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HIP ARTHROPLASTY

Validity of a preoperative scoring system for surgical management of periprosthetic hip infection: one-stage vs. two-stage revision

Kenichi Oe[1] · Hirokazu Iida[1] · Yosuke Otsuki[1] · Takashi Toyoda[1] · Fumito Kobayashi[1] · Shohei Sogawa[1] · Tomohisa Nakamura[1] · Takanori Saito[1]

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Abstract

Introduction There are no widely accepted algorithms for determining optimal treatment for periprosthetic joint infection (PJI). Our study aimed to confirm the validity of a previously published scoring system in a larger number of patients to support a rational surgical treatment strategy for periprosthetic hip infection.

Materials and methods Between February 2001 and December 2020, we performed 155 consecutive revision total hip arthroplasties (THAs) for PJI, with mean follow-up of 6 years. One-stage revision THA was performed in 56 hips and two-stage revision THA in 99 hips. Prosthesis survival from recurrent infection was determined by Kaplan-Meier analysis, using implant removal as the endpoint. The pre-operative scoring system (full score of 12 points), including 6 essential elements, was retrospectively evaluated.

Results The 10-year survival rates were 98% for one-stage (95% confidence interval [CI], 94–100) and 87% (95% CI, 79–96) for two-stage revision THA. Multivariate Cox regression analysis provided a total preoperative score as an independent risk factor for implant removal (hazard ratio, 0.17; 95% CI, 0.06–0.49; $p < 0.001$). The sensitivity and specificity at the cut-off of 4 points on the scoring system were 80% and 91%, respectively. The average score for one-stage revision THA in successful and failed cases were 8.9 and 6.0, and for two-stage revision THA were 6.5 and 3.9, respectively. We found significant differences between successful cases in one- and two-stage revision THA ($p < 0.05$).

Conclusions The preoperative scoring system was useful for managing PJI. One-stage revision THA is recommended in patients scoring ≥ 9 points, and meticulously performed two-stage revision THA is encouraged for patients scoring ≥ 4 points.

Keywords Infection · One-stage revision · Scoring system · Total hip arthroplasty · Two-stage revision

Introduction

The number of revision surgeries for primary total hip arthroplasty (THA) is increasing worldwide, with prosthetic joint infection (PJI) being the second most common reason for revision in the United Stated and the third in the United Kingdom [1–5]. PJI severely impacts morbidity and mortality rates, as well as patient quality of life [6], so optimizing treatment is clearly a high priority. However, the optimal treatment for PJI remains controversial, in part because the bacteria subsist within biofilms on the implant surfaces. The probability of implant retention is thus limited [7], with most patients requiring implant removal following infection.

Two-stage revision THA is considered the gold standard for treating PJI, but some European hospitals favour one-stage revision THA, including replacement of the prosthesis during the procedure, in selected patients. This may be because certain European surgeons sometimes use cemented THA with antibiotic-loaded acrylic cement (ALAC) [8], while "cementless" techniques are widely used in North America. Although two-stage revision THA is safe and secure, disadvantages include a second operation, higher costs, longer treatment periods, and greater economic burden [9, 10]. One-stage revision THA involves shorter treatment periods, earlier postoperative mobilization, and less expense, but provides inferior infection control in some cases and is thus not suitable for all patients. In 2013, the

✉ Kenichi Oe
oeken@hirakata.kmu.ac.jp

1 Department of Orthopaedic Surgery, Kansai Medical University, 2-5-1 Shinmachi, Hirakata, Osaka 573-1010, Japan

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Infectious Diseases Society of America (IDSA) issued guidelines for PJI treatment that noted the feasibility of one-stage revision THA under the following conditions: PJI had developed within the previous 3 weeks or within 30 days of the initial THA surgery, the patient had good soft tissue and good bone stock, the organism had been identified preoperatively and was susceptible to oral agents with high oral bioavailability, ALAC had been used in the initial surgery, and no bone grafting was required [11]. Other algorithms and staging systems are also used to select procedures for PJI, but they are not supported by hard evidence, and they do not provide criteria for choosing the optimal treatment strategy for one-stage or two-stage revision surgery.

