Case Report | Journal of Orthopaedic Case Reports 2026 September:16(9):Page 374-378

Hybrid Prosthetic and Biological Reconstruction Using Extracorporeal Radiotherapy for Long-Segment Humeral Osteosarcoma: A Case Report

Prabodh Kantiwal[1], Syed Mohammed Adnan[1], Amir Suhail[1], Manveer Singh[1], Siddhi Chawla[2], Sudeep Khera[3]

Learning Point of the Article:

Hybrid reconstruction using a proximal endoprosthesis combined with extracorporeal radiotherapy (ECRT) offers a durable, joint-preserving limb-salvage strategy for pediatric patients with long-segment humeral osteosarcoma.

Abstract

Introduction: Osteosarcoma, the most prevalent malignant primary bone tumor in children and adolescents, can present formidable challenges when involving long segments of the humerus. Reconstruction options must balance oncological clearance with long-term limb function, particularly in skeletally immature patients.

Case Report: We report a case of a 15-year-old female diagnosed with high-grade osteosarcoma involving the proximal epiphysis and most of the diaphysis of the right humerus, sparing only the distal 3 cm. Following neoadjuvant chemotherapy, the patient underwent wide tumor excision and a novel hybrid limb-salvage reconstruction using a custom proximal prosthesis combined with biological reconstruction of the diaphysis via extracorporeal radiotherapy (ECRT). The tumor-bearing bone was irradiated with 50 Gy ex vivo and reimplanted, fixed to the preserved distal humerus with a locking plate. At 18-month follow-up, the patient remained disease-free, with radiographic evidence of graft incorporation and preserved elbow function.

Conclusion: This case highlights the viability of combining prosthetic and biological methods in complex pediatric osteosarcoma, especially when distal joint preservation is possible. ECRT provides a cost-effective, anatomically compatible solution that maintains structural integrity, especially when used with proximal prosthetic support. This hybrid method represents an optimal limb-salvage strategy in selected pediatric cases involving long bone tumors.

Keywords: Osteosarcoma, humeral neoplasms, extracorporeal radiotherapy, limb salvage, megaprosthesis.

Introduction

Osteosarcoma is the most common primary malignant bone tumor in children and adolescents, typically arising during periods of rapid growth [1]. In contrast, the distal femur and proximal tibia are the most frequent sites. Approximately 10–12% of cases involve the humerus [2], and within this group, long-segment involvement extending from the proximal epiphysis through the diaphysis is relatively rare – reported in <5% of humeral osteosarcomas [3]. Surgical management has shifted from amputation toward limb-salvage strategies, enabled by the success of multi-agent chemotherapy and improved imaging. However, when large portions of the humerus are involved – particularly in skeletally immature patients – the choice of reconstruction becomes challenging.

Endoprosthetic reconstruction allows early mobilization but carries concerns regarding longevity, growth disruption, and

Access this article online

Website: www.jocr.co.in

DOI: https://doi.org/10.13107/jocr.2026.v16.i09.8098

Author's Photo Gallery

Dr. Prabodh Kantiwal | Dr. Syed Mohammed Adnan | Dr. Amir Suhail | Dr. Manveer Singh | Prof. Siddhi Chawla | Dr. Sudeep Khera

[1]Department of Orthopaedics, All India Institute of Medical Sciences, Jodhpur, Rajasthan, India,
[2]Department of Trauma and Emergency (Diagnostic and Interventional Radiology, All India Institute of Medical Sciences, Jodhpur, Rajasthan, India,
[3]Department of Pathology, All India Institute of Medical Sciences, Jodhpur, Rajasthan, India.

