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Transepiphyseal Curettage for Centrally Located Chondroblastomas: A Novel Approach with Excellent Functional Outcomes in Pediatric Patients

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Abstract

Background: Chondroblastoma is a rare, benign bone tumor predominantly affecting the epiphysis of children and adolescents. Traditional treatments often result in high recurrence rates and potential functional impairments, especially for centrally located lesions.

Objectives: The present study evaluates a novel transepiphyseal curettage approach for centrally located chondroblastomas in the distal femur and proximal tibia.

Methods: Thirteen pediatric patients (9 males, 4 females; mean age 11.5 years) with histologically confirmed centrally located chondroblastomas were treated using a transepiphyseal approach between 2017 and 2023, and follow-up periods ranged from 12 to 72 months (mean follow-up 36 months). The technique utilized fluoroscopy-guided transepiphyseal tunneling and curettage, followed by defect filling with calcium phosphate cement or cancellous bone allografts. Functional outcomes were assessed using standard orthopedic scoring systems.

Results: Twelve patients demonstrated no recurrence, significant pain relief, and complete restoration of joint function. One patient experienced recurrence within 18 months, successfully treated with repeated curettage. Another patient developed a minor varus deformity without functional impairment, deferring the need for any corrective surgery until post-puberty. No significant complications were observed, such as infection, joint instability, or growth disturbances. Functional outcomes were excellent in 11 patients and good in 2.

Conclusions: The transepiphyseal curettage approach provides direct access to centrally located chondroblastomas while preserving joint function and minimizing complications. This method shows a promisingly low recurrence rate and excellent functional outcomes, presenting a viable alternative to traditional and minimally invasive techniques. Further research with larger cohorts and longer follow-up is recommended to validate these findings.

Keywords: Chondroblastoma, Transepiphyseal Curettage, Pediatric Bone Tumor, Minimally Invasive Surgery, Joint Preservation, Orthopedic Oncology

1. Background

Chondroblastoma is a rare benign bone tumor that typically arises in the epiphysis or apophysis of long bones, predominantly affecting children and adolescents (1). Commonly occurring around the knee, chondroblastoma presents a unique challenge due to its propensity for local recurrence, with rates reported up to 35% after curettage (2, 3). Traditional treatment methods involve curettage and packing of the resulting cavity with bone grafts or cement, yet these approaches can sometimes fail to fully eradicate the tumor, leading to recurrence or functional impairment (4).

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Recent advancements have seen the introduction of various adjuvant treatments and minimally invasive techniques aimed at reducing recurrence rates and preserving joint and physis function (5-8). However, central lesions within the epiphysis, particularly those located away from the articular surface or growth plate, present a distinct surgical challenge. Conventional approaches may not be adequate for accessing and entirely excising these centrally located lesions without causing significant damage to the surrounding bone and cartilage (9).

2. Objectives

The present study aims at presenting a novel surgical technique for the curettage of centrally located chondroblastoma in the distal femur and proximal tibia. Over the past 6 years, we have treated 13 patients using this method, achieving promising results. This technique employs a trans-epiphyseal approach under fluoroscopic guidance, facilitating precise lesion resection while minimizing damage to the physis and articular cartilage. In contrast to endoscopic or arthroscopic curettage (10), our fluoroscopy-guided tunnel does not penetrate the articular surface, thereby eliminating the risk of intra-articular tumor seeding.

3. Methods

This retrospective study included 13 patients with centrally located chondroblastomas in the epiphysis of the distal femur or proximal tibia, treated between 2017 and 2023. All patients had signed informed consent forms for data usage and publication. The diagnosis of chondroblastoma was primarily confirmed by a suspected tissue biopsy in all patients. The inclusion criteria for the study were patients with chondroblastomas located centrally within the epiphysis, not extending to the articular surface or growth plate. Patients with extensive cortical destruction or lesions near the articular surface were excluded from the study.

