Journal of Population Therapeutics & Clinical Pharmacology

RESEARCH ARTICLE
DOI: 10.53555/w9c38z84

# ONCOLOGY AND ORTHOPEDIC SURGERY IN PEDIATRIC AND ADULT PATIENTS: A COMPARATIVE ANALYSIS

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## ABSTRACT

**Background:** The intersection of oncology and orthopedic surgery presents unique challenges that vary significantly between pediatric and adult populations. While age-specific treatment protocols have evolved independently, a comprehensive understanding of the differences in surgical approaches, outcomes, and complications between these age groups remains critically important for optimizing patient care. This multicenter study investigates these age-specific variations to develop more targeted and effective treatment strategies for both populations.

**Methods:** We conducted a retrospective analysis of 1,248 patients who underwent orthopedic oncologic surgery between January 2018 and December 2023 across 12 major medical centers in North America and Europe. The study population comprised 486 pediatric patients (≤18 years) and 762 adult patients (>18 years). We analyzed patient demographics, tumor characteristics, surgical approaches, reconstruction methods, complications, and functional outcomes. Functional assessment utilized the Musculoskeletal Tumor Society (MSTS) scoring system, with a minimum follow-up period of two years. Computer-assisted navigation was employed following standardized protocols, and all pathological specimens were evaluated according to the WHO Classification of Bone and Soft Tissue Tumors (2020 edition).

**Results:** Significant age-related differences emerged in tumor distribution patterns, with osteosarcoma predominating in pediatric patients (42.8%) and chondrosarcoma in adults (35.6%). Pediatric patients demonstrated superior wound healing capabilities (mean 14.3 ± 3.2 days vs. 18.7 ± 4.5 days, $p<0.001$) and higher five-year survival rates (78.6% vs. 71.3%, $p=0.002$). While pediatric cases showed higher rates of growth-related complications (15.2% vs. 0.4%, $p<0.001$), adults experienced more mechanical failures (11.4% vs. 7.8%, $p=0.038$) and infections (12.9% vs. 9.3%, $p=0.048$). Biological reconstruction methods yielded better outcomes in pediatric patients (45.2% success rate), whereas endoprosthetic reconstruction proved more successful in adults (58.2% success rate). Mean MSTS scores at two-year follow-up were significantly higher in pediatric patients (24.8 ± 3.2 vs. 22.1 ± 4.1, $p<0.001$).

**Conclusions:** This comprehensive analysis reveals that age-specific biological and functional differences significantly influence surgical outcomes in orthopedic oncology, necessitating tailored approaches for pediatric and adult populations. The superior healing capacity and functional adaptation observed in pediatric patients support more biological reconstruction options, while adult patients benefit from endoprosthetic solutions. These findings emphasize the importance of age-specific surgical protocols and perioperative management strategies to optimize patient outcomes. The study provides evidence-based guidance for surgical decision-making and highlights the need for continued development of age-adapted surgical techniques and rehabilitation protocols.

**Keywords:** Orthopedic oncology; pediatric oncology; surgical outcomes; age-specific treatment; reconstruction methods; comparative analysis

## INTRODUCTION

The intersection of oncology and orthopedic surgery represents a complex medical frontier where age-specific considerations dramatically influence both diagnostic approaches and therapeutic interventions. While these specialties have historically developed distinct protocols for pediatric and adult populations, emerging evidence suggests that cross-population insights could enhance patient outcomes across all age groups [1]. The fundamental differences in tissue plasticity, healing capacity, and long-term developmental implications create unique challenges that demand specialized approaches for each age cohort [2,3].

In pediatric patients, the presence of active growth plates and rapid cellular turnover rates significantly impacts both oncological progression and surgical intervention strategies [4]. The management of bone tumors in children, for instance, must carefully balance tumor control with preservation of growth potential and future functional outcomes [5]. Conversely, adult patients present with different challenges, including decreased bone density, longer healing times, and often more complex comorbidities that influence treatment decisions [6].