Address of Correspondence:
Dr. Syed Mohammed Adnan,
Department of Orthopaedics, All India Institute of Medical Sciences, Jodhpur, Rajasthan, India.
E-mail: syedadnan24@gmail.com

Submitted: 21/06/2026; Review: 05/07/2026; Accepted: August 2026; Published: September 2026

DOI: https://doi.org/10.13107/jocr.2026.v16.i09.8098

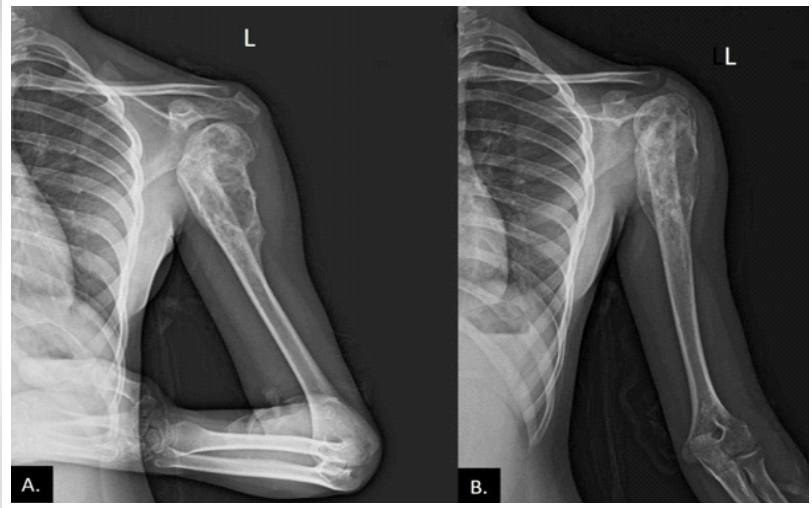

Figure 1: Pre-operative anteroposterior (a) and lateral (b) radiographs of the left arm demonstrating a mixed expansile lytic-sclerotic lesion in the proximal epimetaphysis of the humerus, accompanied by extraosseous soft tissue extension and periosteal elevation.

functional outcomes in the upper limb [4]. Biological reconstructions, such as autografts, allografts, vascularized fibula, and extracorporeally irradiated autografts, offer long-term solutions with potential for osteointegration but involve longer recovery times and risk of mechanical failure [5, 6].

Extracorporeal radiotherapy (ECRT), in which the tumor-bearing bone is irradiated ex vivo and reimplanted, has emerged as a versatile method that offers precise anatomical fit and avoids immunological complications associated with allografts [7]. Zhao et al. proposed a reconstruction strategy based on tumor location and bone strength score, recommending biological reconstruction for diaphyseal tumors with preserved epiphyses and low strength scores [8]. Their findings indicated that functional outcomes were comparable between biological and prosthetic reconstructions when patients were appropriately selected.

This report describes a unique case of long-segment humeral osteosarcoma managed with a hybrid approach – proximal endoprosthetic reconstruction combined with ECRT-based biological reconstruction of the diaphysis – preserving the distal humerus and elbow function.

Case Report

A 15-year-old right-hand-dominant female presented with insidious onset of pain and swelling in the left upper arm over 2 months. There was no history of trauma, fever, or weight loss. Examination revealed a firm, mildly tender swelling involving the proximal humerus, with restricted shoulder motion but preserved elbow and hand functions. Neurovascular examination was normal.

Radiographs demonstrated a long-segment mixed lytic-sclerotic lesion in the proximal epimetaphyseal location of the humerus with extraosseous soft tissue and osteoid matrix (Fig. 1). Magnetic resonance imaging showed that the lesion involved the proximal epiphysis and diaphysis, sparing only the distal 3 cm (Fig. 2). No skip lesions were identified. Computed tomography of the chest and whole-body bone scan were negative for metastases. Core needle biopsy revealed high-grade conventional osteosarcoma.

Following diagnosis, the patient received neoadjuvant chemotherapy with the mean arterial pressure protocol (methotrexate, adriamycin, and cisplatin) over 10 weeks. She responded well clinically and radiologically, with reduction in pain and swelling and decreased soft tissue involvement.

Surgical management

Given the tumor extent and skeletal maturity, a decision was made to perform wide en bloc excision of the tumor followed by limb salvage using a hybrid reconstructive approach. Total humerus replacement was avoided to preserve distal growth and elbow joint function. The surgical plan included wide resection of the proximal and mid-humerus (approximately 17 cm), preservation of the distal 3 cm of the humerus, proximal reconstruction with a cemented modular prosthesis, and mid-diaphyseal reconstruction using ECRT.