In 2015, Oe et al. [12] reported on a scoring system that included 6 essential elements and laid out a definitive surgical strategy for PJI. This scoring system produced 10-year joint survival rates of 94% for one-stage and 87% for two-stage revision THA, respectively. The present study assessed the usefulness of the system in over 150 consecutive revised THAs for PJI. Our aim was to confirm retrospectively, in a larger number of patients, the validity of this scoring system in rationalizing strategies for the surgical treatment of periprosthetic hip infection. We hypothesized that the scoring system could be mapped to actual patient outcomes, contributing to more effective management of PJI and possibly supporting broader indications for one-stage revision THA.

Materials and methods

Study design and patients

Between February 2001 and December 2020, surgeons at our hospital performed 155 consecutive revision THAs (147 patients) for periprosthetic hip infection. One-stage revision THA was carried out in 56 hips, and two-stage revision THA in 99 hips. Two-stage revision included 7 instances of multiple-stage revision requiring ≥ 2 debridements. We used the criteria established by Giulieri et al. to evaluate periprosthetic hip infection and healing [13]. A case was classified as "successful" if we found no infection at the follow-up visit $>$ 24 months after first revision, and as "failure" if the implant was removed because of recurrent infection. All cases of THA failure were included regardless of time of occurrence. From 2014, we added the use of sonication, using the sonicate fluid culture method to strip the biofilm from the removed implant, to diagnose the infection [7]. In the current study, we analysed a total of 149 hips in 100 women and 41 men having a mean age of 68 (34–90) at the time of surgery. One patient developed infection in both hips, 7 patients experienced relapse followed by re-replacement of the prosthesis, and 6 patients were lost to follow-up (follow-up rate, 96%) (Fig. 1). The patients who were lost to follow-up could not be contacted via postcards and telephone. The infected implant was associated with THA in 61 hips and hemiarthroplasty in 88 hips. The mean duration of postoperative monitoring was 5.5 years (0.3–20 years). Our institutional review board approved this prospective cohort study, and each patient gave informed consent for patient data to be included in the published findings.

Management of PJI

In accordance with criteria reported in a range of published articles, one-stage revision THA was performed in cases where general patient condition was good, there were no wound complications, the pathogenic infection was low-grade and highly sensitive to antibiotics, and the bone defect for reconstruction was small. We generally performed two-stage revision THA if cases did not meet the criteria for one-stage revision, although the final decision was made intraoperatively by the surgeon [14]. We determined individual bacterial sensitivities from the pre-operative aspirate for each patient and prepared a custom-mixed ALAC for cemented THA in all patients. The use of ALAC was included in accordance with the protocol by Jiranek et al. [15].

The details of surgical procedures have been previously reported [12]. We initiated appropriate intravenous systemic antibiotic therapy, which was continued postoperatively for 2 weeks. Subsequent oral antibiotic therapy was tailored to the clinical signs, and CRP and was administered for a minimum of 3 months. For two-stage revision THA, after completing thorough debridement, we temporarily placed a handmade rod and beads including a sufficiently high dose of ALAC. We initiated appropriate intravenous systemic antibiotic therapy for 2 weeks after the surgery. At 6 to 8 weeks, after the initial debridement, we performed a second thorough debridement followed by THA using ALAC. Postoperative therapy was identical to that for one-stage revision THA. If surgery failed to control the infection, debridement was repeated (i.e., multiple-stage revision THA).

Follow-up protocol

For two-stage revision THA, during the waiting period for implantation following the first surgical procedure, wheelchair use was permitted on the second postoperative day, but full weight-bearing was not advised. After implantation in either procedure, full weight-bearing was advised on the 2nd postoperative day. All patients had weekly follow-up for 2 months, then follow-up at 3, 6, and 9 months, and biannually thereafter. A retrospective analysis was performed by 2 blinded orthopedic surgeons. For clinical assessment, the

