Research Square

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Does The Novel PJI-TNM Classification Have Predictive Value for The Failure of One-Stage Revision Hip Arthroplasty?

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Abstract

Background

One-stage revision has emerged as an effective treatment option for periprosthetic joint infection (PJI) of the hip. However, reliable tools to predict failure remain limited. The PJI-TNM classification is a novel, standardized system incorporating implant status (T), pathogen characteristics (N), and host comorbidities (M). This study evaluated whether preoperative PJI-TNM classification predicts failure following one-stage revision hip arthroplasty.

Methods

A retrospective matched cohort study was performed of patients undergoing one-stage revision for hip PJI between 2009 and 2017. Thirty patients who required subsequent re-revision surgery (failure group) were matched 1:1 by age and sex to 30 patients with successful outcomes and minimum 6-year follow-up. All patients met International Consensus Meeting criteria for PJI. Preoperative PJI-TNM scores were assigned. Group comparisons were performed using t-tests, chi-square tests, and Mann-Whitney U tests as appropriate.

Results

T and N components did not differ significantly between groups (T: χ^2=0.31, $p = 0.989$; N: χ^2=2.97, $p = 0.396$). The M component differed significantly, with higher comorbidity burden in the failure group (χ^2=9.59, $p = 0.008$). Polymicrobial and gram-negative infections were more common among failures (χ^2=6.28, $p = 0.043$). Time from index arthroplasty to revision was significantly shorter in the failure group ($p = 0.0047$).

Conclusion

Host comorbidity (M component) is the strongest predictor of failure following one-stage revision. While T and N components remain clinically relevant, patient systemic health appears paramount. PJI-TNM provides a structured framework for preoperative risk stratification and may guide patient selection and perioperative optimization.

Level of Evidence:

III (retrospective cohort)

Introduction

Total hip arthroplasty remains one of the most successful operations in modern medicine, with the number of the arthroplasties projected to rise substantially in the coming years. [1,2] Despite technical advances, complication rates are expected to rise proportionally. Among these, periprosthetic joint infection (PJI) represents the most devastating complication, associated with high morbidity, mortality and healthcare burden.[3] The reported incidence of PJI remains approximately 1–2%. [4–6]

While multiple surgical strategies exist, one-stage revision has gained increasing acceptance due to comparable reinfection rates, reduced hospitalization, and improved patient satisfaction.[7–11] Reliable methods to predict the success of revision surgery remain lacking. The novel PJI-TNM Classification, modeled after the oncologic TNM staging, incorporates implant condition (T), pathogen and the extent of biofilm formation (N), and host comorbidity burden (M).[12 13] The purpose of this study was to evaluate the predictability of PJI-TNM Classification on failure following one-stage revision hip revision for PJI.

Materials and Methods

Study Design

Study design and protocol were reviewed by regional Ethic Committee (2024-300534-WF). All the participants in the study consented in accordance with the most recent version of Helsinki Declaration. We conducted a retrospective study, involving patients who had undergone one stage hip revision following periprosthetic hip infections. A search was conducted in the electronic database to identify patients who underwent one-stage revision surgery between 2009–2017. All included patients were diagnosed according to the latest ICM criteria.[14] Prerequisites for being eligible for one-stage revision were not showing concurrent sepsis symptoms, already identified causative agent, adequate soft tissues quality and absence of any neurovascular complications.

Patient Population, Baseline Characteristics and Data Collection

From retrospectively scanned one-stage revision hip arthroplasty cases, 88 patients were identified required a subsequent re-revision surgery. Among them patients who fulfilled the all the inclusion criteria were included in the study. Inclusion criteria were having undergone a primary hip arthroplasty and requiring additional re-revision surgery following the one stage revision. Exclusion criteria were absence of complete

documentation about the primary operation and the treatment between the primary surgery and one-stage revision, inadequate or missing data that unable evaluation using PJI-TNM Classification. After excluding cases with missing or incomplete data or those lost to follow-up a total of 30 patients were included in the study group. The control group was matched 1:1 by sex and age with no additional patient data considered to avoid selection bias. The inclusion criteria for the control group differed from the study group in that these patients did not require any further revision procedures during a follow-up period of at least 6 years. Like the study group, they also required to have all the data to allow evaluation using PJI-TNM Classification system.

After establishing the control and study group, each case was analyzed individually. For each patient, we reviewed not only the one stage revision but also all available information related to the primary hip implantation surgery. All the relevant information for the study such as, implant type, soft tissue condition, radiology report, BMI, time between primary and revision surgery, microbiological results and comorbidities have been entered into an encrypted databased after anonymization.

