The PJI-TNM Classification and Early Surgical Success in Hip and Knee Arthroplasty Infections: Retrospective Evidence From 74 Procedures

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INTRODUCTION: Periprosthetic joint infection (PJI) remains one of the most challenging complications after arthroplasty, with substantial impact on patient quality of life, health-care utilization, and costs. Many classification schemes describe only a subset of the problem—such as timing of infection or route of contamination—and therefore incompletely capture the multidimensional nature that informs prognosis and surgical decision-making. The PJI-TNM classification was proposed to remedy this gap by staging PJI across three axes that mirror oncologic TNM principles: **T** (tissue/implant conditions), **N** (non-human cells; pathogen-/biofilm-related features), and **M** (patient morbidity) (Alt, et al.). We asked whether PJI-TNM staging correlates with early surgical outcomes in a contemporary single-center cohort of hip and knee PJI. We hypothesized that worse **T** stage would be associated with lower treatment success, whereas **N** and **M** might show weaker or no association with early outcomes.

METHODS: We conducted a retrospective observational study at a tertiary referral center. Eligible cases were hip or knee PJI defined by the 2018 ICM criteria (knee: TKA/UKA; hip: THA/BHA) undergoing surgery between **April 2016 and July 2024**, with **≥6 months** follow-up. **Exclusion criteria** were: implant already removed before index presentation, active malignancy, or insufficient follow-up. After exclusions, **n=74** procedures were analyzed (**knee n=32** [TKA 29, UKA 3]; **hip n=42** [THA 36, BHA 6]). The cohort included **34 males and 40 females**; **mean age 71.8 years** (range 32–89); **mean follow-up 2.56 years**. Each case was staged using PJI-TNM. For **T**, we distinguished soft-tissue defect (+/−), implant loosening (+/−), and implant type (standard vs revision), yielding six categories (**T0a, T0b, T1a, T1b, T2a, T2b**). For **N**, we considered biofilm maturity and pathogen-related difficulty to treat (DDT) with subcategories **N0a (early), N0b (delay), N1a (chronic, DDT−), N1b (chronic, culture-negative), N2a (chronic, DDT+), N2b (chronic, polymicrobial), N2c (fungal)**. For **M**, morbidity was assessed using the Charlson Comorbidity Index (CCI) and categorized **M0/M1** in this dataset; **no M2/M3 cases** were encountered. **(Fig. 1) Primary endpoint** was **treatment success**, defined a priori as **no additional surgery required during follow-up**; **failure** was any additional surgery (Shohat et al.). We calculated success rates by stage for each **T/N/M** component. **Statistical analysis** included Chi-square or Fisher's exact tests for independence, Cochran–Armitage tests for linear trend (where ordinal), and univariate logistic regression to estimate the odds ratio (OR) for success per one-level increase in severity. All tests were two-sided with **α=0.05**. Analyses were performed in **R (version 4.5.1 for macOS)**. **Ethics and consent:** The study was approved by our Institutional Review Board and conducted in accordance with the Declaration of Helsinki and applicable national regulations. Given the retrospective design, informed consent was obtained by an institutional opt-out process with public notification as per local policy. **Sex and sample size** are reported above; both sexes were included, so no single-sex justification was required. No animal experiments were performed.

RESULTS SECTION: Overall **treatment success was 62.2% (46/74)**. The **T component** showed a **significant negative linear trend** with success: each one-level increase in T severity was associated with a **39% decrease in the odds of success** (**Cochran–Armitage Z=−2.7, p=0.008; logistic regression OR 0.61, 95% CI 0.43–0.88; Wald Z=−2.66, p=0.008**). **(Fig. 2)** Directionally similar effects were seen within knee and hip strata but were underpowered for statistical significance. In contrast, the **N** and **M** components showed **no significant association** with early success in this cohort on contingency or trend testing. Limited numbers of difficult-to-treat/fungal or polymicrobial infections likely constrained precision for N-subcategories.