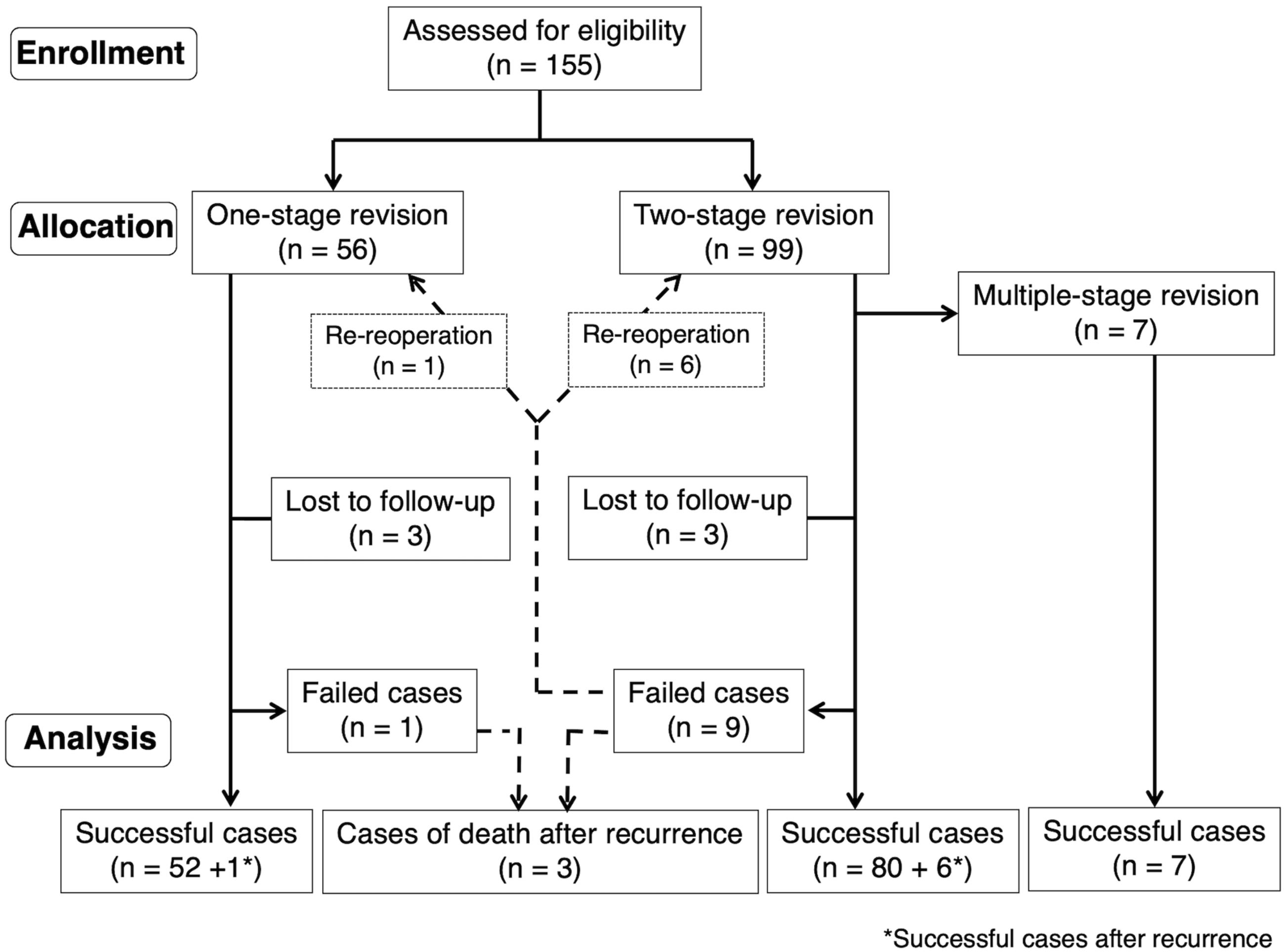

Fig. 1 Flowchart of participants

Merle d'Aubigné and Postel grading system was used pre-operatively and at the last follow-up [16].

The pre-operative scoring system was retrospectively evaluated as explained by Oe et al. [12], including the parameters of general condition, duration of infection and number of previous operations, wound complications after the initial surgery, the presence of microorganisms, CRP levels, and the necessity for bone grafting (Fig. 2). Each parameter was scored from 0 to 2 points, with a full score being 12 points.

Statistical analysis

Prosthesis survival was determined from Kaplan-Meier analysis with 95% confidence intervals (CI), using the removal of implants due to recurrent infection as the end-point. We created univariate Cox's proportional hazards models to assess the relationship between risk factors and implant removal, applied multivariate Cox analysis to all independently related variables, and used receiver operating characteristic (ROC) curves to assess the validity of the scoring system. We used multivariate analysis to identify the parameters that defined the threshold for implant removal and then applied ROC analysis to those parameters, which allowed us to calculate sensitivity and specificity more effectively. We defined prognostic sensitivity as the total number of cases divided by the number of implant removals, and we constructed the ROC curve with sensitivity on the vertical axis and 100 minus specificity on the horizontal axis for a given cut-off point. ROC analysis can be used to define the threshold of the best sensitivity and specificity for a scoring system, which also allows the most valuable cut-off point for each score to be estimated. We constructed a two-way table of scores and outcomes to predict the percentage risk of recurrence for each score. All data were analysed using one-way analysis of variance with SAS version 9.2 (SAS Institute, Cary, NC). p value < 0.05 was considered significant.