Data Analysis

Statistical analyses were performed using SPSS Statistics v. 28 (IBM Corp., Armonk, New York). Continuous variables such as age and body mass index (BMI) were first assessed for normal distribution. Since the data met the assumption of normality, independent t-tests were used to compare age and BMI between the study and control groups, separately for male and female patients. For categorical variables such as T, N and M components as well as pathogen type, the chi-square test was used to assess differences between the study group and control groups. As total time after implantation of the last prosthesis until one-stage revision did not meet normality, a Mann-Whitney U test was used for the analysis. All tests were two-tailed and a p-value of < 0.05 was set for statistical significance.

Results

In our study, a total of 60 patients who underwent one-stage hip revision surgery following a periprostatic joint infection were included in the final analysis. Patients were separated into two groups, each consisting of 30 individuals, for study and control group. The study group comprised cases that required a second surgical intervention following the first one-stage revision surgery, while the control group did not require any further revision surgery after one-stage revision. Both groups included 16 females and 14 males. The mean age of the study group was 69.4 ± 7.50 for males and 69.0 ± 8.20 years for females, while the control group had a mean age of 69.3 ± 7.53 years for males and 69.6 ± 8.29 years for females. Thus, age and sex were matched between the groups without statistically

significant differences. (t-test p(m):0.98 /p(f):0.84) The mean BMI of the study group was 31.68 ± 7.42 for females and 29.19 ± 2.91 for males, while in the control group it was 29.0 ± 6.55 for females and 27.56 ± 4.77 for males. (Table 1) Although a slightly higher BMI was observed in the study group, the difference was not statistically significant (t-test p(m):0.28 /p(f):0.28), indicating that BMI was not a confounding factor in our analysis.

Table 1
Comparison of age and body mass index between the control and study groups stratified by gender

Variable	Gender	Control group	Study group	P value
Age (years)	Female (n = 16)	69.56 ± 8.29	69.00 ± 8.20	0.848
	Male (n = 14)	69.29 ± 7.53	69.36 ± 7.50	0.980
BMI (kg/m²)	Female (n = 16)	29.00 ± 6.55	31.68 ± 7.42	0.287
	Male (n = 14)	27.56 ± 4.77	29.19 ± 2.91	0.287

The T component indicating implant stability was sub-analyzed using categories T0a, T0b, T1a, T1b, T2b. The majority of cases were classified as T0a (Study group:10 / Control group:11) and T0b (Study group:14/ Control group:12). There was no statistically significant difference in the distribution of T values between the study and control groups, indicating that implant stability prior to one stage revision was not associated with the need for further revision surgery. ($Chi^2 = 0.31$, $p = 0.989$). The N component, describing infection profile in terms of pathogen type and biofilm maturity, showed N1a, N2b and N2c as the most common subgroups in the analysis. No significant difference was observed in the distribution suggesting that N subclassification alone is not a differentiating factor in the surgical outcome of one stage procedures. ($Chi^2 = 2.97$, $p = 0.396$). The final component M, which evaluates patient morbidity, showed a significant difference between the two groups. Patients in the study group had higher rates of moderate and severe comorbidities compared to the control group. (Table 2) This suggests that the preoperative health status of the patient is a strong predictive factor for the failure of one-stage revision surgery. ($Chi^2 = 9.59$, $p = 0.008$). In the analysis of cultured organisms, Gram-positive bacteria were the most frequently identified pathogen in both groups. However, polymicrobial and gram-negative infections appeared more frequently in the study group. ($Chi^2 = 6.28$ $p = 0.043$) The total time since the implantation of the last prothesis was significantly shorter in the study group compared to control group. This suggest that earlier complication may be associated with worse surgical outcome of one-stage revision. (Control group: mean = 134.7 ± 78.6 / Study group mean = 99.9 ± 118.6 / Mann–Whitney U test: U = 261.0, p = 0.0047)