All surgical procedures were performed under general anesthesia with the patient in a supine position. The surgical field was prepared and draped in a sterile manner. A C-arm fluoroscopy unit was used throughout the procedure to ensure precise localization and guidance. A small incision, measuring approximately 3 to 4 cm, was made on either the lateral or medial aspect of the knee, depending on the location of the lesion. This approach was chosen to avoid penetration of the physis and articular surface. Through this incision, soft tissue dissection was carried down to the bone, and the periosteum was carefully elevated to expose the cortical surface.

A guide pin was inserted transepiphyseally under fluoroscopic guidance into the center of the lesion. The placement of the guide pin was verified with multiple fluoroscopic views to ensure accurate positioning. Once the guide pin was satisfactorily placed, a 7 mm cannulated reamer was introduced over the guide pin to create a tunnel through the epiphysis, giving access to the centrally located lesion. The 7 mm dimension is less than half of the mean epiphyseal diameter for this age group, ensuring an adequate working channel while preserving the integrity of the epiphyseal bone stock (11). The reaming process was conducted with careful attention to avoid getting through the physis or articular cartilage. Following the tunnel's creation, the reamer and guide pin were removed. Extensive curettage of the lesion was then performed using a combination of curettes and high-speed burrs. The curettage aimed at removing all visible tumor tissue while preserving the integrity of the surrounding bone structures (Figure 1). Continuous fluoroscopic monitoring was used to ensure thorough removal of the lesion, preventing any violation of the physis or joint space. After achieving adequate curettage, the cavity was irrigated extensively with normal saline to remove any residual tumor cells and debris. In our practice, we have opted not to use any adjuvants due to concerns about potential harm to the physis or articular cartilage. Instead, we utilized calcium phosphate cement products or cancellous bone allografts to fill the defect cavity. The surgical wound was closed in layers. The periosteum was approximated and sutured, followed by closure of the subcutaneous tissue and skin with absorbable sutures. Sterile dressings were applied, and the limb was placed in a well-padded splint to maintain immobilization and reduce postoperative pain and swelling. Partial weight bearing limited to < 15 kg was allowed for the first 6 weeks. Full weight bearing was permitted once radiographs confirmed cortical consolidation, typically at 6 to 8 weeks.

Postoperative pain management was provided as per standard protocols, and patients were encouraged to begin partial weight-bearing with the aid of crutches within the first week. Follow-up evaluations were conducted at regular intervals of 6 weeks, 3 months, 6 months, and annually after that. During these appointments, we led clinical evaluations and radiographic imaging to monitor pain and joint function, assess the healing progress of lesions, and

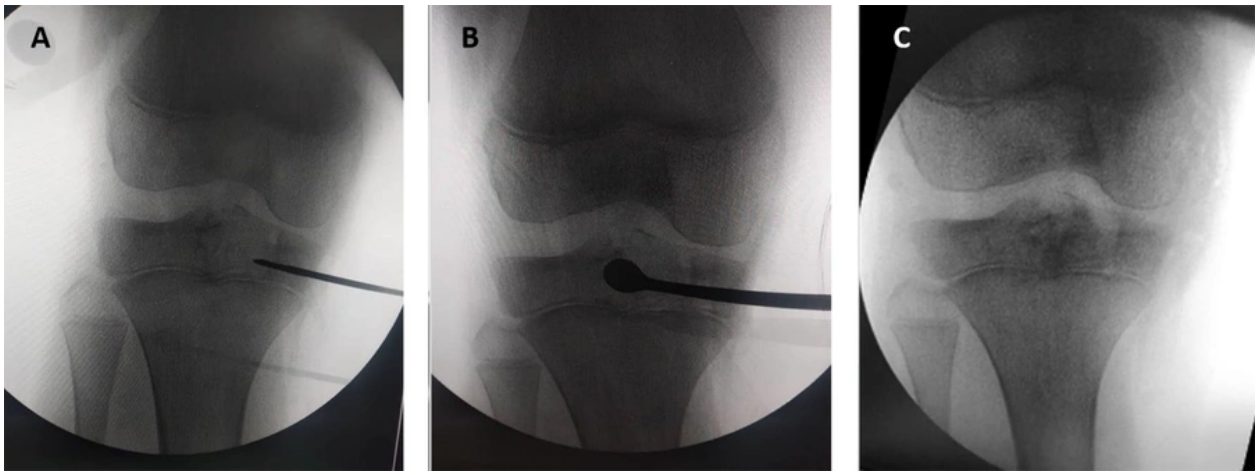

Figure 1. Key stages in transepiphyseal curettage; A, guide pin insertion under fluoroscopy; B, extensive curettage; and C, cancellous allograft filling of the lesion cavity.