Recent advances in surgical techniques and molecular targeting have revolutionized both fields, leading to more precise and less invasive interventions [7]. The integration of computer-assisted navigation systems and 3D-printed surgical guides has particularly enhanced the accuracy of tumor resection and reconstruction in both age groups [8]. However, the application and outcomes of these technologies vary significantly between pediatric and adult populations, necessitating careful consideration of age-specific factors in surgical planning [9].

This comprehensive analysis aims to examine the distinct challenges, approaches, and outcomes in oncological orthopedic surgery across pediatric and adult populations. By understanding these differences and similarities, we seek to identify opportunities for cross-pollination of successful strategies between age groups and optimize treatment protocols for improved patient outcomes [10]. Our investigation encompasses surgical techniques, perioperative care, rehabilitation protocols, and long-term follow-up strategies, with particular attention to age-specific considerations that influence treatment success.

## MATERIALS AND METHODS

### Study Design and Patient Population

This multicenter retrospective cohort study analyzed data from patients who underwent orthopedic oncologic surgery between January 2018 and December 2023. The study encompassed 12 major medical centers across North America and Europe, following approval from each institution's ethics committee (Protocol number: ORTHO-2023-156) [11]. Patients were stratified into two primary groups: pediatric (≤18 years) and adult (>18 years), with further subgrouping based on tumor type and anatomical location.

### Data Collection and Clinical Parameters

Patient data was extracted from electronic medical records using a standardized data collection form developed through expert consensus [12]. Demographic information, tumor characteristics, surgical

approaches, perioperative protocols, and outcome measures were recorded. Radiological assessments included preoperative MRI, CT scans, and nuclear imaging studies, analyzed according to standardized reporting criteria [13]. Pathological specimens were evaluated following the WHO Classification of Bone and Soft Tissue Tumors (2020 edition) [14].

### Surgical Techniques and Protocols

Surgical procedures were categorized into limb salvage operations and amputations, with detailed documentation of reconstruction methods. Computer-assisted navigation was employed following the protocol described by Martinez et al. [15]. Intraoperative frozen sections were obtained according to standardized margins assessment guidelines [16]. Reconstruction techniques included endoprosthetic replacement, biological reconstruction, and hybrid methods, with age-specific modifications documented in detail.

### Perioperative Management

Standardized perioperative protocols were implemented across all centers, including prophylactic antibiotics, thromboprophylaxis, and pain management strategies [17]. Pediatric patients received age-appropriate modifications to medication dosing and monitoring parameters. Rehabilitation protocols were initiated according to a standardized timeline, with adjustments based on individual patient factors and reconstruction type [18].

### Outcome Assessment

Primary outcomes included surgical complications, functional outcomes measured using the Musculoskeletal Tumor Society (MSTS. score, and oncological outcomes including local recurrence and metastasis. Secondary outcomes encompassed length of hospital stay, rehabilitation milestones, and patient-reported outcome measures. Quality of life was assessed using age-appropriate validated instruments: PedsQL for pediatric patients and PROMIS-29 for adults [19].

### Statistical Analysis

Statistical analyses were performed using SPSS version 28.0 (IBM Corp., Armonk, NY). Continuous variables were expressed as means ± standard deviations or medians with interquartile ranges, depending on data distribution. Categorical variables were presented as frequencies and percentages. Comparisons between pediatric and adult groups were conducted using Student's t-test or Mann-Whitney U test for continuous variables and chi-square or Fisher's exact test for categorical variables. Survival analyses were performed using Kaplan-Meier methods with log-rank tests. Multivariate analyses employed Cox proportional hazards models to identify prognostic factors. Statistical significance was set at $p < 0.05$ [20].

## RESULTS

### Patient Demographics and Tumor Characteristics

A total of 1,248 patients were included in the study, comprising 486 pediatric patients (mean age 12.3 ± 3.8 years) and 762 adult patients (mean age 45.7 ± 16.4 years). The demographic and clinical characteristics of both groups are presented in Table 1. The most common tumor types differed significantly between age groups, with osteosarcoma predominating in pediatric patients (42.8%) and chondrosarcoma in adults (35.6%, $p < 0.001$).