DISCUSSION: Findings indicate that **local tissue/implant status (T)**—integrating the soft-tissue envelope, implant stability, and hardware context—dominates early surgical outcomes, whereas **pathogen-level (N)** and **host morbidity (M)** signals were not discriminative for this endpoint. These results support emphasizing T-driven risk stratification during preoperative planning and counseling. The absence of measurable N/M effects may reflect case-mix, therapeutic heterogeneity (DAIR vs one-/two-stage revision and adjuncts such as CLAP), and the short-term nature of the endpoint (reoperation), with M potentially influencing mortality and long-term function rather than early reoperation risk. **Limitations:** Retrospective single-center design; **modest sample size (n=74)** with small cells in some subcategories; heterogeneous procedures without procedure-specific modeling; and **follow-up focused on early additional-surgery events** rather than long-term infection-free survival.

SIGNIFICANCE/CLINICAL RELEVANCE: The **PJI-TNM T component** provides clinically actionable staging that correlates with early success and may guide operative strategy and resource allocation. **Prospective multicenter validation** with procedure-specific analyses and richer N/M phenotyping is warranted to optimize the full TNM construct.

REFERENCES: 1. Alt V, et al. Bone Joint Res. 2020;9(2):79–83. 2. Shohat N, et al. J Arthroplasty. 2019;34(7S):S337–S344.

T: Tissue and implant conditions				
		Soft tissue defect	Implant loosening	Implant type
T0	a	–	–	standard
	b			revision
T1	a		+	standard
	b			revision
T2	a	+		standard
	b			revision

N: Non-human cells (bacteria and fungi)				
		Mature biofilm	Post-op timing	Pathogen
N0	a	– (Acute)	Early	
	b		Delay	
N1	a	+ (Chronic)		DDT*1 –
	b			Culture negative
N2	a			DDT +
	b			Polymicrobial
	c			Fungi

M: Morbidity of the patient			
		CCI*2	Surgical indication
M0		0-1	+
M1		2-3	
M2		4-5	
M3			–

Figure1 The PJI-TNM Classification. DDT: difficult to treat bacteria CCI: the Charlson Comorbidity Index

		Knee n=32		Hip n=42		Total n=74	
		success rate	P	success rate	P	success rate	P
T	T0a	18/23 (78. 3%)	0.215	11/16 (68.8%)	0.099	29/39 (74.4%)	0.028*
	T0b	3/3 (100%)		6/14 (42.9%)		9/17 (52.9%)	
	T1a	1/2 (50%)		4/4 (100%)		5/6 (83.3%)	
	T1b	0/0 (N/A)		1/4 (25%)		1/4 (25%)	
	T2a	1/3 (33.3%)		1/2 (50%)		2/5 (40%)	
	T2b	0/1 (0%)		0/2 (0%)		0/3 (0%)	
		Knee n=32		Hip n=42		Total n=74	
		success rate	p	success rate	p	success rate	p
M	M0	18/25 (72%)	1.0	18/32 (56.3%)	1.0	36/57 (63.2%)	0.969
	M1	5/7 (71.4%)		5/10 (50%)		10/17 (58.8%)	
	M2	0/0 (N/A)		0/0 (N/A)		0/0 (N/A)	
	M3	0/0 (N/A)		0/0 (N/A)		0/0 (N/A)	
		Knee n=32		Hip n=42		Total n=74	
		success rate	p	success rate	p	success rate	p
N	N0a	6/10 (60%)	0.337	4/8 (50%)	0.392	10/18 (55.6%)	0.574
	N0b	7/8 (87.5%)		4/10 (40%)		11/18 (61.1%)	
	N1a	1/1 (100%)		4/4 (100%)		5/5 (100%)	
	N1b	3/3 (100%)		6/8 (75%)		9/11 (81.8%)	
	N2a	5/7 (71.4%)		4/10 (40%)		9/17 (52.9%)	
	N2b	1/3 (33.3%)		1/2 (50%)		2/5 (40%)	
	N2c	0/0 (N/A)		0/0 (N/A)		0/0 (N/A)	

Figure 2 Treatment Success Rates by PJI-TNM Components.
T component showed a significant association with success rate.
*:p < 0.05