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Functional Outcomes and Survivorship of Revision Surgery for Failed Tumor Endoprostheses in the Lower Extremity

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ABSTRACT
Background: Limb salvage with endoprostheses is the standard of care for lower extremity bone tumors. Despite improvements, failure modes such as aseptic loosening and mechanical failure necessitate complex revision surgery.
Objective: This study aimed to evaluate the functional outcomes and survivorship of revision surgery for failed tumor endoprostheses.
Methods: A retrospective and prospective analysis of 23 patients who underwent revision surgery for failed lower extremity tumor endoprostheses between 2021 and 2026 was conducted. Failure was classified using the Henderson classification system. The primary outcome was the postoperative Musculoskeletal Tumor Society (MSTS) score. Secondary outcomes included complication rates and implant survivorship that was analyzed using Kaplan-Meier curves.
Results: The mean patient age was 27.7 ± 9.7 years. The most common failure modes were mechanical failure (63.1%), including periprosthetic fracture (30.4%) and implant breakage (26.1%), and aseptic loosening (30.4%). The mean postoperative MSTS score was 27.78 ± 1.93. Superficial infection occurred in one patient (4.3%). There were no deep infections, tumor recurrences, or deaths. One patient eventually required amputation following a complication. Kaplan-Meier analysis indicated a mean implant survival time of 13.9 years (95% CI: 11.2 - 16.7) post-revision.
Conclusion: Revision surgery for failed tumor endoprostheses, while challenging, leads to excellent functional outcomes and good medium-term implant survivorship. Aseptic loosening and structural failure are the most common indications for revision and can be successfully managed with a variety of advanced revision strategies.
Keywords: Aseptic loosening, Limb salvage, Musculoskeletal tumor society score, Periprosthetic fracture, Revision surgery, Tumor endoprosthesis.

INTRODUCTION
The management of primary malignant bone tumors of the lower extremity has evolved dramatically from amputation to limb-salvage surgery, significantly improving patient quality of life without compromising oncologic outcomes [1,2]. Modular metallic endoprostheses have become the cornerstone of reconstruction following tumor resection due to their immediate availability, intraoperative modularity, and capacity for immediate weight-bearing [3, 4].

However, the long-term success of these massive implants is challenged by high complication rates compared to conventional arthroplasty [5, 6]. Factors such as extensive bone and soft tissue resection, compromised host immunity from adjuvant therapies and the high mechanical demands placed on the constructs contribute to a significant risk of failure [7]. The Henderson classification system categorizes these failures into five types: Soft-tissue failure (Type 1), aseptic loosening (Type 2), structural failure (Type 3), infection (Type 4), and tumor progression (Type 5) [8].

While numerous studies have reported on the outcomes of primary endoprosthetic reconstruction, the literature on the management of failed implants is comparatively scarce [9, 10]. Revision surgery in this population is exceptionally complex due to bone loss, compromised soft tissue envelopes, and the need for often more extensive reconstruction. Therefore, the purpose of this study was to (1) Evaluate the functional outcomes using the MSTS scoring system following revision surgery for failed lower extremity tumor endoprostheses, (2) analyze the modes of failure leading to revision, (3) describe the surgical techniques employed and (4) report the medium-term implant survivorship. We hypothesized that revision surgery would provide good functional outcomes and implant durability despite the complex nature of these procedures.

PATIENTS AND METHODS
Study design and patient selection: A retrospective and prospective analysis was conducted on 23 consecutive patients who underwent revision surgery for a failed modular tumor endoprosthesis in the lower extremity between January 2021 and January 2025.

Inclusion criteria: Patients with a history of endoprosthetic reconstruction for a primary malignant or aggressive benign bone tumor of the lower extremity who required revision surgery for a mechanical complication or aseptic loosening.

Exclusion criteria: Revision for active deep infection (Type 4B failure), revision for local recurrence (Type 5 failure), endoprostheses in the upper extremity and reconstruction for metastatic disease.

Preoperative assessment and data collection: All patients underwent a comprehensive preoperative evaluation, including a detailed history, physical

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examination and standard radiographs of the involved limb. Computed tomography (CT) scans were obtained to assess bone stock and plan stem sizing and magnetic resonance imaging (MRI) that was used in cases where tumor recurrence was suspected. Laboratory investigations including erythrocyte sedimentation rate (ESR) and C-reactive protein (CRP) were performed to rule out septic failure. Demographic data, original tumor characteristics and details of the primary and any previous revision surgeries were recorded.