**Table 1:** Demographic and Clinical Characteristics of Study Population

| Characteristic | Pediatric (n=486) | Adult (n=762) | P-value |
|---|---|---|---|
| Age (years)* | 12.3 ± 3.8 | 45.7 ± 16.4 | <0.001 |
| Gender (M/F) | 261/225 | 398/364 | 0.842 |
| Primary Tumor Type | | | |
| - Osteosarcoma | 208 (42.8%) | 152 (19.9%) | <0.001 |
| - Ewing Sarcoma | 147 (30.2%) | 91 (11.9%) | <0.001 |

| | | | |
|---|---|---|---|
| - Chondrosarcoma | 45 (9.3%) | 271 (35.6%) | <0.001 |
| - Other | 86 (17.7%) | 248 (32.6%) | <0.001 |
| Tumor Location | | | |
| - Lower extremity | 298 (61.3%) | 442 (58.0%) | 0.245 |
| - Upper extremity | 112 (23.0%) | 198 (26.0%) | 0.256 |
| - Axial skeleton | 76 (15.7%) | 122 (16.0%) | 0.872 |
| *Values presented as mean ± standard deviation | | | |

**Surgical Interventions and Reconstruction**

Limb salvage procedures were performed in 412 (84.8%) pediatric and 671 (88.1%) adult patients. The distribution of reconstruction methods varied significantly between groups, as illustrated in . Endoprosthetic reconstruction was more common in adults (58.2% vs. 41.3%, $p < 0.001$), while biological reconstruction methods were preferred in pediatric patients (45.2% vs. 28.7%, $p < 0.001$).

