

A NOVEL TECHNIQUE FOR BONE CYST ASPIRATION AND INJECTION: CT-GUIDED SINGLE-NEEDLE TECHNIQUE AS A SUCCESSFUL ALTERNATIVE TO THE CLASSIC TWO-NEEDLE APPROACH



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ABSTRACT

Background: Simple bone cysts (SBCs) are common benign lytic lesions in children and adolescents. Percutaneous simple bone cyst aspiration and steroid injection under computed tomography guidance is a well-known treatment method performed using a double-needle technique (DNT). We herein evaluated the utility of an alternative single-needle technique (SNT) in bone cyst aspiration/injection.

Methods: Data of 23 subjects who had undergone bone cyst aspiration and injection between January 2010 and December 2022 were retrieved from our archive. Twelve patients who were treated using SNT were compared with eleven patients who underwent DNT(control group). The demographic profiles and plain radiography data at baseline and within 24 months following treatment were reviewed. Radiological healing was assessed according to the modified Neer classification system. Fisher's exact test was performed to analyze the association between the procedure type and the outcome.

Results: The mean follow-up duration of all patients subjected to SNT was 11 months after the first intervention. The same procedure was repeated twice in four patients and three times in one patient. The cysts were healed or healed with defects in seven patients and remained persistent in five patients. After the second intervention, eight cysts were successfully treated. None of the cysts recurred or progressed following treatment. A comparable response rate was recorded in the control group after the first and second interventions. No statistically significant difference was observed between SNT and DNT.

Conclusions: Percutaneous bone cyst aspiration and injection using SNT is effective, less invasive, and less time-consuming than classic DNT with comparable outcomes

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Keywords: simple bone cyst, unicameral bone cyst, aspiration, injection, computed tomography

1. ABBREVIATIONS

SBC = simple bone cyst, UBC = unicameral bone cyst, MPA = methylprednisolone acetate, CT = computed tomography, MRI = magnetic resonance imaging

2. INTRODUCTION

Simple bone cysts (SBCs) are common benign lytic lesions typically located in the metaphysis of long bones in children and adolescents. The proximal humerus and proximal femur are the most common sites of involvement [1–3]. Although SBCs can heal spontaneously on their own when patients approach skeletal maturity, these lesions carry high pathological fracture risks, especially when located in weight-bearing areas, often making treatment necessary.

The aims of SBC treatment are to prevent pathologic fractures or re-fractures and promote cyst healing. Various open and percutaneous treatment options have been used to manage SBCs. However, minimally invasive techniques are usually preferred over surgical interventions because they are more cost-effective with comparable outcomes and shorter recovery times.

In 1974, Scaglietti introduced percutaneous intralesional steroid injection, which led to a revolution in the field of bone cyst management and provided the opportunity to explore other injectable materials, such as autologous bone marrow, allogenic demineralized bone matrix, and cement [4–7]. All previously published studies of percutaneous image-guided bone cyst aspiration/lavage with or without intralesional injection were performed using two large trocars/needles to simultaneously evacuate the cyst fluid and install the injectate in a closed-circuit system, thereby avoiding the risk of leakage into the surrounding tissues [4, 8, 9].

In this study, we developed a novel intralesional bone cyst aspiration/injection method using a coaxial single-needle technique (SNT) and evaluated the utility of this approach in comparison with the standard double-needle technique (DNT).

3. METHODS

3.1 Study design

This retrospective study received institutional review board approval, and the requirement for informed consent was waived. From January 2010 to December 2022, twenty-three patients with bone cysts who were referred to us from orthopaedic oncology for image guided bone cyst aspiration and injection were enrolled.

The demographic profiles and imaging findings on plain radiography at baseline and within 24 months following treatment were reviewed.

We excluded all patients with no baseline or post-treatment imaging follow-up, and bone cysts exposed to hybrid treatment methods or complicated by fracture between the intervention and follow-up.

3.2 Single needle procedural technique

Preprocedural assessments for all patients, including clinical, laboratory, and radiological assessments, were performed by an orthopedic oncologist and musculoskeletal radiologist, who decided whether the patient was eligible for percutaneous treatment.

After obtaining appropriate informed consent, all procedures were performed under either general anesthesia or conscious sedation and local anesthesia by musculoskeletal interventional radiologists. All treatments were performed using computed tomography (CT) guidance on a 64-slice scanner (GE Healthcare Systems, Chicago, IL, USA). Patients were placed in a prone, supine, or lateral decubitus position depending on the lesion location. Radiopaque grids were used to decide the optimal access site, which was marked with a pen. Under aseptic conditions, a skin incision was made using a scalpel blade after providing adequate local anesthesia using 1% lidocaine.