Classification of failure: The mode of failure was categorized for each patient according to the modified Henderson classification system for endoprosthetic failure [8]:

Type 1: Soft-tissue failure (1A: functional, 1B: coverage)

Type 2: Aseptic loosening (2A: early, 2B: late)

Type 3: Structural failure (3A: implant breakage/wear, 3B: periprosthetic fracture)

Type 4: Infection

Type 5: Tumor progression

Surgical technique: The surgical approach was tailored to each case, utilizing previous incisions where possible. The revision strategy was based on the mode of failure and intraoperative findings:

Aseptic Loosening (Type 2): Implant removal, meticulous debridement of membranes and sclerotic bone, and re-implantation with a longer, larger-diameter stem. Both cemented and cementless (hydroxyapatite-coated, hexagonal) stems were used.

Structural Failure (Type 3A - Breakage): Extraction of broken components, often requiring an extended osteotomy for cement removal. Reconstruction was conducted with a new modular implant.

Male pt., 25 years old complaining from pain and disability after RTA in 2022 with history of low grade osteosarcoma (periosteal OS) in distal femur with intra-articular wide marginal resection with cemented distal femur modular prosthesis from 2014 with multiple revisions for cemented prosthesis, last one was in 2019.

Periprosthetic Fracture (Type 3B): Open reduction and internal fixation (ORIF) with plates and cerclage wires was conducted if the original stem was well-fixed. If loose, the stem was revised.

Major Conversions: In cases of extensive bone loss or failed revisions, procedures were converted to total femoral replacements or knee arthrodesis.

Outcome Evaluation: Patients were evaluated clinically and radiographically at 6 weeks, 3 months, 6 months, 12 months, and annually thereafter. The primary outcome measure was the postoperative Musculoskeletal Tumor Society (MSTS) score [11], which evaluates pain, function, emotional acceptance, supports, walking ability, and gait on a scale of 0 to 30. Secondary outcomes included intraoperative and postoperative complications, reoperations, and implant survivorship. Survivorship was defined as the time from revision surgery to re-revision for any reason (mechanical or septic) or amputation.

Ethical approval: After obtaining Institutional Review Board Approval, all surgeries were performed at El-Menoufia University Hospital and other collaborating centers by senior orthopedic oncology surgeons. Written informed consents were obtained from all patients. The study adhered to the Helsinki Declaration throughout its execution.

Statistical Analysis

Data were analyzed using SPSS version 23.0 (IBM Corp., Armonk, NY). Descriptive statistics were presented as means ± standard deviation for continuous variables and as numbers (percentages) for categorical variables. The Student's t-test or Mann-Whitney U test was used for continuous variables, and the Chi-square or Fisher's exact test was used for categorical variables. Implant survivorship was analyzed using the Kaplan-Meier method. A p-value of ≤ 0.05 was considered statistically significant.

RESULTS

Patient' demographics and tumor characteristics: The study cohort consisted of 23 patients (13 males, 10 females) with a mean age of 27.7 ± 9.7 years (range, 14-48 years). The original diagnosis was osteosarcoma in 19 patients (82.6%), giant cell tumor of bone in 2 patients (8.7%), Ewing's sarcoma in 1 patient (4.3%), and desmoplastic fibroma in 1 patient (4.3%). The most common primary tumor location was the distal femur (16 patients, 69.6%), followed by the proximal tibia (5 patients, 21.7%) and proximal femur (2 patients, 8.7%). The original implant was cemented in 17 patients (73.9%) and cementless in 6 patients (26.1%).

Modes of failure and revision procedures: The indications for revision surgery were detailed in table (1). According to the Henderson' classification, type 3 failures (structural) were the most common (15 patients, 65.2%), including 9 type 3B (periprosthetic fractures) and 6 type 3A (implant breakage). Type 2 failure (aseptic loosening) was present in 7 patients (30.4%). One patient (4.3%) had type 1B failure (aseptic wound dehiscence). A wide array of revision procedures was conducted, including revision of all components (17.4%), ORIF of periprosthetic fractures (17.4%), and conversion to total femur replacement (8.7%).