Under general anesthesia, the tumor was resected with oncological margins, preserving the distal humerus and elbow

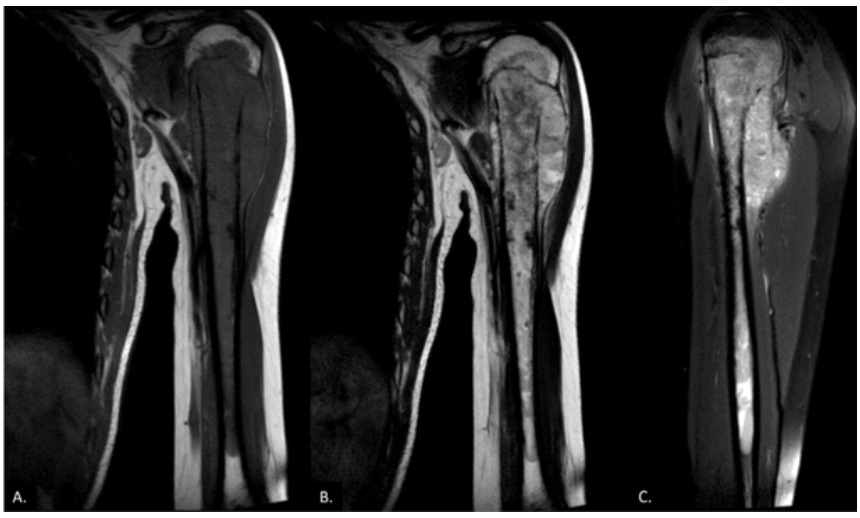

Figure 2: Pre-operative anteroposterior (a) and lateral (b) radiographs of the left arm demonstrating a mixed expansile lytic-sclerotic lesion in the proximal epimetaphysis of the humerus, accompanied by extraosseous soft-tissue extension and periosteal elevation.

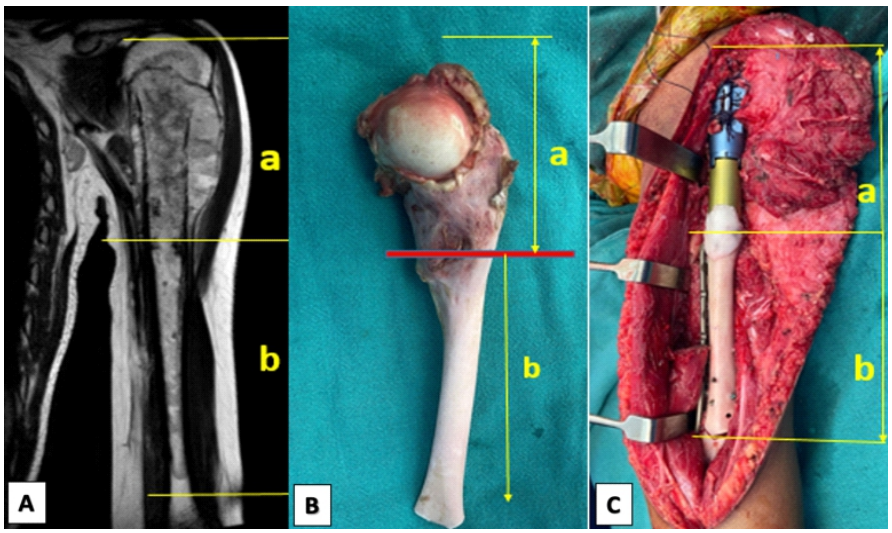

Figure 3: Intraoperative photographs detailing the hybrid reconstruction technique. The en bloc resected proximal humerus specimen is measured to determine the precise length for the intercalary graft (a and b). Following extracorporeal radiotherapy, the devitalized autograft is reimplanted and secured using a custom proximal endoprosthesis cemented into the graft, augmented with a locking compression plate fixed to the preserved distal humerus (c).

joint (Fig. 3). The excised diaphyseal segment was transported for ECRT and irradiated with a single 50 Gy dose. After sterilization, the autograft was reimplanted and fixed to the distal segment using a locking compression plate. The proximal prosthesis was cemented into the reimplanted graft and secured with a plate-screw construct. The rotator cuff was reattached to the prosthesis using heavy sutures.