Table 2
Comparision of T,N and M stages between the control and study groups

Stage	Category	Control group (n = 30)	Study group (n = 30)	Chi-Square, (df), *p* value
T stage	T0a	11 (36.7%)	10 (33.3%)	0.313, (df = 1), 0.989
	T0b	12 (40.0%)	14 (46.7%)	
	T1a	1 (3.3%)	1 (3.3%)	
	T1b	5 (16.7%)	4 (13.3%)	
	T2b	1 (3.3%)	1 (3.3%)	
N stage	N0b	0 (0.0%)	1 (3.3%)	2.974 (df = 3), 0.396
	N1a	28 (93.3%)	24 (80.0%)	
	N2b	2 (6.7%)	4 (13.3%)	
	N2c	0 (0.0%)	1 (3.3%)	
M stage	M0	22 (73.3%)	9 (30.0%)	9.591 (df = 2), 0.008
	M1	7 (23.3%)	9 (30.0%)	
	M2	1 (3.3%)	12 (40.0%)	

Discussion

The success of one-stage revision for hip PJI is central to its long-term viability as a treatment strategy. Since Bucholz first described this approach in 1979, there was initial skepticism among surgeons.[15 16] However, as surgical experience expanded and evidence supporting its effectiveness accumulated, it gained widespread acceptance. Recent studies indicate that about 33.5% of all hip PJIs are treated with one-stage revision in Germany and its use continues to rise. [17] Recent meta-analyses have demonstrated no significant difference in reinfection rates between one- and two-stage revision strategies. [18,19] The wider adoption of one-stage revision, along with continuous outcome-based reevaluation will help improve peri- and postoperative success.

Comprehensive preoperative assessment remains essential. Implant stability, soft tissue quality, pathogen profile, and host comorbidity status should all be carefully considered when selecting patients for one-stage revision. [20–22] Our findings underscore the importance of incorporating these variables into surgical decision-making, and further studies are warranted to validate and refine risk stratification tools in this setting.

In routine clinical decision-making, outcomes often depend on surgical experience and risk assessment, which are subjective and difficult to standardize across centers or even between departments within the same clinic. Therefore, the use of a validated system like PJI-TNM Classification enhances objectivity and precision in case evaluation. In our study, T and N components did not show significant differences among the study and control groups in predicting failure. This is likely because the indication for one-stage revision already requires good soft-tissue quality, so cases with poor or complicated soft tissue status were not expected in either group. In contrast, the M component, reflecting host comorbidity burden was the strongest predictor of failure. This finding emphasizes that preoperative evaluation should extend beyond the infection management to include the patient's overall health, multidisciplinary consultations prior to operation based on the comorbidities may improve outcomes. The use of PJI-TNM Classification system offers not only potential in outcome prediction but also practical value in routine clinical use for standardization and education, especially for surgeons who may be less familiar with complex PJI scenarios. A structured treatment methodology based on a scoring system may help to better understand prognosis counseling and shared decision making.

Although the PJI-TNM classification assigns equal weight to the T, N and M components, our findings suggest they might not contributive equally to outcome and thus for prediction. Therefore, weighted scoring or weighted evaluation of TNM score might enhance predictive accuracy in future studies. While this represents a novel concept, wider adaptation and multicenter validation will be necessary to confirm its clinical utility and generalizability.

Conclusion

One-stage revision is a promising, cost-effective option for treating PJI.[23] In addition to shorter hospitalization duration, patient based satisfaction is significantly high.[24] The main challenge lies in determining whether a patient is likely to benefit from the surgery or in other words how the success of revision surgery can be predicted. Accurate prediction can guide clinicians recognize the need for more focused postoperative care. The PJI-TNM Classification system enables the structured and objective evaluation of implant and tissue condition, pathogen characteristics, biofilm formation and patient comorbidities. This system facilitates communication across disciplines and standardized documentation for registries or clinical databases. Furthermore, it serves as a great guide for non-experienced and non-specialists involved in managing periprosthetic joint infection. Patient comorbidity should be prioritized in the decision-making for one-stage revision. Optimizing systemic health with the help of consultations from other disciplines might reduce the likelihood of revision failure.

Declarations

Competing Interests

Conflicts of interest T.G. is paid consultant for Waldemar Link and Zimmer Biomet. M.C. isa paid consultant for Waldemar Link.Funding: No funding was received to assist with the preparation of this manuscript.

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Author Contribution

AE.N.: Conceptualization, methodology, data analysis, original draft writing andediting.TD.L.: Conceptualization, methodology, original draft writing and editing.V.A.: Conceptualization, project administration and supervision, review of the original draft.T.G.: Project administration and supervision, review of the original draft.M.C.: Conceptualization, project administration and supervision, review and editingof the original draft.

Data Availability

All data generated or analysed during this study are included in this published article and its supplementary information files.

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Tables

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