International Orthopaedics (2025) 49:2207–2217
https://doi.org/10.1007/s00264-025-06603-3

RESEARCH

Aneurysmal bone cysts (ABC): Retrospective analysis of two hundred and fifty eight cases

Mustafa Onur Karaca[1] · Orhun Eray Bozkurt[2] · Merve Dursun Savran[1] · Mustafa Özyıldıran[3] · Kerem Başarır[4] · Hüseyin Yusuf Yıldız[1]

Received: 2 November 2024 / Accepted: 30 June 2025 / Published online: 11 July 2025
© The Author(s) 2025

Abstract

Purpose Aneurysmal bone cysts (ABCs) are bone tumours characterised by blood-filled cystic lesions. Management strategies for ABCs vary widely and lack consensus. This study aims to evaluate outcomes in 258 patients and investigate the factors affecting the recurrence rates.

Methods This study is a single-centre retrospective analysis of patients diagnosed with ABC between January 1990 and December 2020. Patients who were histologically diagnosed with ABC, had available pathology, radiology, and surgery records, and were followed up for at least 24 months were included. Secondary ABCs were excluded. Presenting symptoms and location, computerised tomography (CT) and magnetic resonance imaging (MRI), treatment modalities, and recurrence were investigated.

Results The mean age of the 258 ABC patients was 17.25 ± 12.37 years, 67.44% being under 18 years, and 12.40% under five years. 49.45% were female. The average follow-up duration was 47.80 ± 41.92 months. Pain was the most common presenting symptom, reported by 79.97% of patients. 5.04% were asymptomatic and diagnosed incidentally, whereas 11.63% were diagnosed following a pathological fracture. The median disease-free survival was ten months, with the average time to first recurrence being 24.22 ± 22.14 months. Recurrence was more common in patients under five years of age (34.38% vs. 19.03%, $p=0.046$) and in those with pathologic fractures (40.00% vs. 18.42%, $p=0.006$). Conversely, recurrence was less common when burr and/or cautery was added to curettage (31.97% vs. 11.03%, $p<0.001$). Time to recurrence was significantly shorter in cases with soft tissue oedema (median 5 vs. 12 months, $p=0.010$) or fluid-fluid levels (median 6 vs. 12 months, $p=0.038$).

Conclusions The study found that pathological fractures and age under five years are associated with a higher risk of recurrence in aneurysmal bone cysts. Electrocauterization and/or high-speed burring as local adjuvant therapy is associated with low recurrence rates.

Keywords Aneurysmal bone cyst · Recurrence · Electrocautery · Burr · Curettage

✉ Merve Dursun Savran
dursunm@ankara.edu.tr

Mustafa Onur Karaca
onurkaraca@ankara.edu.tr

Orhun Eray Bozkurt
borhuneray1803@gmail.com

Mustafa Özyıldıran
mozyildiran@gmail.com

Kerem Başarır
kerembasarir77@gmail.com

Hüseyin Yusuf Yıldız
hyyildiz@ankara.edu.tr

[1] Ankara University Faculty of Medicine, Orthopedics and Traumatology Department, Ankara, Turkey

[2] Kulu Region State Hospital, Orthopedics and Traumatology Department, Konya, Turkey

[3] Sandıklı State Hospital, Orthopedics and Traumatology Department, Afyon, Turkey

[4] Private Practice, Orthopedics and Traumatology, Ankara, Turkey

Introduction

Aneurysmal bone cysts (ABCs) represent a classification of bone tumours distinguished by a cystic lesion within the bone, replete with sanguineous content. Though commonly found in the metaphysis of long bones and vertebrae, ABCs can occur in any bony structure throughout the body. The yearly occurrence rate of ABCs is approximated at 0.14 per 100,000 individuals, constituting a 1–6% prevalence among all primary, benign bone neoplasms [1–3]. ABCs can develop at any age but are notably more prevalent in individuals under 20, accounting for 75–90% of cases within this age group [4, 5].