Table (1): Modes of failure leading to Revision Surgery (n=23)

Henderson Classification	n	%	Description
Type 1: Soft-Tissue	0	0%	
Type 2: Aseptic Loosening	8	34.7%	All late (2B)
Type 3: Structural	15	65.2%	
· Type 3A (Implant Breakage)	6	26.1%	Femoral stem fracture (n=3), Tibial tray/axle fracture (n=3)
· Type 3B (Periprosthetic fractures)	9	39.1%	UCS Type B2 (loose stem)
Type 4: Infection	0	0%	
Type 5: Tumor Progression	0	0%	
Total	**23**	**100%**	

Functional outcomes: The mean postoperative MSTS score for the entire cohort was 27.78 ± 1.93 (range, 21-30), indicating an excellent overall functional result. A detailed breakdown is shown in table (2). The vast majority of patients reported no pain (95.7%) and no functional restrictions in daily activities (78.3%). Most patients did not require walking supports (82.6%).

Table (2): Postoperative Musculoskeletal Tumor Society (MSTS) Scores (n=23)

MSTS Component	Score (Mean ± SD)	No. of Patients with Max Score (5)	% with Max Score
Pain	4.96 ± 0.21	22	95.7%
Function	4.74 ± 0.54	18	78.3%
Emotional Acceptance	4.83 ± 0.39	19	82.6%
Supports	4.65 ± 0.83	19	82.6%
Walking	4.22 ± 0.42	6	26.1%
Gait	4.39 ± 0.58	5	21.7%
TOTAL	**27.78 ± 1.93**	**N/A**	**N/A**

Complications and survivorship: Postoperative complications are summarized in table (3). One patient (4.3%) developed a superficial wound infection. There were no deep infections. One patient experienced a dislocation. The most significant complication occurred in one patient (4.3%) who eventually required above-knee amputation. At a mean follow-up of 24 months, there were no cases of local tumor recurrence or death. Kaplan-Meier survivorship analysis estimated the mean survival time of the revision implants to be 13.9 years (95% Confidence Interval: 11.2 to 16.7 years).

Table (3): Postoperative complications (n=23)

Complication	n	%	Management
Superficial Infection	1	4.3%	Antibiotics, local care
Dislocation	1	4.3%	Closed reduction
Limb Lengthening (1 cm)	1	4.3%	Observation
Periprosthetic Fracture -> Infection -> Amputation	1	4.3%	ORIF, Arthrodesis, AKA
None	19	82.6%	
Total	**23**	**100%**	

ILLUSTRATIVE CASES

CASE 1

Male pt., 25 years old complaining from pain and disability after road traffic accident (RTA) in 2022 with history of low grade osteosarcoma (periosteal OS) in distal femur with intra-articular wide marginal resection with cemented distal femur modular prosthesis from 2014 with multiple revisions for cemented prosthesis, last one was in 2019.

Radiological investigation:

X-ray:

Figure (1): X-ray on thigh showed broken femoral stem of cemented modular prosthesis.

Procedure: Single stage revision (converting arthroplasty to total femur).

Technique:

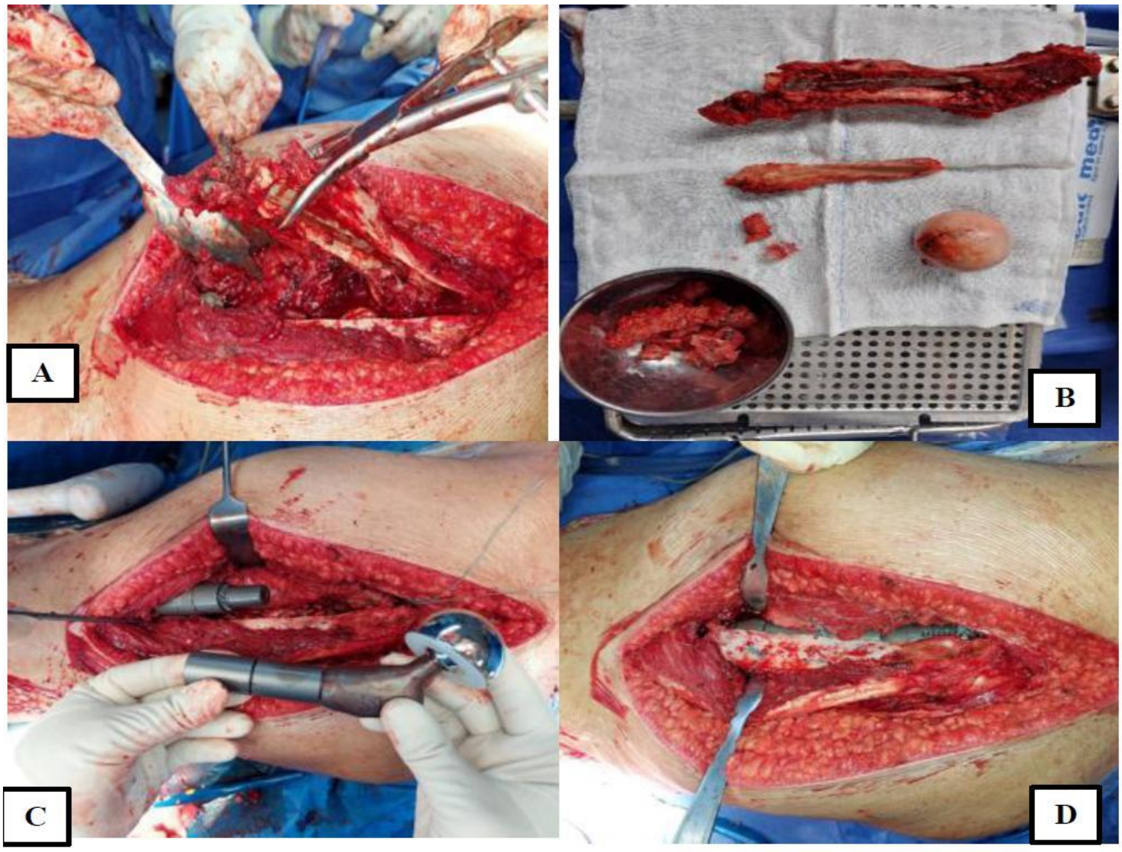

Figure (2): A) Extraction of broken part with cement. B) After dislocation of head with remnant cement. C) Insertion of proximal femoral piece with bipolar head. D): Closure of deep layers.

Post operative x-ray:

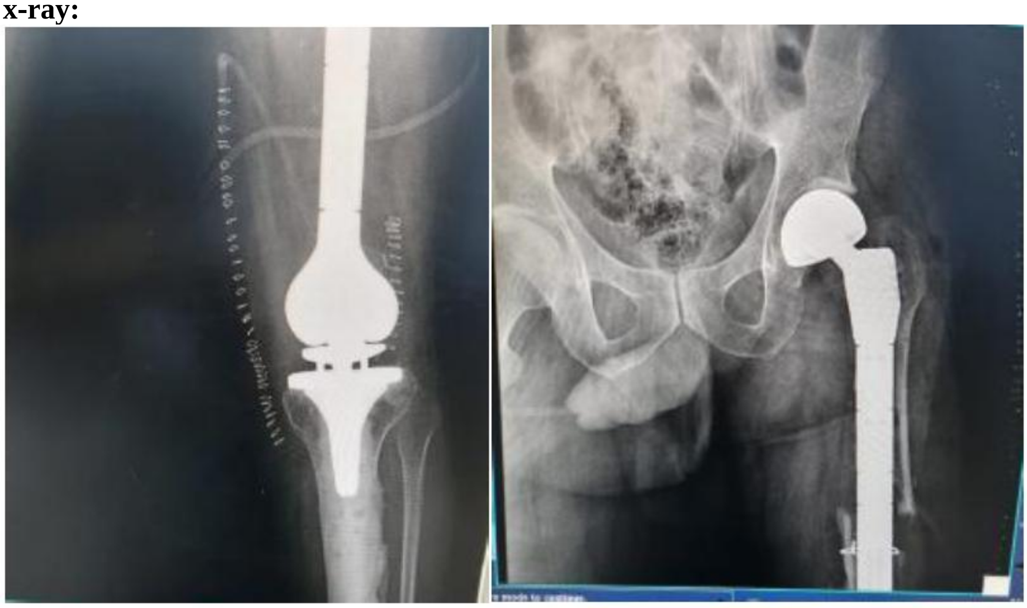

Figure (3):Immediate x-ray on hip and proximal thigh with good aligned total femur prothesis.