Criterion	Points (Total = 12)
1. General condition	
Poor (difficulty in walking, etc.)	0
Moderate (diabetes mellitus, steroid, autoimmune disease, etc.)	1
Good	2
2. Duration of infection, number of past operations	
Past operations ≥ 2 (including osteotomy, debridement, etc.)	0
Late infection	1
Early or delayed infection	2
3. Wound complication after initial operation	
Sinus tract, abscess	0
Slightly damaged	1
Intact	2
4. Presence of microorganism	
Organism resistant to the antibiotics, Gram-negative, MRSA or MRSE	0
Unknown	1
Organism sensitive to the antibiotics	2
5. C-reactive protein (mg/L)	
> 50	0
50-5	1
< 5	2
6. Necessity for bone grafting	
Necessary	0
Unnecessary	2

Fig. 2 Preoperative scoring system, Oe et al. [12]. MRSA methicillin-resistant *Staphylococcus aureus*; MRSE methicillin-resistant *Staphylococcus epidermidis*

Table 1 Patient demographics

Type of surgery	One-stage revision THA	Two-stage revision THA
Mean age at surgery (y) (range)	71 (49–91)	67 (32–86)
Male:Female	17:36	26:70
THA:Hemiarthroplasty	21:32	40:56
Mean time from primary procedure to first-stage revision (y) (range)	4 (0.1–12)	4 (0.1–14)
Mean time from first-stage to second-stage revision (wk) (range)	(-)	8 (5–13)
Mean time from revised THA to final follow-up (y) (range)	6 (0.5–20)	5 (0.3–16)

THA total hip arthroplasty

Results

Demographic data are shown in Table 1. The mean Merle d'Aubigné clinical score improved from 7.5 points (4 – 17 points) preoperatively, to 13.9 points (8 – 18 points) at the last follow-up ($p < 0.0001$). Microorganisms isolated pre- and intraoperatively are shown in Table 2.

Success was achieved in 52 of the 53 hips in one-stage, in 80 of the 89 hips in two-stage, and in 7 of the 7 hips in multiple-stage revision THA (Fig. 3). The 10-year implant survival rate was 98% (95% CI, 94–100) for one-stage revision THA and 87% (95% CI, 79–96) for two-stage revision THA. In the 10 failed hip replacements, consisting of 1 one-stage revision and 9 two-stage revision THAs, the mean duration from revised THA to removal of implants due to recurrent infection was 1.9 years (0.3–6.2 years). Of those 10, re-revision THA was successful in 7 hips, and in 3 hips the patient died after implant removal. These numbers do not include the 6 patients who were lost to follow-up. For all

Table 2 Isolated microorganisms: preoperative and intraoperative

Isolates	One-stage revision THA	Two-stage revision THA
CNS	10	20 + (3)
MRSA	5 + (1)	16 + (2)
MSSA	1	9
MRSE	4	6
MRCNS	1	4
MSSE	3	3
Pseudomonas aeruginosa	1	1 + (2)
Streptococcus sp.	4	2
Staphylococcus sp.	2	2
Peptostreptococcus sp.	1	2
Propionibacterium acnes	3	0
Group B *Streptococcus*	0	3
Corynebacterium sp.	2	0
MSSA	1	0
Micrococcus sp.	1	0
Serratia	0	1
Enterococcus	0	1
Bacteroides sp.	0	1
Proteus vulgaris	0	(1)
Escherichia coli	0	1
Mycobacterium tuberculosis	0	1
Fungus	0	1
Unknown	18	18 + (1)

Figure in parentheses indicates the number of failed cases after implantation

THA Total hip arthroplasty; CNS Coagulase-negative *Staphylococcus*; MRSA Methicillin-resistant *Staphylococcus aureus*; MSSA Methicillin-sensitive *Staphylococcus aureus*: MRSE Methicillin-resistant *Staphylococcus epidermidis*; MRCNS Methicillin-resistant coagulase-negative *Staphylococcus*; MSSE Methicillin-sensitive *Staphylococcus epidermidis*; MSSA Methicillin-sensitive *Staphylococcus aureus*

patients, the final infection control rate was 98% (138/141 patients).