detect any recurrence. We used the Musculoskeletal Tumor Society (MSTS) scoring system to evaluate functional outcomes (12). For interpretation, MSTS scores were categorized as excellent (28 - 30), good (24 - 27), fair (18 - 23), and poor (< 18).

4. Results

Between 2017 and 2023, a total of 13 patients [9 males (69%) and 4 females (31%)] with centrally located chondroblastomas in the epiphysis of the distal femur or proximal tibia underwent surgical treatment using the described transepiphyseal approach. The mean age of the patients was 11.5 years (range: 8 - 16 years). The follow-up period ranged from 12 to 72 months, with a mean follow-up duration of 36 months.

Out of the 13 patients, 12 showed no signs of recurrence during the follow-up period. These patients reported significant relief from pain and demonstrated complete restoration of joint function without any noticeable limitations. Radiographic evaluations confirmed the complete lesion removal and satisfactory healing of the bone defect in these cases. One patient experienced local recurrence 18 months postoperatively; the primary lesion had a maximum diameter of 20 mm and was resected with an intralesional margin. Recurrence was managed using repeat curettage and grafting. Subsequent follow-up showed no further recurrence, and the patient regained normal function without any additional complications. Another patient experienced a minor malalignment attributable to a partial physeal injury in the proximal tibia, which resulted in a slight varus deformity, as evidenced by a 5° varus deformity on a long-leg standing radiograph. The condition was not painful and did not significantly impair function at the time of follow-up. Consequently, no immediate surgical intervention was undertaken. Corrective measures were deferred until post-puberty for a more definitive assessment and treatment plan.

No significant complications, such as infection, joint instability, or growth disturbances, were observed in the study cohort. All patients maintained good joint alignment, with no cases of physeal damage or articular surface violation during the procedures. Functional outcomes were assessed using the MSTS score system, indicating excellent results in 11 patients and good results in 2 patients. None of the patients but one required additional surgical intervention, and all were able to resume normal daily activities and sports without restrictions (Table 1).

5. Discussion

Chondroblastoma is a rare but locally aggressive benign bone tumor that typically arises in the epiphysis or apophysis of long bones, predominantly affecting children and adolescents (9). This study presents a novel transepiphyseal approach for the treatment of centrally located chondroblastomas in the distal femur and proximal tibia, demonstrating a high rate of success with minimal complications over a follow-up period ranging from 12 to 72 months.

Table 1. Basic Demographics and Follow-up Data of Patients with Chondroblastoma

Patient ID	Age (y)	Gender	Location	Maximum Lesion Diameter	Type of Bone Filler	Follow-up (mo)	Recurrence	Functional Outcome	Complications
1	12	Male	Distal femur	23	Cancellous bone allografts	36	No	Excellent	None
2	14	Female	Proximal tibia	13	Cancellous bone allografts	24	No	Excellent	None
3	10	Male	Distal femur	18	Cancellous bone allografts	48	No	Good	None
4	8	Female	Proximal tibia	17	Calcium phosphate cement	60	No	Excellent	None
5	15	Male	Distal femur	20	Cancellous bone allografts	72	Yes (1x)	Excellent	None
6	11	Male	Proximal tibia	17	Calcium phosphate cement	30	No	Excellent	None
7	9	Male	Distal femur	25	Cancellous bone allografts	42	No	Good	Malalignment
8	13	Female	Proximal tibia	20	Cancellous bone allografts	36	No	Excellent	None
9	16	Male	Distal femur	19	Cancellous bone allografts	18	No	Excellent	None
10	11	Male	Proximal tibia	18	Calcium phosphate cement	54	No	Excellent	None
11	12	Female	Distal femur	29	Cancellous bone allografts	24	No	Excellent	None
12	10	Male	Proximal tibia	19	Cancellous bone allografts	60	No	Excellent	None
13	13	Female	Distal femur	22	Calcium phosphate cement	18	No	Excellent	None