Intermittent CT guidance was used to access each bone cyst with a 12- or 14-gauge Bonopty penetration set (AprioMed, Uppsala, Sweden). Once the lesion was accessed, a Smartsite™ Extension Set (SKU/REF 20041E, BD, Franklin Lakes, NJ, USA) was securely placed in the cannula hub, and then 15-cm-long 18-gauge spinal needles (BD) or 15-cm-long 18-gauge Chiba needles (Cook Medical, Bloomington, IN, USA) were advanced into the cannula through the valve in a coaxial manner (any alternative coaxial bone biopsy set can be used for this purpose; Figure 1). Next, two 10-mL syringes were connected to the spinal needle and the extension tube sideways fluid path. The required instrument set is presented in Figure 1. Cyst fluid was not routinely collected for histological evaluation. Approximately 30–100 mL of 0.9% saline were used for cyst lavage, which was performed via an injection through the spinal needle and simultaneous passive cyst content aspiration

via the syringe connected to the extension tube under negative pressure. Once the contents were removed, methylprednisolone acetate (MPA) was injected into the cyst at a dose of 3 mg/mL cyst volume (a maximum dose of 160 mg per treatment session).

The procedure was repeated as necessary every 3–4 months depending on the cyst's healing response. Up to three sessions were required to obtain the desired healing effect.

Standard regular observation was performed 2–3 h after the procedure. Each patient's vital signs, sensory variables, and motor performance were examined every 30 min. Patients were discharged on the same day of the intervention.

3.3 Image and data analysis

Plain radiographs were used to assess the cysts volume, index, activity, and presence or absence of fracture at baseline. Radiological healing was assessed according to the modified Neer's classification system. Cysts were considered to be healed with the cyst cavity's complete filling by new bone formation (Grade 1) or partial sclerosis within a pre-existing cyst (Grade 2) was achieved [10]. The radiographs were reviewed by two fellowship trained musculoskeletal radiologists, and the findings were reported as a consensus opinion. The follow-up interval in our institution was not fixed, but still, most of the patients had a clinical and radiographic evaluation within 3–12 months post-procedure. At least a 2-year follow-up period was recommended.

3.4 Statistical analysis

Stata statistical software (StataCorp, College Station, TX, USA) was used to analyze the data. Descriptive statistics were reported for the patients' demographics, lesion size and location, and radiographic characteristics. The main outcome was the response. Fisher's exact test was performed to test the association between the procedure type and outcome after the procedure for the first and second response groups. $P < 0.05$ was considered statistically significant.

4. RESULTS

Between 2010 and 2022, 12 patients (mean age: 14.4 ± 7.7 years) with SBCs were treated using the developed technique. The cysts were healed or healed with defects after the first intervention in seven (58%) patients, and the remaining five (42%) patients had persistent cysts. The procedure was performed twice in four patients and three times in one patient. The Neer classification did not change in two of three patients who underwent a second intervention. Thus, a total of 8/12 (67%) patients were successfully treated after the second

intervention. None of the cysts recurred or progressed following the treatment. A fracture following a fall occurred 6 months after the intervention in a patient treated for a proximal femoral lesion. A control group of 11 subjects (mean age: 12.9 ± 5.6 years) was treated using standard DNT during the same period. A comparable response rate was observed in the control group (6/11 [55%]) after their first intervention, and a slightly higher rate (8/11 [73%]) than that in the intervention group was noted after the second intervention. The control procedure was performed two times in three patients and three times in one patient. There were no statistically significant differences in outcomes between SNT and DNT after the first and second interventions as shown in Table 1. The demographic data of both groups are reported in Tables 2 and 3. The total dose of MPA was not documented in most cases. The mean follow-up duration of all patients was 11 months after the first intervention.

A 14-year-old girl who underwent CT-guided bone cyst aspiration and steroid injection twice using SNT is provided as an example in Figure 2.

5. DISCUSSION

The management of SBCs varies significantly among orthopedic surgeons and institutions. Since Scaglietti's introduction of percutaneous steroid treatment for SBCs, this method has been favored over surgical intervention for achieving good clinical and radiological responses [4].

The exact etiology of the development of SBCs has not been established, but many theories have been proposed, including increased production of inflammatory markers, such as prostaglandin-E2 and interleukin-1, and gelatinase-induced bone resorption [11]. An alternative theory suggests that increased intraosseous pressure attributable to venous outflow obstruction leads to cyst formation [12–14].