Figure 4 shows the average preoperative score for each parameter in successful cases. There were significant differences in all parameters between patients treated by one- or two-stage revision THA ($p<0.05$). Table 3 presents the univariate risk factors for implant removal due to recurrent infection. In multivariate Cox regression analysis, the total preoperative score was an independent risk factor for implant removal due to recurrent infection (hazard ratio (HR), 0.17; 95% CI, 0.06–0.49; $p<0.001$). To confirm the validity of the scoring system, sensitivity and specificity were plotted on a ROC curve (area under the curve, 0.91; 95% CI, 0.82–1.00). Table 4 presents pooled estimates of the sensitivity and specificity, accuracy, positive predictive value, and positive likelihood ratio for the utility of preoperative score. The sensitivity and specificity at the cut-off of 4 points on the scoring system were 80% and 91%, respectively.

Figure 5 shows the charts of total preoperative scoring. The preoperative score was 5–12 points for successful cases in one-stage revision THA, and 2–9 points for two-stage revision THA. For one-stage revision THA, the average total preoperative scores in successful cases and failed case were 8.9 and 6.0, respectively. For two-stage revision THA, the average total preoperative scores in successful cases, multiple-revised cases, and failed cases, were 6.5, 5.4 and 3.9, respectively. There were significant differences between the successful cases of one- and two-stage revision THA ($p<0.05$), and in two-stage revision THA there were significant differences between the successful cases and failed cases ($p<0.05$).

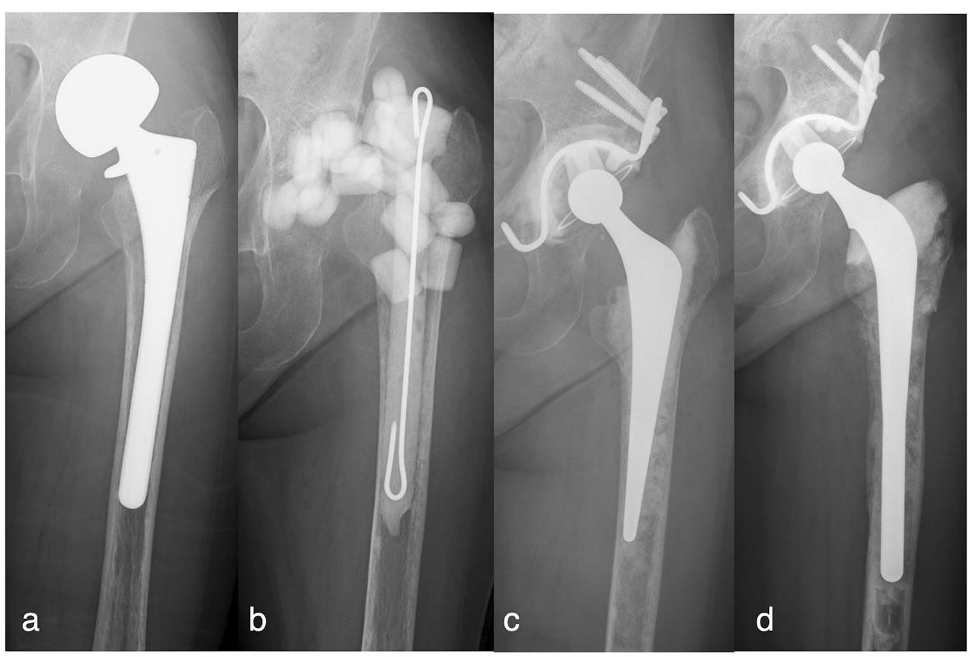

Fig. 3 Radiographs of a 60-year-old female who had undergone two-stage revision total hip arthroplasty (THA) (3-point scoring system), **a** migration of hemi-arthroplasty. **b** antibiotic-loaded acrylic cement beads 7 weeks after the first-stage surgery. **c** re-implantation with allograft reconstruction using a Kerboull-type reinforcement device, with recurrent infection two years later (3-point scoring system). **d** ten years after re-re-implantation using two-stage revision THA, no recurrence

