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Outcomes of hemicortical resection and reconstruction with liquid nitrogen-treated autograft for high-grade sarcomas: A retrospective case series

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ABSTRACT

Hemicortical resection (HCR) is a limb salvage option for eccentrically located bone sarcomas that allows preservation of native bone stock and nearby joint anatomy. Evidence on outcomes in high-grade extremity sarcomas remains limited. We performed a retrospective case series of consecutive patients undergoing HCR for high-grade primary malignant bone tumors of the extremities. Collected variables included demographics, tumor type and location, systemic therapy, local radiotherapy, radiographic union, time to union, complications, local recurrence, distant metastasis, survival status, and last follow-up. Five patients were included (mean age 14.2 years; 3/5 female). Diagnoses were Ewing sarcoma (n = 3) and osteosarcoma (n = 2). Sites were distal femur (n = 2), proximal tibia (n = 1), distal tibia (n = 1), and tibial shaft (n = 1). One patient received local radiotherapy. Union was achieved in all cases. Median time to union was 8.2 months (mean 11.1; range 4.4–18.9). Median follow-up was 20.8 months (mean 19.3; range 11.7–23.4). Complications included one infection treated with antibiotics and one late implant exposure requiring debridement and flap coverage. No local recurrences, distant metastases, or deaths were observed at last follow-up. In this small series, HCR with biological reconstruction achieved universal union and a low early complication rate. No local recurrence, distant metastasis, or death was observed during the available follow-up; however, oncologic safety cannot be inferred from this limited cohort, and larger studies with longer follow-up are required.

INTRODUCTION

Limb salvage surgery has become the standard of care for most localized high-grade extremity sarcomas when wide margins are achievable and function can be preserved[1]. Multiple methods of limb salvage exist, including megaprostheses and biological reconstruction with autografts and allografts. Hemicortical resection (HCR) can be used as a biological reconstruction method with either allograft or autograft in eccentrically based cortical lesions.

These lesions involve part of the circumference of a long bone and can be excised with oncologic safety while preserving the remaining cortex and the native joint[2-4]. The rationale for HCR is to minimize bone loss, preserve the joint, and reduce reconstructive complexity compared with segmental or osteoarticular resections[2-4].

Reconstruction options after HCR include allograft, vascularized or non-vascularized fibula, and recycled tumor-bearing autograft devitalized by methods such as liquid nitrogen (LN), pasteurization, irradiation, or ethanol[5-7]. Among these, LN-treated autograft is widely used because it delivers rapid, deep cytocidal temperatures while preserving collagen architecture and osteoconductive properties of bone, which are important for union and durability of recycled autografts[5,6].

The literature on HCR remains limited to small international series, with none originating from our region[3,4,8]. We report our five-patient experience with HCR for high-grade extremity sarcomas, emphasizing union, early complications, and short-term oncologic outcomes.

MATERIALS AND METHODS

Study design and setting

This was a retrospective case series conducted within the musculoskeletal oncology service at Shaukat

Khanum Memorial Cancer Hospital & Research Centre, Lahore, Pakistan. Institutional review board exemption was obtained (EX 23 10 25 03).

Eligibility

Consecutive patients with high-grade primary malignant bone tumors of the extremities treated by hemicortical resection were included. Benign lesions and palliative resections were excluded.

Preoperative work-up and planning

All patients underwent MRI of the involved bone, CT chest, bone scan, and core needle biopsy. Resection planes were planned on MRI to achieve a planned wide resection while preserving uninvolved host cortex.

Margin assessment and pathology strategy

The recycled hemicortical segment itself cannot be used for definitive histologic bony margin assessment after devitalization. In our operative protocol, the biopsy tract was excised en bloc, and separate specimens were submitted from (1) proximal and distal host bone osteotomy surfaces, with curettings taken immediately after osteotomy and before recycling, and (2) the soft-tissue/periosteal cuff removed from the bone and sent for histopathology. Intraoperative frozen section assessment of soft tissue and host bone interface samples was performed. Once frozen sections were reported negative, the bone was suspended in liquid nitrogen for treatment. This approach allows assessment of host-side and soft-tissue margins, although it does not provide a measured histologic margin width through the recycled cortical segment, which remains a limitation of the procedure.

Surgical technique

After en bloc hemicortical wedge resection, residual soft tissue was removed from the resected segment. The medullary surface was curetted, and multiple drill holes were created to prevent graft fracture due to sudden temperature changes and to facilitate later revascularization. The segment was then devitalized using a liquid nitrogen protocol: immersion in liquid nitrogen for 20 minutes, thawing at room temperature for 15 minutes, followed by thawing in sterile distilled water or saline for 10 minutes. The recycled segment was reimplanted to anatomically match the defect.