Clinically, patients with ABCs present with pain, which may or may not be accompanied by noticeable swelling. In some cases, the initial presentation may include a pathological fracture at the lesion site [6, 7]. Radiographically, ABCs are identified by their well-defined, expansile nature with prominent trabeculations [4, 8]. While some cysts may spontaneously resolve or show resolution following biopsy, the standard treatment approach remains intralesional curettage, potentially combined with bone grafting. Management strategies vary widely and may include embolization, curettage with or without bone grafting, cavity cementation, reconstructive surgery, and, more recently, sclerotherapy [4, 7, 9–15].

Despite the availability of these treatment options, a consensus on the optimal management strategy for ABCs remains elusive. It is known that postoperative recurrence is not uncommon, and the rates of recurrence are reported to range from 3 to 59% in the literature [4, 16–18].

There are several critical questions: Are there any radiological findings that predict recurrence? How do age, physeal status, and related factors affect recurrence? How does the use of adjuvant treatments, such as cauterization and burring, impact recurrence?

This study aims to address these questions by evaluating the experiences of 258 patients within our clinical setting and assessing the impact of adjuvant burring and cauterization in conjunction with curettage on the recurrence of ABCs.

Methods

The study protocol was approved by the University Medical Faculty Human Studies Institutional Ethics Review Board (ID: İ04-362-24).

This study is a single-centre retrospective study. All patients diagnosed as ABC at the University Hospital between January 1990 and December 2020 were investigated. All patients histologically diagnosed as ABC, whose pathology, radiology, and surgery records are available and followed up at least 24 months, were included. From the hospital registries, 572 patients were found for the search "bone cyst." 144 patients with simple bone cysts (SBC) and 132 patients with giant cell tumours (GCT) were excluded. From the remaining 296 ABCs, 28 were secondary, and ten had less than 24 months of follow-up. So, they were excluded, and only 258 ABCs were included (Fig. 1).

The differential diagnosis of aneurysmal bone cysts includes benign lesions as well as malignant tumours, such as telangiectatic osteosarcoma. Accurate histological diagnosis is essential, as the prognosis and treatment of ABCs are different from those of malignant bone lesions [7, 19]. Therefore, patients underwent either core needle biopsy or incisional biopsy preoperatively. All patients whose diagnosis was verified histologically according to the pathology report were included in the study.

Presenting symptoms and location from the initial outpatient clinic notes were recorded. Imaging studies, such as radiographs, computerised tomography (CT) and magnetic resonance imaging (MRI) were investigated. The presence of pathologic fracture, bone destruction, cortical reaction, and periosteal reaction was mainly evaluated using X-rays and CT. On the other hand, bone marrow and soft tissue oedema and fluid-fluid levels were assessed by MRI. The Enneking staging system was used to perform tumour staging. Preoperative radiographs were evaluated and the lesions were classified as inactive, active, or aggressive. Lesions with well-defined rims and confined to the bone were classified as inactive. Lesions that were confined to the bone with incomplete reactive rims were classified as active lesions. Tumours with a poorly defined margin were categorized as aggressive. Imaging interpretations for musculoskeletal tumours are routinely performed by a radiologist specialised in musculoskeletal imaging at the institution. For this study, both the interpretations provided by this radiologist and the results reviewed by an orthopaedic specialist with expertise in musculoskeletal oncology were recorded.

Treatment modalities, including curettage, burr, and cauterization, were extracted, and documented from the surgical operation reports. The presence of recurrence was investigated by examining postoperative radiographic images and medical records. Cases with a persistent radiolucent lesion that showed radiographic progression on follow-up radiographs were considered recurrences. Patients were contacted via telephone for missing data not found in the patient records.

StataMP13 (StataCorp. Stata Statistical Software: Release 13) was used for descriptive and inferential analyses. Shapiro-Wilk test was used to assess normality. Chi-square and Fisher's exact tests were used for categorical variables. A T-test was performed to analyse the parametric