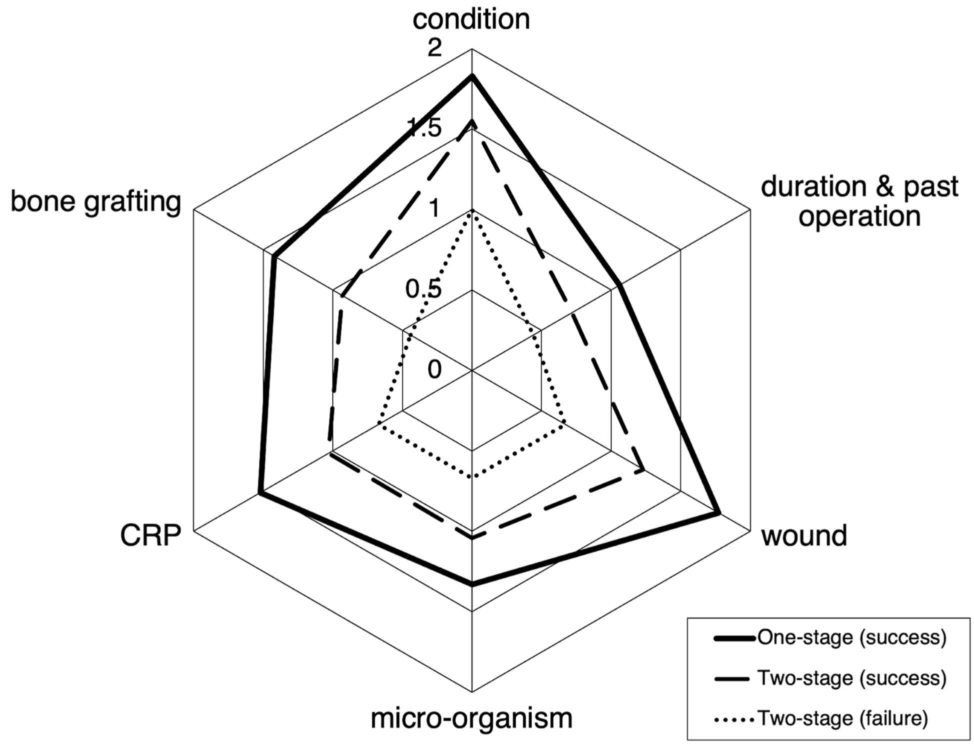

Fig. 4 Average score for each parameter. *CRP* C-reactive protein

Table 3 Univariate analysis of risk factors for implant removal due to recurrent infection (Cox regression analyses)

Variable	Hazard ratio (95% CI)	p value
General condition	0.17 (0.03–0.51)	0.002
Duration of infection and number of past operations	0.45 (0.16–1.24)	0.121
Wound complications after the initial operation	0.39 (0.18–0.83)	0.014
Presence of microorganisms	0.42 (0.19–0.95)	0.037
C-reactive protein levels	0.28 (0.11–0.72)	0.009
Necessity for bone grafting	0.62 (0.32–1.22)	0.168
Total preoperative score	0.43 (0.29–0.64)	< 0.001

CI confidence intervals

Discussion

Although two-stage revision THA is regarded as the gold standard treatment for PJI worldwide, the one-stage revision THA offers notable advantages, including shorter hospitalization, shorter duration of antibiotic treatment, lower mortality, lower rate of complications, and lower overall healthcare costs [17–21]. According to some meta-analyses [22–25], two-stage revision THA with ALAC was associated with an infection control rate of 88–93%, compared with 82–86% for one-stage revision with ALAC. In the absence of ALAC, THA infection control was achieved in 82–91% of cases for two-stage revision and in 56–59% for one-stage revision, emphasizing the extreme importance of ALAC in this one-stage procedure. The promising results from one-stage revision THA with ALAC appear to be

Table 4 Pooled estimates of the sensitivity specificity, accuracy, positive predictive value, and positive likelihood ratio for the utility of preoperative score