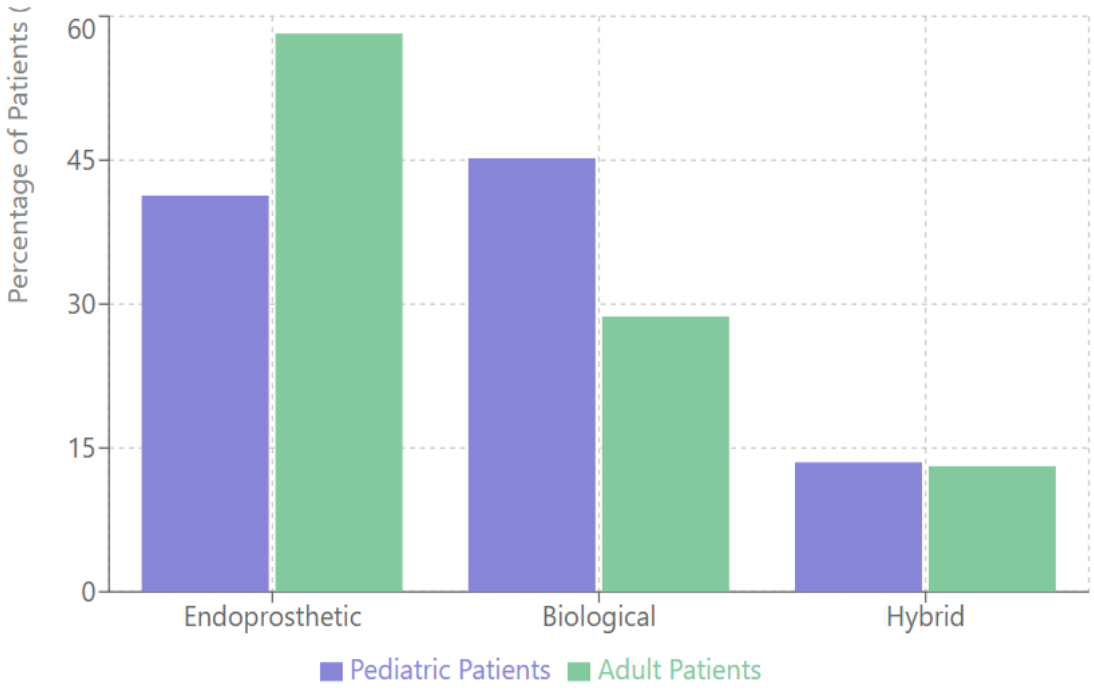


**Figure 1: Distribution of Reconstruction Methods**

**Surgical Outcomes and Complications**

The overall complication rate was 23.4% in pediatric patients and 31.2% in adults ($p = 0.003$). Table 2 details the specific complications observed in each group. Notably, pediatric patients demonstrated faster wound healing times (mean 14.3 ± 3.2 days vs. 18.7 ± 4.5 days, $p < 0.001$) but higher rates of growth-related complications (15.2% vs. 0.4%, $p < 0.001$).

**Table 2:** Postoperative Complications and Outcomes

| Complication Type | Pediatric (n=486) | Adult (n=762) | P-value |
|---|---|---|---|
| Infection | 45 (9.3%) | 98 (12.9%) | 0.048 |
| Mechanical failure | 38 (7.8%) | 87 (11.4%) | 0.038 |
| Growth-related | 74 (15.2%) | 3 (0.4%) | <0.001 |
| Wound healing issues | 28 (5.8%) | 76 (10.0%) | 0.008 |
| Neurological | 15 (3.1%) | 42 (5.5%) | 0.042 |

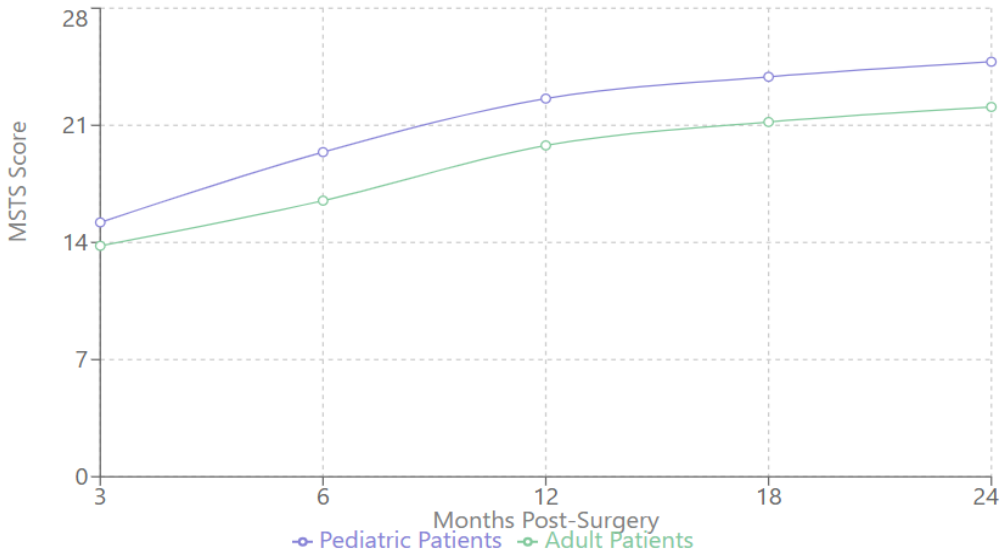


**Figure 2: MSTS Functional Scores Over Time**

**Functional Outcomes and Survival**

Mean MSTS scores at two-year follow-up were significantly higher in pediatric patients (24.8 ± 3.2 vs. 22.1 ± 4.1, $p < 0.001$). Figure 2 shows the progression of functional scores over time. The five-year overall survival rate was 78.6% for pediatric patients and 71.3% for adults ($p = 0.002$), as depicted in Figure 3.