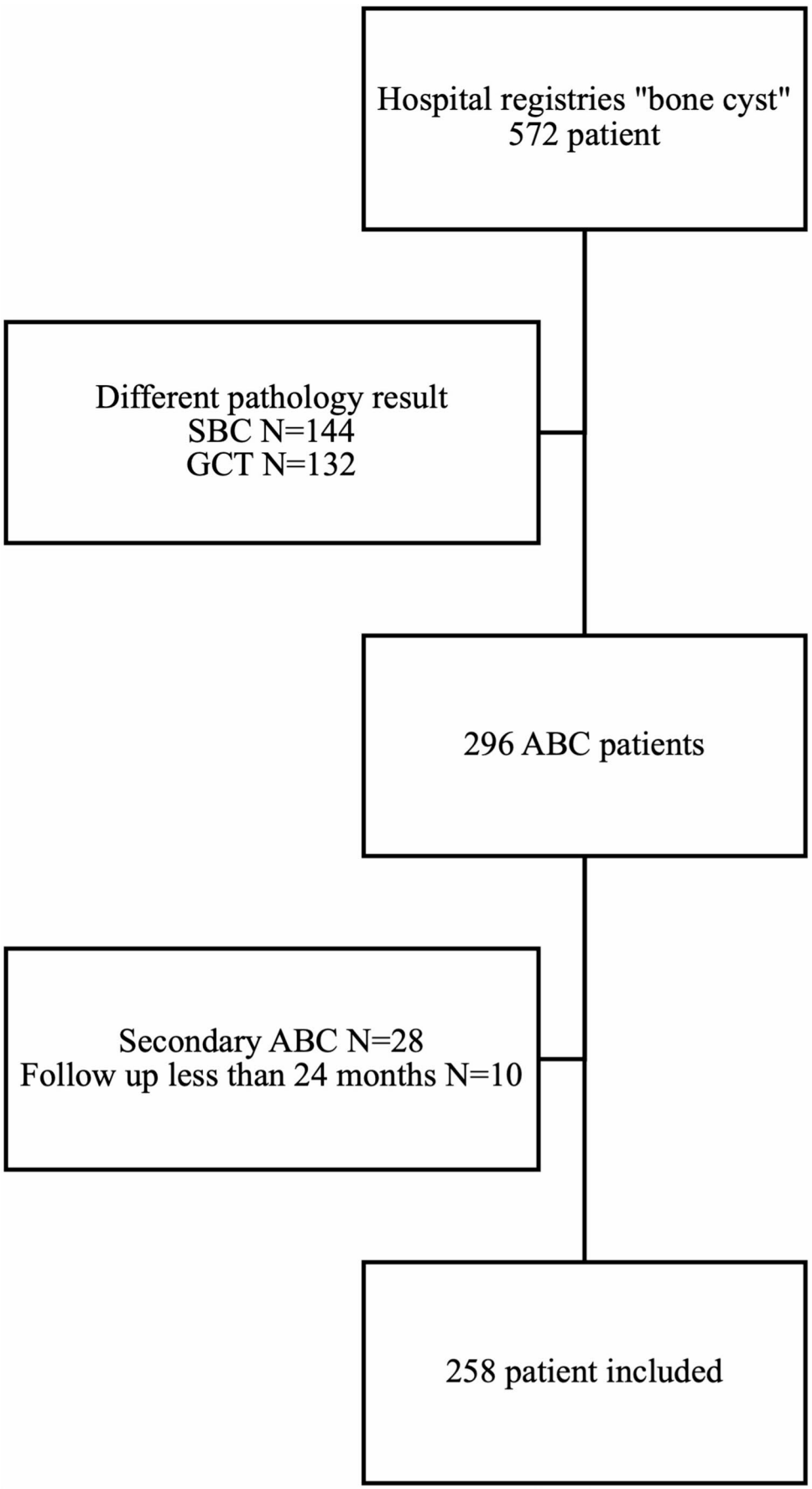


Fig. 1 Excluded and included patients

data between groups. Mann Whitney U test was performed to analyse the non-parametric data between groups. Wilcoxon test was used to analyse data between dependent groups (pre-post comparison). ANOVA test followed by post hoc analysis was performed to analyse the parametric data between multiple groups. Kruskal Wallis test, followed by post hoc analysis, was performed to analyse the non-parametric data between multiple groups. A p-value less than 0.05 was accepted as significant.

Results

The mean age of 258 ABC patients was 17.25 ± 12.37. 67.44% were younger than 18, and 12.40% were younger than five. 49.45% were women and 50.55% were men. The average follow-up was 47.80 ± 41.92 months.