Cut-off score	Failed /Successful cases	Sensitivity	Specificity	Accuracy	Positive predictive value	Positive likelihood ratio
2.0	0/1	0.0	99.3	92.6	0.0	0.0
3.0	4/1	40.0	98.6	94.6	66.7	27.8
4.0	4/10	80.0	91.4	90.6	40.0	9.3
5.0	0/11	80.0	83.5	83.2	25.8	4.8
6.0	1/26	90.0	64.7	66.4	15.5	2.6
7.0	1/22	100.0	48.9	52.3	12.3	2.0
8.0	0/25	100.0	30.9	35.6	9.4	1.5
9.0	0/27	100.0	11.5	17.4	7.5	1.1
10.0	0/9	100.0	5.0	11.4	7.0	1.1
11.0	0/5	100.0	1.4	8.1	6.8	1.0
12.0	0/2	100.0	0.0	6.7	6.7	1.0

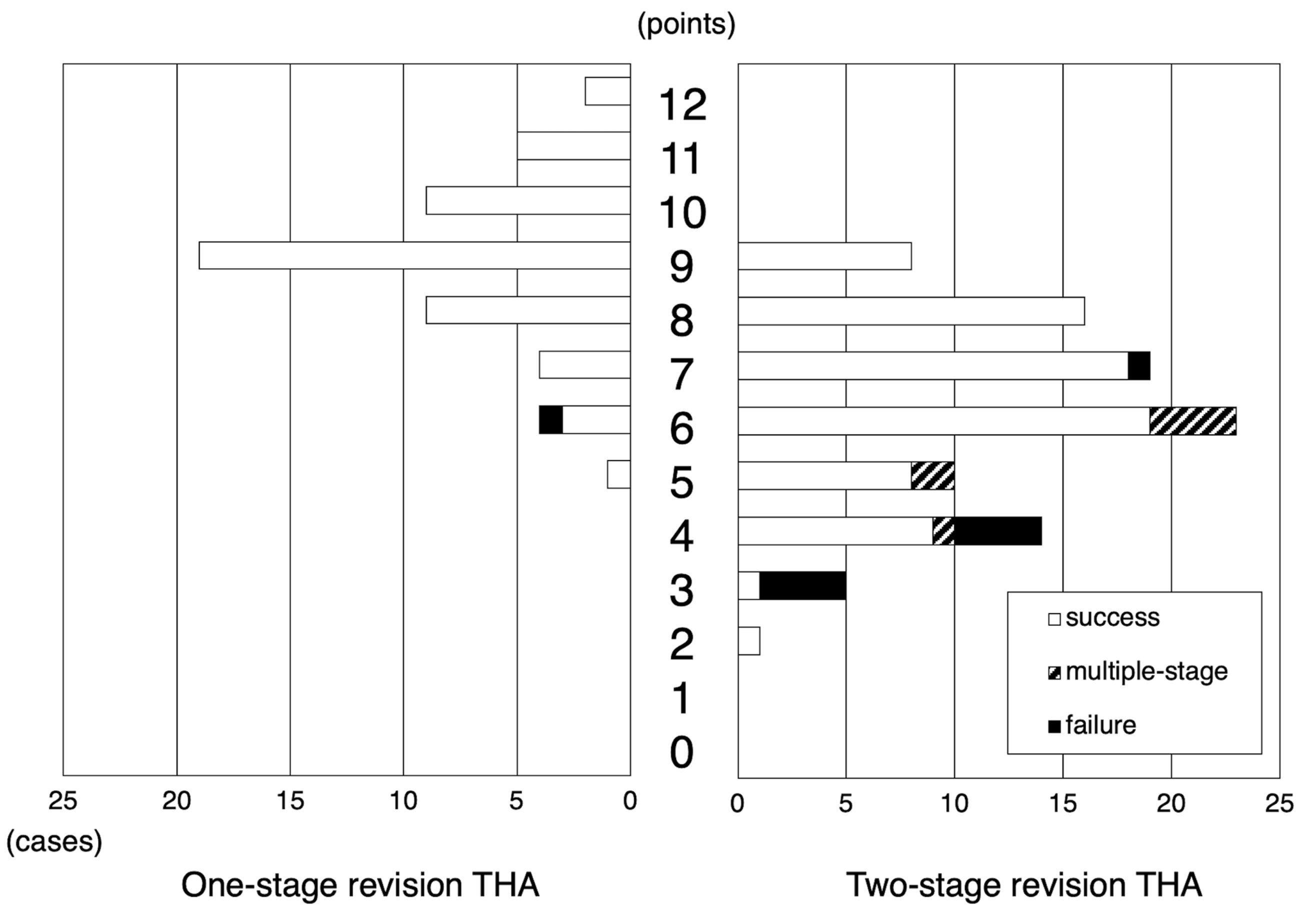

Fig. 5 Charts of total preoperative scoring. *THA* total hip arthroplasty

based in this formulation's dual advantage in the treatment and prevention of infection. Buchholz et al. [8], who first introduced the use of ALAC [26], performed one-stage revision THA without systemic antibiotics in 583 early-stage patients and reported an infection control rate of 77%. Later, the ENDO Klinik group reported a minimum 10-year infection-free survival of 94% following one-stage revision THA [27]. In addition, the Swedish hip register showed that the risk for re-revision due to infection was equivalent between one- and two-staged revision THAs (HR, 0.7; 95% CI, 0.4–1.1; $p=0.2$) [28]. These findings suggest that one-stage revision THA may be suitable for a wider range of patients than was expected.

There are some limitations to this study. First, we retrospectively evaluated the patients without a control group and limited our follow-up period to a minimum of two years. The 6 patients who were lost to follow-up could have sought treatment elsewhere, and there was a discrepancy in follow-up rates between two groups that might have impacted the accuracy of our data. In addition, the 7 multiple-stage revision THAs might actually be considered as failures, since two-stage revision THA was not successful, and they required a third surgery. Second, old diagnostic criteria were used for PJI. We currently use the diagnostic criteria from the Musculoskeletal Infection Society [29], but for consistency over the entirety of this research we used the old criteria. Third, novel antibiotic therapies are currently available, especially for methicillin resistant *Staphylococcus aureus* (MRSA) [30, 31]. The use of antibiotics has changed considerably in the last 20 years. Furthermore, MRSA and MRSE are becoming less problematic in PJI as long as they remain sensitive to rifampicin [32, 33]. Gram-negative pathogens are also non-problematic insofar as they are sensitive to ciprofloxacin [34, 35]. Streptococci, fungi, and other pathogens resistant to rifampicin or ciprofloxacin are associated with a much higher risk of failure than MRSA or MRSE, which are sensitive to rifampicin [36, 37]. In the present study, not all infections were tested for sensitivity to rifampicin, so we could not address that topic here, but we plan to revisit the microorganism criterion in the scoring system in the near future. Fourth, we had relatively few failed cases, so we were unable to use the pre-operative scoring system to fully determine whether one-stage or two-stage revision THA should be selected. Outcomes for the treatment of PJI tend also to be affected by the surgical know-how at each institution.