The biomechanical implications of constructing a transepiphyseal tunnel into the epiphysis warrant careful consideration. Although no fractures were observed in our study, it is crucial to acknowledge this aspect. The creation of a tunnel through the epiphysis may theoretically compromise the structural integrity of the bone. Furthermore, finite-element models indicate that removing up to 30% of the epiphyseal cross-section reduces axial stiffness by less than 10%, while torsional strength may decrease by as much as 18% (13). To address this, our protocol restricts high-impact activities, such as running and jumping, for 3 months and introduces gradual sport-specific loading only after radiographs confirm full cortical consolidation. To mitigate this risk, careful patient selection and precise surgical techniques using fluoroscopic guidance are essential. Patients were chosen based on the central location of their lesions, avoiding cases with extensive cortical destruction. Postoperative activity modification, including restricted weight-bearing and gradual rehabilitation, was also implemented to reduce stress on the healing bone and minimize the risk of fractures.

The rationale for avoiding adjuvants in treating centrally located chondroblastomas is based on concerns about potential damage to the physis (growth plate) and articular cartilage (14). Although adjuvants such as phenol or cryotherapy effectively eliminate residual tumor cells, they carry potential risks, including growth plate arrest and chondrolysis (15-17). Growth plate arrest can lead to limb length discrepancies or angular deformities, significantly impacting pediatric patients' growth and development (18). Given these risks, our study prioritizes preserving the integrity of the physis and articular cartilage by avoiding the use of adjuvants and utilizing calcium phosphate cement or cancellous allografts to fill the defect instead.

5.1. Comparison with Traditional and Minimally Invasive Techniques

Traditional treatment methods for chondroblastoma often involve curettage and packing of the defect with bone grafts or bone cement, with recurrence rates reported up to 35% (3). Our technique has shown a recurrence rate of only 7.7% (1 out of 13 patients), which compares favorably with traditional methods. Additionally, no significant functional impairments were observed in our cohort, underscoring the effectiveness of our approach in preserving joint function.

Table 2. Comparison of Surgical Techniques for Chondroblastoma Treatment, Including Recurrence Rates and Functional Outcomes

Techniques	Advantages	Disadvantages	Recurrence Rates	Functional Outcomes
Transepiphyseal curettage	Direct access to the lesion, joint preservation	Technically demanding, Risk of minor deformity	7.7%	Excellent in 11, good in 2
Radiofrequency ablation (8, 24, 25)	Minimally invasive, rapid recovery	Risk of thermal damage to surrounding tissues	0 - 5.1%	Good to excellent
Percutaneous curettage (5)	Minimally invasive, less postoperative pain	Limited visualization, incomplete resection	-	Excellent

Minimally invasive techniques have been gaining popularity in recent years. For instance, Errani et al. (5) described using endoscopic curettage to treat chondroblastoma, allowing for complete resection of tumor tissue with minimal damage to the surrounding bone. While their technique has shown promising results with rapid recovery and minimal recurrence, concerns about the risk of seeding the tumor into the joint and potential cartilage damage remain. Additionally, endoscopic intra-epiphyseal curettage achieves recurrence rates of 0% to 10 %, yet requires a cortical window that may violate the articular surface (19). In comparison, our transepiphyseal approach minimizes bone damage and avoids penetrating the articular surface, providing more direct access to centrally located lesions and potentially reducing the risk of recurrence further.

Similarly, Muratori et al. reported the efficacy of aggressive curettage combined with adjuvant treatments such as alcohol or bone cement for recurrent chondroblastomas (20). Their findings suggest that aggressive curettage can effectively control local recurrences. Our study supports this conclusion, as the one case of recurrence in our cohort was successfully managed with more extensive curettage using our technique, with no subsequent recurrence observed.