The most common presenting symptom was pain (79.97%), followed by swelling (36.82%). Pain was less common if the patient was younger than five years ($p=0.003$). 13 patients (5.04%) had no symptoms and were diagnosed incidentally, whereas 30 patients (11.63%) were diagnosed after a pathological fracture. Presenting symptoms according to age groups are given in Fig. 2. The mean duration of symptoms before the presentation was 7.77 ± 19.48 months.

15.89% of the ABCs were located in the spine and flat bones, whereas 84.11% were in long bones. There was no difference in recurrence rates between flat bones and long bones ($p=0.134$). Detailed distribution of ABCs along the body is given in Fig. 3. The most common bones were the femur, humerus, and tibia. 32.26% ABSs were metadiaphyseal, 23.96% were metaphyseal, 20.74% were metaepiphyseal, 17.51% were diaphyseal, and only 5.53% were epiphyseal.

The distribution of cortical reactions, periosteal reactions, and bone destruction were given in Fig. 4 (A-C). The most common type of bone destruction was geographical type IB, and the most common type of cortical reaction was enlarged, intact cortex type. Shell formation was present in 48.4%, 24.3% were partial, and 24.1% were complete. According to MRI findings, soft tissue edema was present in 29 (11.24%) cases, bone marrow oedema in 38 (14.73%) cases, and a fluid-fluid level in 178 (68.99%) cases.

According to the Enneking staging system, the lesions were inactive in 33 (12.79%) cases, active in 134 (51.94%) cases, and aggressive in 91 (35.27%) cases. According to Capanna classification, 35 (13.56%) lesions were type I, 114 (44.18%) were type II, 55 (21.31%) were type III, 10 (3.87%) were type IV, and 34 (13.18%) were type V, and ten (3.87%) were mixed type. The relationship between the Enneking stage and Capanna morphological subgroups with recurrence was also investigated. The recurrence rate was not found to be statistically associated with these classification systems. The Enneking and Capanna distributions are presented in Table 1; Fig. 4 (D, E).