A number of reports, including the guidelines from the IDSA, also offer conditions under which single-stage revision THA can be performed, but those reports provide no consensus of opinion, and because the surgical procedures vary from one report to the next, systemic review and meta-analysis are of limited usefulness. However, individual parameters are available for choosing between the one-stage and two-stage revision procedures, including sinus tract involvement, duration of infection, presence of MRSA, and need for bone grafting. In the current study, Cox regression analysis demonstrated that the total preoperative score was an independent risk factor for implant removal. Consequently, there are situations in which one-stage revision THA is successful even in the presence of MRSA, involvement of the sinus tract, the need for bone grafting, or considerations of duration of infection. Although one-stage revision THA was recommended in patients scoring ≥ 9 points, one-stage revision THA may be feasible even with lower scores.

In conclusion, the 10-year prosthesis survival rates were 98% and 87% for one- and two-stage revision THA, and the preoperative scoring system was useful for the management of PJI. One-stage revision THA is recommended in patients who score above 9 points because the average score was 8.9 in successful cases. At the cut-off of 4 points, the scoring system showed sensitivity of 80% and specificity of 91%, so if the score is four points or above, we consider two-stage revision surgery.

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Author contributions KO designed the study. YO, TT, FK, and SS collected and performed the analysis of the data. KO wrote the manuscript. HI, TN, and TS supervised the study. All authors gave their final approval of the version to be published.

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Data availability Data available within the article.

Declarations

Ethics approval This study was approved by the Ethical Committee of the Kansai Medical University (H120167).

Consent to participate All authors have participated in the research.

Consent to publish All authors of this paper have read and approved the final version submitted.

Informed consent Informed consent was obtained from all individual participants included in the study.

Conflict of interest The authors declare that they have no conflict of interest.

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