Histopathology

The gross specimen measured 10 × 3.5 × 3 cm. The medullary cavity showed a 6 cm cavity with a 1 cm luminal diameter, and a yellow-gray lesion of 4 × 1 cm located 2 cm from the resection margin. Microscopy revealed scant residual tumor within the medullary cavity. Tumor cells were moderate to markedly pleomorphic, with coarse chromatin and occasional giant cells. Significant chemotherapy-induced changes were observed, including extensive fibrosis, hyalinization, hemorrhage, and lacy osteoid deposition. Mitotic rate was low (2/10 HPF), including atypical forms. There was no lymphovascular invasion identified, and bone resection margins were free of tumor. The case was staged as pT1 (ypT1, AJCC 8th edition). Histologic grade was G3 (poorly differentiated) (Fig. 4).

Outcome

Postoperatively, the arm was immobilized in a sling for 4 weeks to protect the soft-tissue reconstruction, followed by the initiation of cautious passive range-of-motion exercises. X-rays showed a stable fixation of the hybrid composite construct (Fig. 5). Active physiotherapy began at 6 weeks with a focus on maximizing distal joint mobility and strengthening the preserved musculature. Adjuvant chemotherapy was resumed after complete wound healing without any delays. At the 18-month follow-up, the patient demonstrated an excellent functional recovery and reported being entirely pain-free. The functional assessment yielded a Musculoskeletal Tumor Society (MSTS) score of 26 out of 30 and a Disabilities of the Arm, Shoulder, and Hand score of 12, indicating high function with minimal upper extremity disability.

Physical examination revealed a highly functional and stable preserved elbow joint with a range of motion consisting of 130° of flexion, an extension lag of only 5°, and full forearm supination and pronation of 80° each. Shoulder active abduction and forward flexion were limited to 60° and 70°, respectively, an expected consequence of the extensive deltoid and rotator cuff resection; however, the patient successfully returned to routine daily activities and schooling with excellent structural integration of the graft.

Discussion

Limb salvage surgery with joint preservation allows pediatric and adolescent patients with humeral malignancies to retain

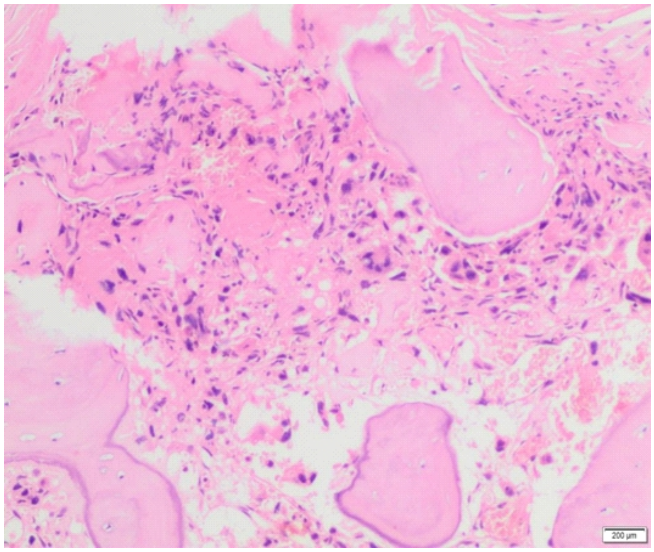

Figure 4: Histopathological examination (×40) of the resected specimen showing scant residual malignant mesenchymal cells with hyperchromatic nuclei and moderate cytoplasm within the intertrabecular spaces. The field demonstrates extensive hyalinization, fibrosis, and lacy osteoid deposition, consistent with a poorly differentiated, high-grade conventional osteosarcoma (ypT1).

