1/5	4/5
	Klebsiella pneumonia	0/3	0/3	1/3	2/3	2/3	0/3	0/3	0/3	1/3	0/3	1/3	3/3
	Pseudomonas aeruginosa	-	-	-	-	-	-	-	-	-	-	-	-

Table 7: Percent susceptible in knee PJI cases

PE-Penicillin, SM-Streptomycin, CIP-Ciprofloxacin, CTX-Cefotaxime, CRO-Ceftriaxone, TC-Tetracyclin, GM-Gentamicin, AMP-Ampicillin, RIF-Rifampicin, CP-Chloramphenicol, AMK-Amikacin, LVX-Levofloxacin, E. coli-Escherichia coli, PJI: Periprosthetic Joint Infection

Species		Recommended antibiotics
Gram-positive	*Staphylococcus aureus*	Ceftriaxone, Cefotaxime, Rifampicin, Levofloxacin,
	Enterococcus spp	Gentamicin, Cefotaxime, Ceftriaxone
	Streptococcus spp	Gentamicin, Amikacin, Levofloxacin
Gram-negative	*Escherichia coli*	Levofloxacin, Ceftriaxone, Cefotaxime
	Klebsiella pneumonia	Levofloxacin, Ciprofloxacin, Amikacin
	Pseudomonas aeruginosa	Ceftriaxone, Levofloxacin

Table 8: Recommended antibiotics for the treatment of the hip and knee PJI cases

Discussion

Hip and knee arthroplasties are the most successful procedures in orthopedic surgery and have remarkably increased the QOL of patients with advanced osteoarthritis. There has been an increasing number of hip and knee arthroplasties due to improved survivorship and prosthetic designs [1, 2]. However, the annual number of revision arthroplasty tends to increase with primary arthroplasty. Revision arthroplasty indicates the failure of primary arthroplasty and therefore, many authors are attempting to find out the causes of revision in every possible side.

Many arthroplasty registries reported the annual number of revisions with every failure cause [1, 2]. It is important to systematically identify the failure causes of primary arthroplasty and upgrade the implant design as well as surgical technique for prevention of their occurrence. Therefore, we performed the analysis of failure causes in BHA and TKA cases.

The most common cause was aseptic loosening (76%) in primary BHA, and it was observed in 7.1% of failed revision cases, which was similar to the previous studies [2, 31, 34-36]. Malchau et al. reported that 75% of failed cases were due to aseptic loosening in the analysis of 14081 failed hip arthroplasty cases, while Melvin et al. suggested that it was the most common cause of 1168 revision arthroplasty cases with failed primary arthroplasty [2, 32]. The second most common cause was periprosthetic joint infection (36.9%) in primary BHA, and it was the most frequent cause (57.2%) in failed revision cases. Previous studies suggested that PJI was observed in 7% of failed arthroplasty cases [2, 33]. Such a difference in infection rate might be produced by the fact that retractable arthroplasty cases must be dealt with in our institution. Several authors insisted that the pathogen was discovered in failed cases with aseptic loosening [34-36]. It might be another reason why the infection rate was so high, considering the recently improved testing sensitivity of inflammation markers and novel diagnostic criteria of PJI. In addition, the most common causes were followed by dislocation of the inner head due to liner wear, periprosthetic fracture, and heterotopic ossification, incidence rates of which were below or comparable to the other studies [37-41]. Of note, the low incidence rate of HO and stem breakage might be related to the celecoxib-based institutional guideline for HO prevention and the small BMI of patients. According to the time interval between BHA and failure, various failure causes were identified as the most common one in the present study. We found out that early failure cases accounted for 33% of all failure cases in which the most frequent causes were PJI, AL and dislocation. In delayed and late cases AL and PJI and LW were the most common causes.

In TKA, the most common failure causes were PJI, FC, and AL regardless of primary and revision, which were consistent with previous results [8, 15, 42, 43]. PJI accounted for 52.1% of all primary failure cases and 78% of revision failure cases, which occurred 38.9 months after arthroplasty. FC due to arthrofibrosis was observed in 10.4 and 15.4% of primary and revision failures, which occurred 3.7 months after arthroplasty. AL was observed in 16.6 and 7.7% of primary and revision failures, with the onset time of 52.1 months. The incidence rate of TIW and PF in primary failures were 4.2 and 2.1%, respectively, which were similar to the previous studies [44-46]. Failure with <2 years occurred in 60.4% of failed TKA cases and failure with <5 years in 83.3%, which was comparable to previous results [8, 15]. Like BHA, there were some differences between the previous studies and our results, but these differences might be derived from the deviation of study population and the mismatch of Apollo Knee prosthesis among the Korean population. Mechanical malalignment due to a mismatch of knee prosthesis could reduce survivorship.

PJI, one of the common failure causes, remains a serious complication in orthopedic surgery, and a remarkably heterogeneous spectrum of microbiological testing results have been reported across the world. Many

institutions and regions have cumulative antibiograms created by testing antibiotic sensitivities of previously infecting organisms that have already been treated in the institution or region [47]. Culture-negative rates were 26.4 and 19.2%, respectively, in hip and knee PJI cases, which was in the range reported in previous studies [21, 34]. Our patients with culture-negative had a history of antibiotic use and it emphasizes the necessity of a well-established antibiogram based on antibiotic susceptibility database for empiric regimen. The mean onset times of infection were different between hip and knee PJI cases, which were caused by the depth of the surgical wound. Infection rates were 64.2/61.6% and 15.1/19.2%, respectively, for Staphylococcus aureus and E. coli in hip and knee PJI cases. Gram-positive bacilli were detected in 71.7 and 69.2% in hip and knee, whereas 28.3 and 30.8% for gram-negative bacilli. Enterococcus spp and streptococcus spp showed infection rates of 5.6/1.9% and 3.8/3.8%, respectively, in the hip and knee, while Klebsiella pneumonia and pseudomonas aeruginosa were detected in 11.3/1.9% and 11.6/0% of hip and knee PJI cases. Such microbiological features were similar to previous reports except for a considerably higher infection rate of Klebsiella pneumonia [48, 49]. It might be due to the characteristics of our institutional nosocomial infection. Mixed infection rates were 9.45% and 11.55%, respectively, in hip and knee PJI cases in which the predominant bacteria were Staphylococcus aureus and E. coli. There was no difference in antibiotic susceptibility between hip and knee PJI cases. Our susceptibility results suggested that ceftriaxone plus rifampicin could be the most optimal empiric regimen for PJI cases with Staphylococcus aureus. We recommend ceftriaxone plus rifampicin plus gentamicin for PJI cases with Enterococcus spp and Streptococcus spp, based on our antibiotic susceptibility results. Interestingly, our recommendation (amikacin plus levofloxacin) on Klebsiella, E. coli, and Pseudomonas aeruginosa was somewhat different from the other institutional data, which consists of a vancomycin-based regimen [17, 27, 47]. Taking cost-effectiveness into consideration, our recommendation might be reasonable in our study population.

However, this study has certain limitations. First, it is an institutional study with a small sample size. Second, it is a retrospective study of PJI cases without MRSA. Despite such limitations, this study could give not only a better understanding of the failure mode in BHA and TKA but also detailed information about microbiological features and antibiotic susceptibility among Korean PJI cases. It might contribute to the improvement of implant design, survivorship, and empiric antibiotic regimen.

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Conclusion

This study provides information about failure causes of BHA and TKA, causative microorganisms, and antibiotic susceptibility which might be helpful to the improvement of the outcome of arthroplasty and the establishment of an empiric antibiotic regimen.

Declaration of conflict of interest: None.

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