Fixation and reconstruction principles

Reconstruction was stabilized with plate-and-screw fixation spanning the host-graft junctions. A locking compression plate construct was used, aiming for rigid fixation with at least three bicortical screws on each side of the junction and compression across interfaces where feasible. Soft-tissue coverage was performed as needed; one case required a gastrocnemius flap and skin graft.

Outcomes and definitions

Union was defined as the first radiographic evidence of bridging at the host-graft interface with pain-free functional use, as determined by the senior orthopedic surgeons among the authors. Time to union was calculated from the date of surgery to the first radiographic union. Complications were recorded, including infection, wound or implant problems, fracture, and nonunion. Functional outcome was assessed using the Musculoskeletal Tumor Society (MSTS) score at the most recent clinic follow-up. Oncologic outcomes included local recurrence, distant metastasis, and survival status at last follow-up. Given the small sample and absence of oncologic events, outcomes were reported descriptively without time-to-event analysis.

RESULTS

Five patients underwent HCR for high-grade extremity sarcomas (mean age 14.2 years; 3/5 female). Histology comprised Ewing sarcoma (n = 3, 60%) and osteosarcoma (n = 2, 40%). Sites included distal femur (n = 2), proximal tibia (n = 1), distal tibia (n = 1), and tibial shaft (n = 1). All patients received chemotherapy per histology-specific protocols; one patient received local radiotherapy.

Union was achieved in all cases. Median time to union was 8.2 months (mean 11.1; range 4.4–18.9). Median follow-up was 20.8 months (mean 19.3; range 11.7–23.4). One patient developed a superficial wound infection managed with antibiotics. One patient developed late implant exposure requiring debridement and flap coverage. No fractures or nonunions occurred.

At last follow-up, there were no local recurrences or distant metastases, and all patients were alive. Functional outcomes were high, with MSTS percentages averaging 84.0% (range 76.7–90.0%) (Table I).

DISCUSSION

In this five-patient HCR cohort for high-grade extremity sarcomas, we observed universal union (median time to union 8.2 months) and a low early

complication burden. During a median follow-up of 20.8 months, no local recurrence or distant metastasis was observed, and all patients were alive (Table I; Figs. 1-3). Early complications were limited to one infection treated non-operatively and one late implant exposure requiring soft-tissue coverage, without mechanical failure or nonunion. The high MSTS score is consistent with the joint-preserving intent of HCR around the knee and proximal tibia, where preservation of articular geometry and ligament insertions may facilitate early recovery. While margin reporting through the recycled segment was not possible because the resected bone was treated in liquid nitrogen and used as an autograft, several frozen sections from host bone and soft tissue were used to confirm negative margins during surgery. The soft-tissue sleeve and periosteum were sent for margin examination and to determine tumor necrosis where possible. Allografts, when available, can avoid the need for bone recycling and provide bone for histopathological analysis, but allograft use is itself associated with high complication rates[11]. The absence

Table I. — Case series of outcomes of hemicortical resections and baseline characteristics.

Serial No	Age (y)	Sex	Histology	Tumor location	NACT + ACT	RT	Time to union (mo)	LR	DM	Follow-up (mo)	MSTS (%)	Complications
1	11	male	osteosarcoma	Distal femur	Yes	no	4.4	no	no	23.4	90.0	infection
2	14	female	Ewing sarcoma	Distal tibia	Yes	no	18.9	no	no	22.1	76.7	none
3	16	female	Ewing sarcoma	Proximal tibia	Yes	no	8.2	no	no	20.8	83.3	none
4	19	female	osteosarcoma	Tibial shaft	Yes	no	15.7	no	no	18.6	83.3	Late implant exposure
5	11	male	Ewing sarcoma	Distal femur	Yes	yes	8.1	no	no	11.7	86.7	none

Abbreviations: NACT + ACT = neoadjuvant + adjuvant chemotherapy; RT = radiotherapy; LR = local recurrence; DM = distant metastasis; MSTS = Musculoskeletal Tumor Society score.