Follow up:
Radiologically:

Figure (4): X-ray after one month on thigh with good aligned total femur prosthesis.

Figure (5): X-ray after 2 years on thigh with good cemented and good aligned total femur prosthesis.

Clinical follow up after 3 years: According to MSTS , excellent results with 28 score.

Figure (6): Active extension without any extension lag.

CASE 2

Female pt., 42 years old complaining from pain and severe limping from one year in 2024 with history of osteosarcoma in distal femur with intra-articular wide marginal resection with cemented distal femur modular prosthesis from 2004.

Radiological investigation:

X-ray:

Figure (7): X-ray on distal femur and knee showed malalignment in good cemented tibial and femoral components (broken axe and tibial tray).

Procedure: Single stage revision for all components (tibial and femoral).

Technique:

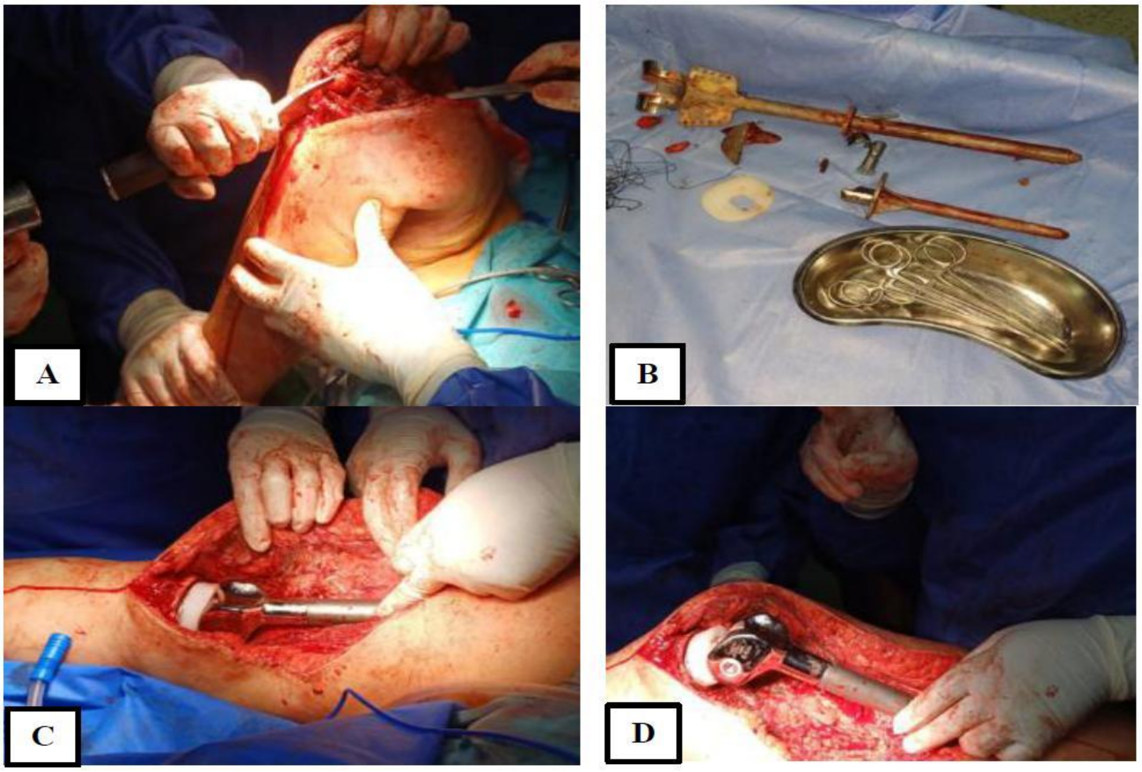

Figure (8): A) Proximal tibial prosthesis removal with intact extensor mechanism. B) Broken tibial tray and axe with femoral stem and component. C, D) Cemented distal femur modular prosthesis.