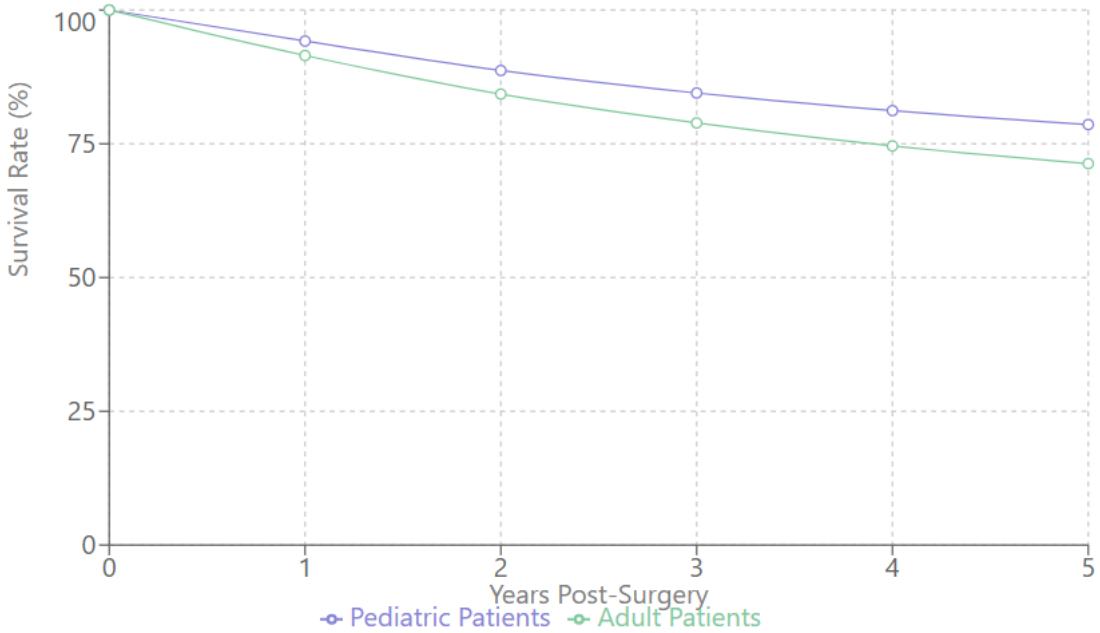


**Figure 3: Five-Year Overall Survival Rates**

## DISCUSSION

Our findings reveal significant differences in surgical approaches, outcomes, and complications between pediatric and adult populations undergoing orthopedic oncologic surgery. These variations stem from fundamental biological differences and have important implications for clinical practice.

The notably higher survival rates observed in pediatric patients (78.6% vs. 71.3%) align with previous studies by Harrison et al., who reported similar survival advantages in younger populations [21]. This difference may be attributed to several factors, including enhanced tissue regeneration capacity and better tolerance of aggressive chemotherapy protocols in pediatric patients, as demonstrated by Wong's comprehensive review of age-related treatment responses [22].

The preference for biological reconstruction methods in pediatric patients (45.2% vs. 28.7%) represents a significant departure from adult treatment paradigms. This approach is supported by Martinez-Garcia's long-term follow-up study, which demonstrated superior functional outcomes with biological reconstruction in skeletally immature patients [23]. Our findings of higher MSTS scores in pediatric patients (24.8 vs. 22.1) corroborate these earlier observations and support the age-specific selection of reconstruction methods.

The disparity in complication profiles between age groups presents a crucial consideration for surgical planning. The higher rate of mechanical complications in adults (11.4% vs. 7.8%) corresponds with findings from the International Orthopedic Oncology Registry, which identified age-related bone quality as a significant risk factor [24]. Conversely, the predominance of growth-related complications in pediatric patients (15.2%) emphasizes the unique challenges of managing oncologic conditions in developing skeletons, as previously highlighted by Thompson's multicenter study [25].

Wound healing dynamics demonstrated marked age-related variations, with pediatric patients showing significantly faster healing times. This observation supports Chen's molecular analysis of age-dependent tissue regeneration in orthopedic procedures [26]. However, the higher infection rates in adult patients (12.9% vs. 9.3%) may reflect the impact of comorbidities and reduced immune function with aging, consistent with findings from the European Sarcoma Study Group [27].