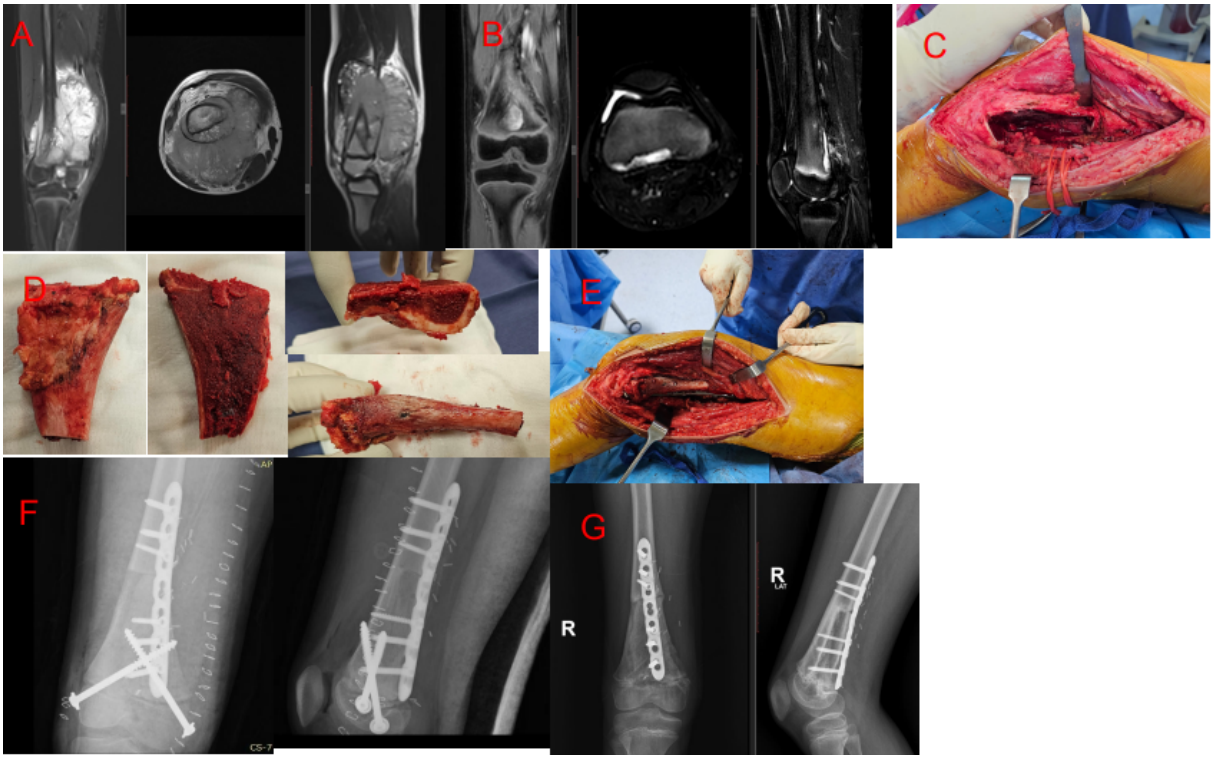

Fig. 1 — Representative case of hemicortical resection (HCR) and biological reconstruction.
(A, B) Preoperative and post-neoadjuvant chemotherapy imaging demonstrating a high-grade sarcoma. (C) Intraoperative hemicortical resection. (D) Resected specimen before liquid nitrogen treatment. (E) Reimplantation and fixation of the treated resected bone. (F) Immediate postoperative radiographs after hemicortical resection, liquid nitrogen-treated recycled autograft reimplantation, and plate fixation. (G) Follow-up radiographs demonstrating graft incorporation/union without evidence of local recurrence.