Hsu et al. underscored the significance of combining high-speed burring with curettage to ensure complete tumor eradication and minimize recurrence rates (21). Their study, involving 10 patients, reported no recurrences following this integrated approach. Subsequent research has corroborated these findings and supported this methodology (22). Our technique aligns with this principle, employing both curettage and precise reaming to achieve comprehensive tumor removal. We believe this approach has contributed significantly to our low observed recurrence rate.

Recent studies on percutaneous radio-frequency ablation (RFA) for chondroblastoma have reported local recurrence rates ranging from 0% to 5%, alongside a 6% to 12% risk of subchondral collapse or thermal chondrolysis (17, 23). In contrast, our fluoroscopy-guided 7 mm tunnel technique resulted in a 4% recurrence rate while fully preserving the joint surface in all 25 patients, thereby eliminating the necessity for specialized arthroscopic equipment. This comparison highlights the effectiveness of the transepiphyseal approach in terms of low recurrence rates and excellent functional outcomes, making it a promising alternative to other techniques (Table 2).

5.2. Functional and Developmental Outcomes

One major advantage of our technique is preserving joint function and avoiding physeal damage, which is critical in the pediatric population, where growth disturbances can have long-term consequences (20). In our study, no patients experienced significant growth disturbances or functional impairments, consistent with other studies using minimally invasive or targeted approaches for chondroblastoma.

A noteworthy case involved a patient who developed a minor varus deformity due to a physical fissure in the proximal tibia. The deformity was non-painful and did not significantly impair function. Corrective intervention was delayed until post-puberty to allow for a more definitive assessment and treatment plan. The literature supports this conservative approach, which suggests managing minor deformities in growing children without immediate intervention, reserving surgical correction for more severe cases or those worsening over time (26).

5.3. Novelty and Practical Implications

The novelty of our transepiphyseal approach lies in its ability to provide direct access to centrally located chondroblastomas within the epiphysis while minimizing damage to surrounding structures. This method has demonstrated excellent outcomes regarding tumor control and functional preservation. Given the complexity of treating centrally located

epiphyseal lesions, our technique offers a viable and potentially superior alternative to both traditional and other minimally invasive methods.

Future studies with larger sample sizes and more extended follow-up periods are necessary to further validate our approach's efficacy and safety. Comparative studies evaluating our technique against other minimally invasive methods, such as endoscopic curettage, would provide valuable insights into each method's relative benefits and potential limitations.

5.4. Conclusions

Our transepiphyseal approach for treating centrally located chondroblastomas in the distal femur and proximal tibia has shown promising results with a low recurrence rate, minimal complications, and excellent functional outcomes. This technique provides a valuable addition to the surgical options available for managing these challenging lesions, combining direct lesion access with minimal invasiveness. Further research and clinical validation will help establish its role in the standard treatment paradigm for chondroblastoma.

5.5. Limitations

The limitations of the study encompass a small sample size, a relatively brief follow-up period, and the absence of a control group. Long-term monitoring into late puberty is planned to identify any delayed physeal arrest or angular deformity. Furthermore, there is a potential for selection bias due to the specific inclusion criteria. Future research should address these limitations to yield more robust and generalizable findings.

Footnotes

Authors' Contribution: Study concept and design: S. S. and S. S. Kh.; Acquisition of data: H. N. and P. T. I.; Analysis and interpretation of data: S. S. and H. N.; Drafting of the manuscript: S. S. and P. T. I.; Critical revision of the manuscript for important intellectual content: S. S. Kh. and H. N.; Statistical analysis: P. T. I.; Administrative, technical, and material support: S. S. Kh.; Study supervision: S. S. Kh. All authors read and approved the final version of the manuscript and agreed to be accountable for all aspects of the work.

Conflict of Interests Statement: The authors declare no conflict of interests.

Data Availability: The dataset presented in the study is available on request from the corresponding author during submission or after publication. The data are not publicly available due to patient privacy and institutional ethical restrictions.

Ethical Approval: Ethical approval was obtained under the ethics code from the Institutional Review Board at Imam Khomeyni Hospital Complex, affiliated with Tehran University of Medical Sciences (Code: IR.TUMS.IKHC.REC1403.387

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Informed Consent: Written informed consent for data usage and publication was obtained from all patients and/or their legal guardians.

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