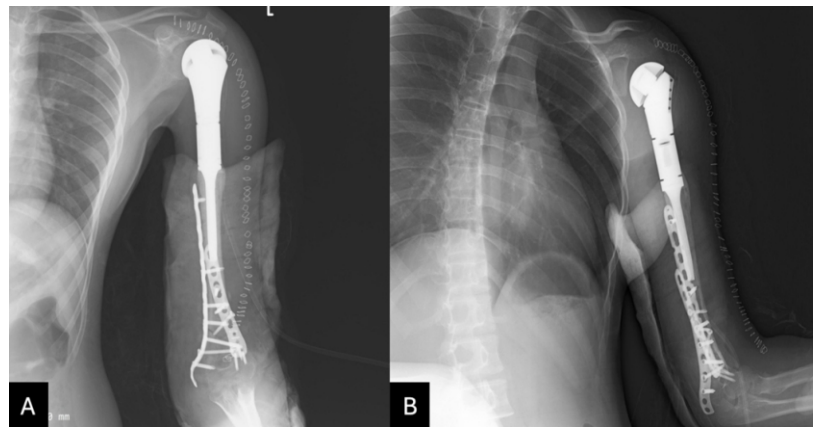

Figure 5: Post-operative anteroposterior (a) and lateral (b) radiographs confirming the anatomical alignment and stable fixation of the hybrid composite reconstruction, showing the proximal humeral endoprosthesis and the lateral locking plate securing the irradiated autograft to the distal humerus.

critical function while maintaining oncologic safety. Zhao et al.'s retrospective series of 28 patients with diaphyseal or metaphyseal humeral malignant tumors offers a valuable framework, using tumor origin, location, and bone strength scoring to guide reconstruction type [8].

Their data suggest that biological reconstruction – such as devitalized autograft replantation – is most suitable when the bone strength score is low (≤10), and the tumor is confined to the diaphysis or metaphysis with an uninvolved epiphysis. In their series, the biological group (mean score 9.7 ± 1.3) achieved excellent MSTS outcomes (27.2) comparable to the prosthetic group (26.1), with no statistically significant difference ($P > 0.05$) [8].

Extracorporeal irradiation offers several advantages. The technique preserves the natural shape and joint articulation, allows for potential osteointegration, and avoids immunologic or disease transmission risks associated with allografts [7, 9]. Multiple studies report satisfactory mechanical strength in irradiated segments, especially for diaphyseal intercalary reconstructions [10].

In the present case, the hybrid approach balanced the need for early mechanical stability (via prosthesis) and long-term biological durability (via ECRT). The preserved distal segment permitted rigid fixation and avoided a total humeral prosthesis, which often results in poor shoulder and elbow function. The literature suggests that failure rates are significantly lower in ECRT reconstructions involving diaphyseal regions than in joint-involved grafts [11]. Common complications include infection, non-union, and graft fracture; however, these risks are mitigated with precise fixation and aseptic technique [7, 11].

Moreover, ECRT is cost-effective and widely applicable in resource-constrained settings where allografts or custom prosthetics may not be readily available [12]. The irradiated bone, though devitalized, serves as an ideal scaffold for creeping substitution over time, which was observed radiographically in our case.

At 18-month follow-up, the patient had no local recurrence or metastasis, showed evidence of graft union, and retained functional elbow movement. The shoulder abduction was limited to 60°, acceptable given resection of the deltoid and rotator cuff. The MSTS score of 24/30 reflected good functional recovery.

This case supports the decision-making approach advocated by Zhao et al., favoring biological reconstruction when anatomical and mechanical conditions permit. Combining prosthetic and biological methods enables tailored reconstruction, especially in growing children, allowing durable, functional, and oncologically sound outcomes.