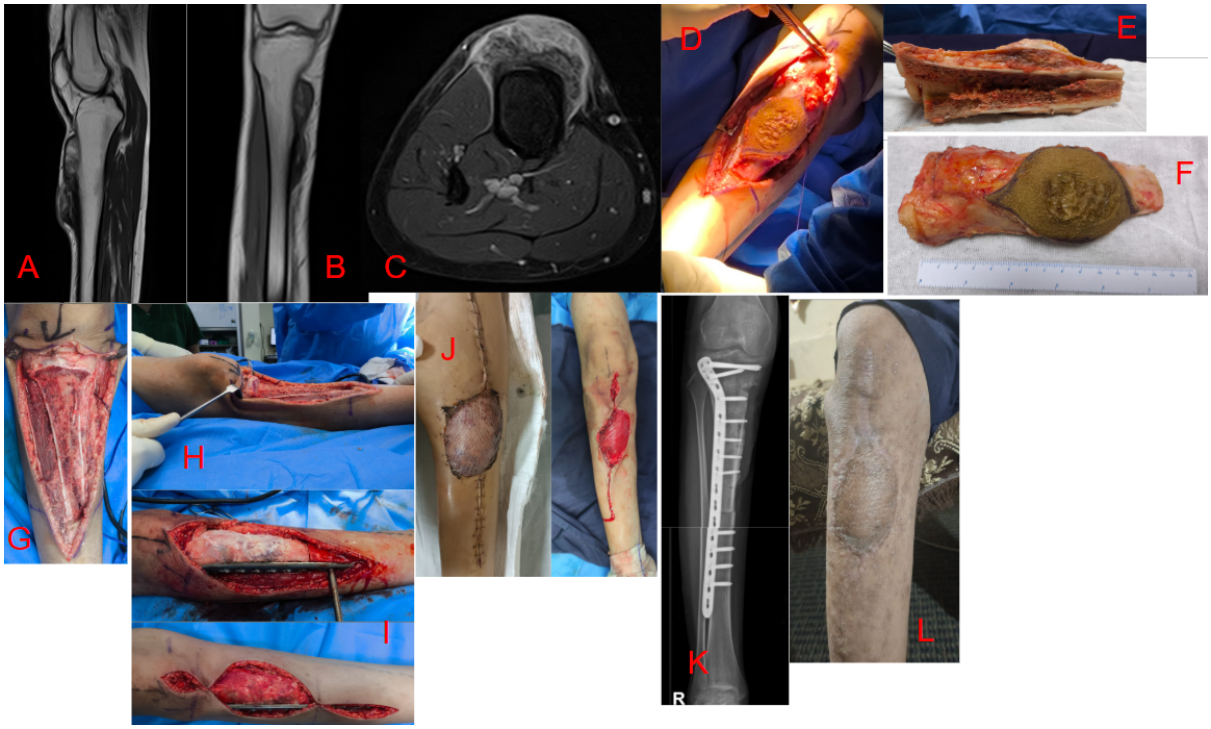

Fig. 2 — Key steps of hemicortical resection and liquid nitrogen (LN) recycled autograft reconstruction.
(A-C) Preoperative imaging showing hemicortical involvement by high-grade sarcoma. (D-I) Hemicortical wedge resection, graft preparation, and reimplantation while preserving the uninvolved host cortex. (J) Coverage with gastrocnemius flap and skin graft. (K) Rigid internal fixation to restore stability and alignment. (L) One-year postoperative clinical appearance with good cosmesis.