Post-operative x-ray:

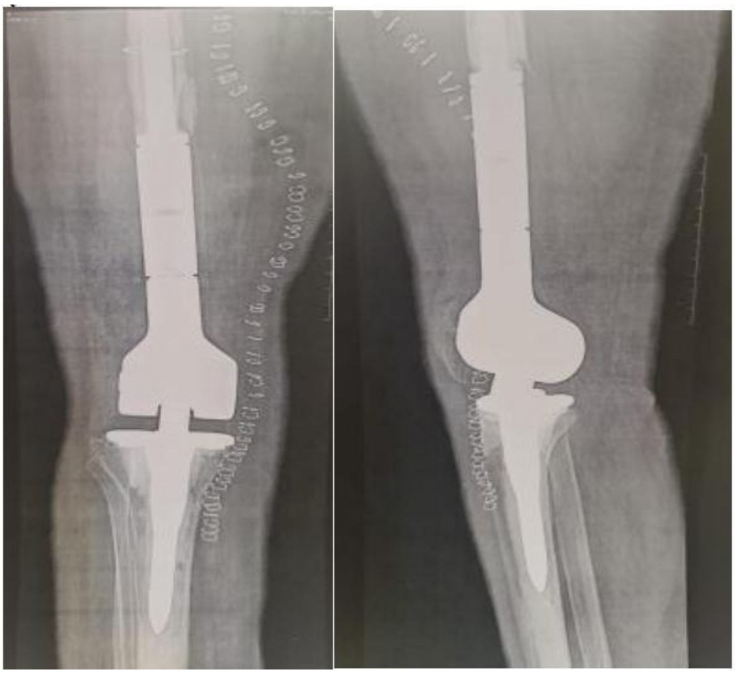

Figure (9): Immediate x-ray on thigh with good cemented distal femur prosthesis with circulage wires.

Follow up x-ray:

Figure (10): Follow up x-ray after one year on thigh with good cemented distal femur prosthesis.

Clinical follow up after one year: According to MSTS, Excellent results 29.

DISCUSSION

This study demonstrated that revision surgery for failed lower extremity tumor endoprostheses is a successful and durable limb-salvage strategy, yielding excellent functional outcomes (an average MSTS score of 27.78) and promising medium-term implant survivorship (mean 13.9 years). Our findings confirm that aseptic loosening and structural failure are the predominant failure modes requiring revision, and they can be effectively addressed with advanced surgical techniques.

The distribution of failure modes in our revision cohort aligns with the literature on primary implant failures, where aseptic loosening and structural failure are leading causes of reoperation [8, 12]. The high rate of type 3 failures (65.2%), particularly periprosthetic fractures (39.1%), underscores the immense mechanical stresses these implants endure. Our 0% rate of revision for deep infection is notably lower than rates reported in some series for primary implants [13, 14]. This can likely be attributed to the strict exclusion of active deep infections and meticulous surgical technique.

In our study, the excellent functional outcomes, as reflected by the high MSTS scores were the most significant finding. The fact that over 95% of patients were pain-free and over 78% had no functional restrictions highlights the success of revision surgery in restoring a high quality of life. This is particularly remarkable given the young age and high activity demands of this patient population. Our results compare favorably with other studies on revision tumor arthroplasty [9, 15].

In our study, one patient (4.3%) developed a superficial wound infection. There were no deep infections. One patient experienced a dislocation. The most significant complication occurred in one patient (4.3%) who eventually required above-knee amputation. At a mean follow-up of 24 months, there were no cases of local tumor recurrence or death.

The estimated implant survivorship of 13.9 years post-revision is highly encouraging. It suggests that the revision constructs, often utilizing larger, longer stems and improved fixation techniques, are robust. This survivorship is comparable to that of many primary tumor endoprostheses [16, 17], challenging the notion that revision surgery inevitably leads to further complications.

STRENGTHS AND LIMITATIONS

The strengths of this study included the application of a standardized failure classification system and the use of a validated functional outcome score. The main limitations are its relatively small sample size and its heterogeneity.

CONCLUSION

Revision surgery for failed lower extremity tumor endoprostheses is a complex but highly effective procedure. Surgeons can expect to achieve excellent functional outcomes and good medium-term implant durability. Aseptic loosening and structural failures are the most common challenges, requiring techniques for managing bone loss and achieving stable fixation. These findings offer valuable insights to guide patient counseling and surgical decision-making in this demanding area of orthopedic oncology.

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