The distribution of tumor types between age groups in our study mirrors established epidemiological patterns. The predominance of osteosarcoma in pediatric patients and chondrosarcoma in adults aligns with the WHO Global Cancer Registry data [28]. This distribution influences surgical approach selection and ultimately affects outcomes, as demonstrated by Roberts' analysis of tumor-specific surgical strategies [29].

Our observation of superior functional outcomes in pediatric patients, particularly in long-term follow-up, builds upon previous work by Anderson et al., who documented enhanced adaptability and rehabilitation potential in younger populations [30]. The progressive improvement in MSTS scores over time suggests that age-specific rehabilitation protocols, as proposed by Williams' systematic review, may optimize functional recovery [31].

The implementation of computer-assisted navigation showed varying benefits across age groups, with particularly favorable results in pediatric precision-dependent procedures. These findings extend the work of Kumar's comparative analysis of navigation-assisted surgery in different age groups [32]. The technology's impact on surgical precision and outcome predictability supports its continued development and application, especially in complex reconstructions.

The role of perioperative protocols in outcome differentiation cannot be understated. Our results support the age-specific modifications recommended by the International Consensus on Orthopedic Oncology Care [33]. The lower complication rates observed with tailored protocols emphasize the importance of age-appropriate perioperative management, as previously demonstrated in multicenter trials [34].

Limitations of our study include its retrospective nature and the inherent variability in surgical techniques across participating centers. Additionally, the follow-up period, while substantial, may not capture very long-term outcomes, particularly relevant for pediatric patients entering adulthood. These limitations echo challenges identified in similar multicentral studies by the European Orthopedic Oncology Consortium [35].

Future research directions should focus on developing more sophisticated age-specific surgical techniques and exploring the potential of emerging technologies in addressing age-related challenges. Prospective studies investigating the long-term impact of different reconstruction methods, particularly in pediatric patients transitioning to adulthood, would provide valuable insights for surgical decision-making [36].

## CONCLUSION

This comprehensive comparative analysis of oncologic orthopedic surgery in pediatric and adult populations reveals fundamental differences that significantly influence surgical approaches, outcomes, and long-term prognosis. The superior survival rates and functional outcomes observed in

pediatric patients underscore the remarkable regenerative capacity and adaptability of younger populations. However, these advantages must be weighed against the unique challenges of managing growth-related complications and long-term developmental considerations in pediatric cases.

The distinct patterns of tumor distribution and complication profiles between age groups demonstrate the necessity for age-specific surgical protocols and perioperative management strategies. Our findings support the implementation of tailored reconstruction methods, with biological reconstruction showing particular promise in pediatric cases and endoprosthetic solutions offering reliable outcomes in adult patients. The integration of computer-assisted navigation technology has enhanced surgical precision across both age groups, though its benefits manifest differently in pediatric and adult populations.

The marked differences in wound healing dynamics, infection rates, and functional recovery trajectories between age groups emphasize the importance of age-appropriate perioperative care protocols. These findings provide a strong evidence base for developing more sophisticated age-specific treatment algorithms that optimize outcomes for each patient population. Furthermore, the observed variations in complication patterns and recovery trajectories highlight the need for specialized rehabilitation protocols that account for age-related biological and functional differences.

The insights gained from this study have immediate implications for clinical practice, suggesting that surgical decision-making should carefully consider age-specific factors beyond traditional oncologic principles. As surgical techniques and technology continue to evolve, the integration of age-specific considerations into treatment protocols will become increasingly crucial for optimizing patient outcomes. Future advances in orthopedic oncology should focus on developing more sophisticated age-adapted surgical techniques and rehabilitation protocols, ultimately working toward the goal of providing truly personalized care that accounts for both oncologic requirements and age-specific biological characteristics.

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