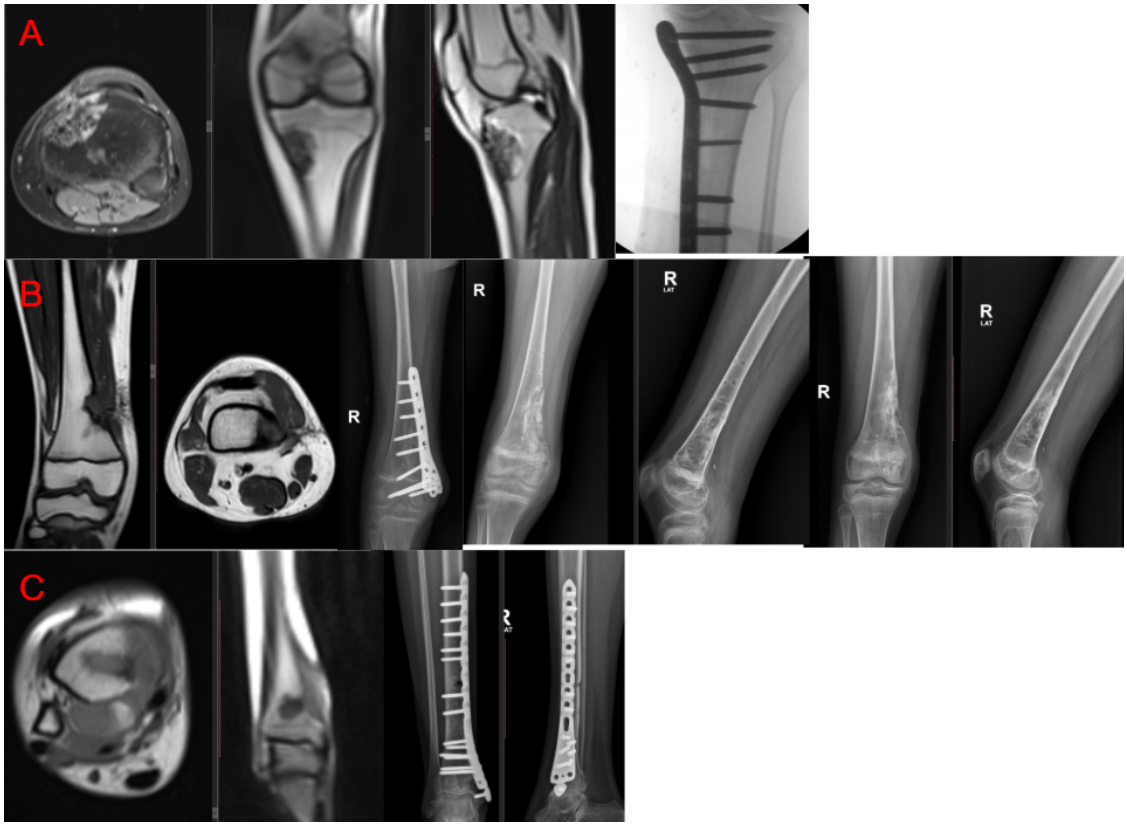

Fig. 3 — Pre- and post-resection imaging of patients undergoing hemicortical resection and reconstruction with rigid fixation.

of local recurrence in this small cohort is reassuring, but should be interpreted cautiously given the limited sample size and short follow-up. Careful MRI-based planning, meticulous execution of wide planes, and stable fixation remain essential.

Historically, HCR was primarily reserved for low-grade surface tumors and select benign or aggressive benign etiologies, such as parosteal osteosarcoma, adamantinoma, and osteofibrous dysplasia, where the eccentric cortical pattern and favorable biology allowed partial cortex resection with biological reconstruction and high functional scores[2,4-8]. As multimodal care has matured through improved MRI planning, neoadjuvant regimens, rigid fixation, and improved biological constructs, several centers have cautiously extended HCR to carefully selected high-grade lesions with true wide planes, particularly around the knee, seeking to preserve native joint mechanics without compromising oncologic safety[3,4,8,9]. Our results of 100% union and no early local recurrence or distant metastasis align with this evolution in indication, while emphasizing the need for meticulous planning and robust fixation.

Published experiences with LN-treated recycled autograft consistently report union within approximately 6-12 months and good to excellent function in most patients, with long-term series showing autograft survival of approximately 80-85% at 5-10 years[5,6]. Complications cluster in osteoarticular constructs, including infection and fracture, whereas intercalary segments perform best. Within the HCR domain, small high-grade osteosarcoma cohorts and larger parosteal osteosarcoma series using LN-treated, pasteurized, or allograft reconstructions report high union rates and MSTS scores of approximately 85-95% when margins are adequate, supporting oncologic safety in eccentric cortical lesions[3,4,8,9]. Several studies comparing devitalization methods suggest that liquid nitrogen achieves rapid, deep cytocidal temperatures while preserving collagen and osteoconductive architecture, translating to predictable tumor lysis and favorable union compared with ethanol and some alternatives. Our union rate is comparable to the available literature, with an 8.2-month median time to union[5,7]. For borderline stability scenarios, such as long segments or partial articular involvement, autograft-prosthesis composites that combine LN-treated biology with mechanical reliability have achieved union in approximately 4-13 months and MSTS scores of approximately 70-80%, providing an alternative in selected scenarios[10].

Two developments are likely to sharpen indications and execution of HCR in the coming years. First, patient-specific, 3D-printed cutting jigs and navigation- or augmented reality-assisted osteotomies can translate MRI and CT planning into precise cortical windows that respect planned margins while maximizing host-bone preservation. Second, patient-specific fixation, such as contoured locking plates and custom augments, and adjuncts such as vascularized fibula augmentation or antibiotic-loaded carriers may further reduce mechanical and infectious complications and support earlier rehabilitation[12,13]. As these technologies diffuse, prospective data should test whether precision osteotomy and custom fixation shorten time to union and decrease failure modes without compromising margins.

Our findings reinforce HCR as a joint-sparing option for select eccentric high-grade lesions when wide margins are feasible. We recommend prospective standardization of margin width, complication capture, and MSTS or Toronto Extremity Salvage Score assessment. Larger, prospective multicenter cohorts are needed to refine indications and benchmark HCR against segmental resection with endoprostheses.

CONCLUSION

Hemicortical resection with reconstruction using liquid nitrogen-treated recycled autograft achieved universal union and favorable early functional outcomes in this small series of high-grade extremity sarcomas. No oncologic events were observed during short-term follow-up; however, definitive conclusions regarding oncologic safety require larger cohorts and longer follow-up.

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