In a recent meta-analysis by Kadhim et al., the rates of SBC healing for treatment with intralesional injections of bone marrow and MPA were 77.4% and 77.9%, respectively [15]. Traub et al. retrospectively compared bone cyst treatment options in 135 patients who underwent either conservative or surgical treatment options, including MPA injection, intramedullary nailing, and curettage with bone grafting [6]. The failure rate following intralesional steroid injection was 36.6%, which was comparable to our study and previous trials [12, 15, 16]. Furthermore, they reported that internal fixation in combination with steroid treatment showed a better outcome in the weight-bearing areas compared to isolated treatment.

The role of multiple cyst wall perforations in maintaining the communication between the cyst cavity and the adjacent normal marrow has been discussed by some researchers,

who also assessed the osteogenic effect of the injected bone marrow [11, 17]. Delloye et al. believed that the use of two large-gauge needles can cause more mechanical disruption and prolonged cyst decompression, thereby improving the clinical response [8]. Theoretically, it is difficult to separate mechanical effect, namely, cyst wall breach, from the effect of the injectable substance, including osteoinduction induced by bone marrow or anti-inflammatory effects induced by injected steroids.

Coaxial SNT was first performed (by Alshaalan) in 2010. This technique achieves the same effect as DNT by maintaining the intralesional pressure balance via relieving intralesional positive pressure, which can cause pain in the patient and increase the leakage risk, during the injection and simultaneously avoiding the negative-pressure effect, which also causes pain to the patient and potentially increases the intralesional bleeding risk from the surrounding bone marrow. We have been successfully using this technique in the treatment of some of our patients without a noticeable difference in outcomes compared with DNT.

This study had some limitations, including its retrospective nature and small sample size in both groups. With this research design, we could not obtain some procedural details, such as amount of steroids injected, the radiation dose, post procedural pain score and the timing of follow-up was not standardized. In addition, our experience in using SNT mostly involved intralesional steroid injection, which might be another limitation because this method can be used with any other injectable materials compatible with the available bone biopsy systems in the market. Further multicenter controlled studies are required to address these issues.

This study described image-guided bone cyst aspiration/injection using SNT, which is an effective, less invasive, and less time-consuming approach for managing symptomatic unicameral bone cysts compared with classic DNT with comparable outcomes.

Table 1 Overall demographic and relative data of patients with simple bone cyst treated with the single-needle technique

	Gender	Freq	Percent	
Group 1	Female	7	58.33	
	Male	5	41.67	
	Total	12	100.00	
Location	Upper extremity long bone	5	41.67	
	Lower extremity long bone	5	41.67	
	Other(calcanus)	2	16.67	
	Total	12	100.00	
	Fracture at presentation	No	12	100.00

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Table 1 continued

Total	12	100.00
Number of interventions		
1	9	64.00
2	4	29.00
3	1	7.00
Total	14	100.00
Activity		
N	10	83.33
Y	2	16.67
Total	12	100.00
Complication post procedure		
No	11	90.91
Yes (fracture)	1	9.09
Total	12	100.00
Cyst volume(cc)	Median	Min/Max
	5.4	1.2/54
Cyst index	Median	Min/Max
	2.05	.5/3.8

Table 2 Overall demographic and relative data of patients with simple bone cyst treated with the double-needle technique

	Gender	Freq	Percent
Group 2	F	5	45.45
	M	6	54.55
	Total	11	100.00
Location			
	Upper extremity long bone	6	54.55
	Lower extremity long bone	4	36.36
	Other (iliac bone)	1	9.09
	Total	11	100.00
Fracture at presentation			
	No	10	90.91
	Yes	1	9.09
	Total	11	100.00
Number of interventions			
	1	8	67.00
	2	3	25.00
	3	1	8.00
	Total	12	100.00
Activity			
	No	8	72.73
	Yes	3	27.27
	Total	11	100.00

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Table 2 continued

Complication post procedure		
No	11	100.00
Cyst volume(cc)	Median	Min/Max
	18	3/121
Cyst index	Median	Min/Max
	1.8	.3/4.8

Table 3 Results of Fisher's exact test

Neers after 1st and 2 nd intervention				
Group	1 or 2 (response)	3 (persistent)	Total	Fisher's exact
				1.000
2	8 72.7	3 27.3	11	
Total	16 69.5	7 30.4	23	