Conclusion

In pediatric patients with extensive humeral osteosarcoma, hybrid reconstruction combining a proximal megaprosthesis with ECRT-based autograft reimplantation offers a promising strategy. It ensures wide tumor clearance while preserving limb function and skeletal integrity. When distal joint preservation is possible, this approach avoids total humeral replacement and supports better long-term outcomes. Proper case selection, rigid fixation, and meticulous surgical planning are essential for success. ECRT, particularly in the diaphyseal region, remains a valuable biological option, especially in children where durability, growth potential, and cost are important considerations.

Clinical Message

For pediatric patients presenting with long-segment humeral osteosarcoma, a hybrid reconstruction utilizing a proximal megaprosthesis combined with extracorporeal radiotherapy (ECRT)-sterilized autograft reimplantation represents a highly effective limb-salvage strategy. When tumor anatomy allows for the preservation of the distal humerus, avoiding a total humeral prosthesis through rigid distal plate fixation significantly enhances long-term elbow function, mechanical stability, and skeletal integrity while maintaining oncological safety.

Declaration of patient consent: The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given the consent for his/ her images and other clinical information to be reported in the journal. The patient understands that his/ her names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

Conflict of interest: Nil **Source of support:** None

References

1.Mirabello L, Troisi RJ, Savage SA. International osteosarcoma incidence patterns in children and adolescents, middle ages and elderly persons. Int J Cancer 2009;125:229-34.

2.Geller DS, Gorlick R. Osteosarcoma: A review of diagnosis, management, and treatment strategies. Clin Adv Hematol Oncol 2010;8:705-18.

3.Aponte-Tinao LA, Ayerza MA, Muscolo DL. Allograft-prosthetic reconstruction of the proximal part of the humerus. J Bone Joint Surg Am 2002;84:718-25.

4.Anninga JK, Gelderblom H, Fiocco M, Kroep JR, Taminiau AH, Hogendoorn PC, et al. Prognostic factors in osteosarcoma: A review. Eur J Cancer 2011;47:59-66.

5.Biau DJ, Odumala OA, Campion D, Pelet S, Letson GD. Reconstruction after bone tumor resection in children. J Bone Joint Surg Br 2006;88-B:95-100.

6.Manfrini M, Gasbarrini A, Malaguti C, Cerisoli M, Bacci G, Mercuri M. Intraoperative extracorporeal irradiation of bone segments for tumor sterilization. J Pediatr Orthop 2004;24:303-8.

7.Puri A, Gulia A, Hawaldar R, Rangarajan V, Syed Hasan Q, Desai S. Functional and oncological outcomes after extracorporeal irradiation and re-implantation of tumour-bearing bone segments. Bone Joint J 2014;96-B:1118-21.

8.Zhao J, Zhao Z, Li J, Yin J, Wang B. Tumor location and bone strength score are useful in selecting biological and non-biological reconstruction for humeral malignancies. BMC Surg 2019;19:130.

9.Krieg AH, Mani M, Speth BM, Stalley PD. Extracorporeal irradiation for local treatment of bone tumors. J Bone Joint Surg Br 2010;92-B:862-9.

10.Uyttendaele D, De Schryver A, Claessens H, Roels H, Berkvens P, Mondelaers W. Limb conservation in primary bone tumours by resection, extracorporeal irradiation and re-implantation. J Bone Joint Surg Br 1988;70:348-53.

11.Sanjay BK, Moreau PG, Younge DA. Extracorporeal irradiation and reimplantation in limb salvage for bone tumors. Clin Orthop Relat Res 1999;358:111-22.

12.Abudu A, Carter SR, Grimer RJ, Tillman RM. Extracorporeal irradiation and reimplantation in primary bone tumours. J Bone Joint Surg Br 1996;78:878-82.

Conflict of Interest: Nil
Source of Support: Nil

Consent: The authors confirm that informed consent was obtained from the patient for publication of this article

How to Cite this Article

Kantiwal P, Adnan SM, Suhail A, Singh M, Chawla S, Khera S. Hybrid Prosthetic and Biological Reconstruction Using Extracorporeal Radiotherapy for Long-Segment Humeral Osteosarcoma: A Case Report. Journal of Orthopaedic Case Reports 2026 September;16(09): 374-378.