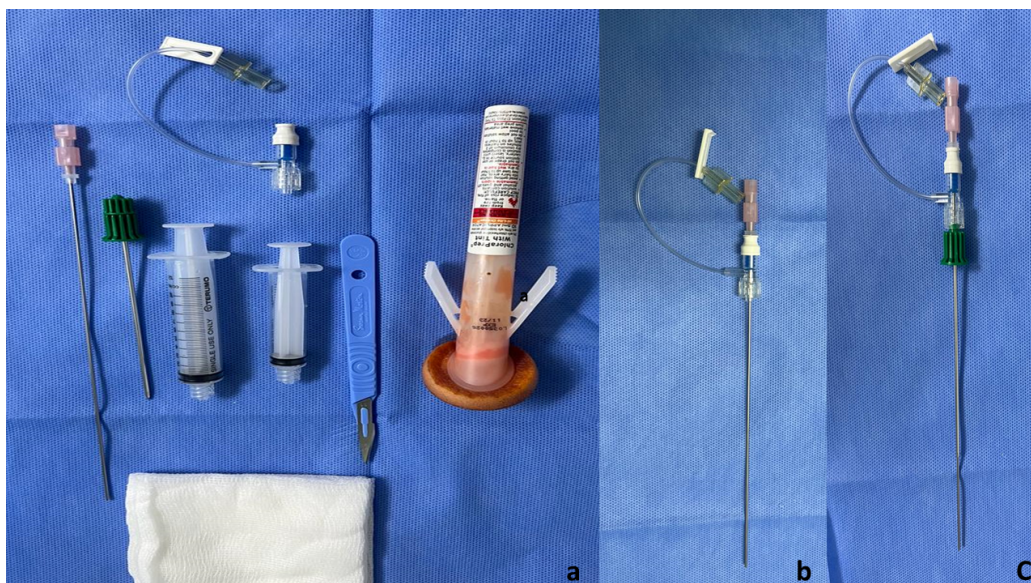


Figure 1 Intraoperative picture of the used set. The length of the spinal needle is longer than the bone penetration cannula (a). The spinal needle is placed through the hub of the extension set and then into the penetration cannula in a coaxial fashion (b and c). A saline-filled syringe is then secured to the spinal needle and another empty syringe is connected to the extension tubing (not shown).

AP and oblique baseline radiographs (a and b) before treatment show mildly expansile lytic lesion with sharp borders. CT-guided aspiration and injection images (c, d, and e) were obtained at baseline, during, and after the aspiration and injection, respectively.

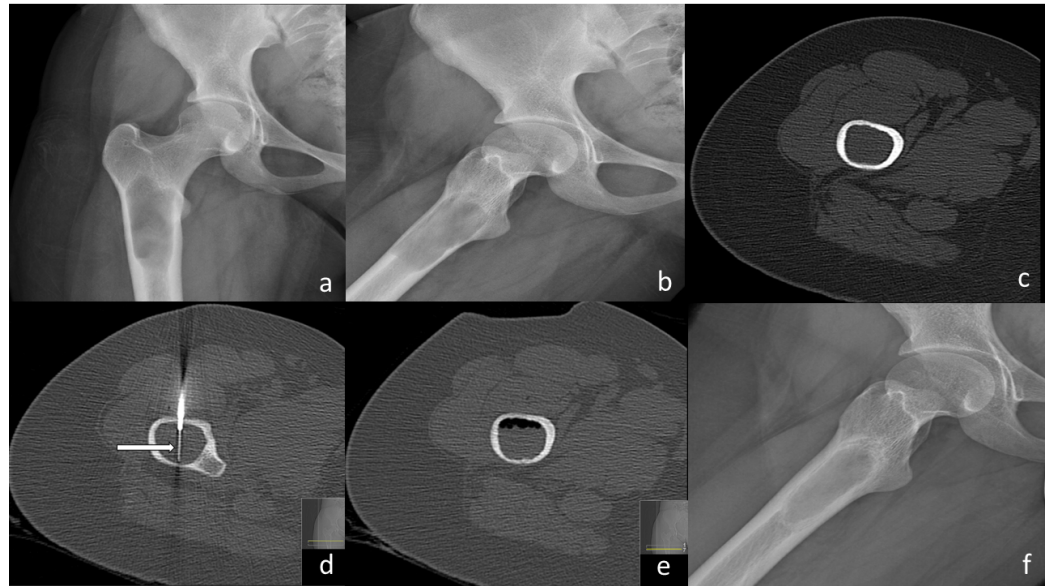


Figure 2 A 14-year-old female patient with right proximal femur simple bone cyst who was treated with aspiration and injection.

The arrow indicates the spinal needle tip. Oblique radiographs obtained after the second session at 4-month follow-up (not shown here) did not show a significant difference in appearance and those at 12-month follow-up (f) revealed diffuse mild sclerosis with adequate cortical rim.

CONFLICT OF INTEREST

All authors of this article have no conflicts of interest with publication of the manuscript.

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