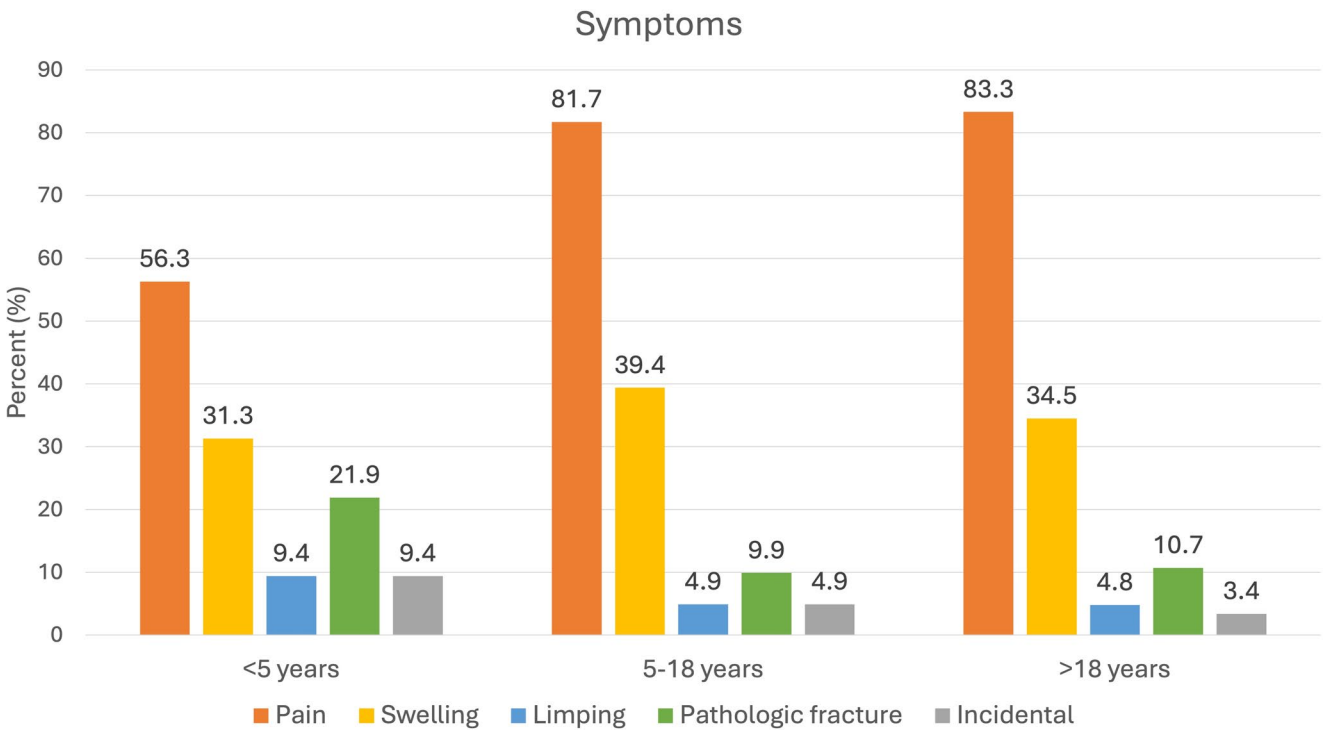
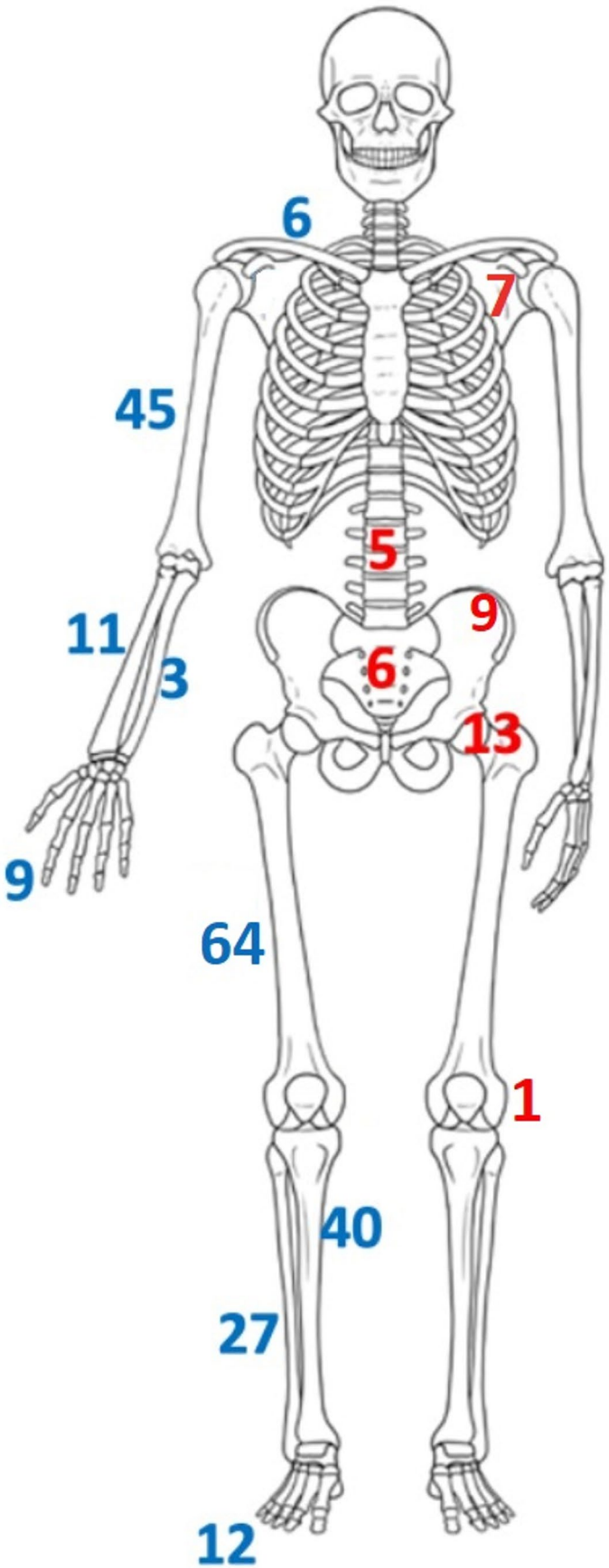


Fig. 2 Symptomatology in different age groups

Fig. 3 Anatomical locations of the lesions



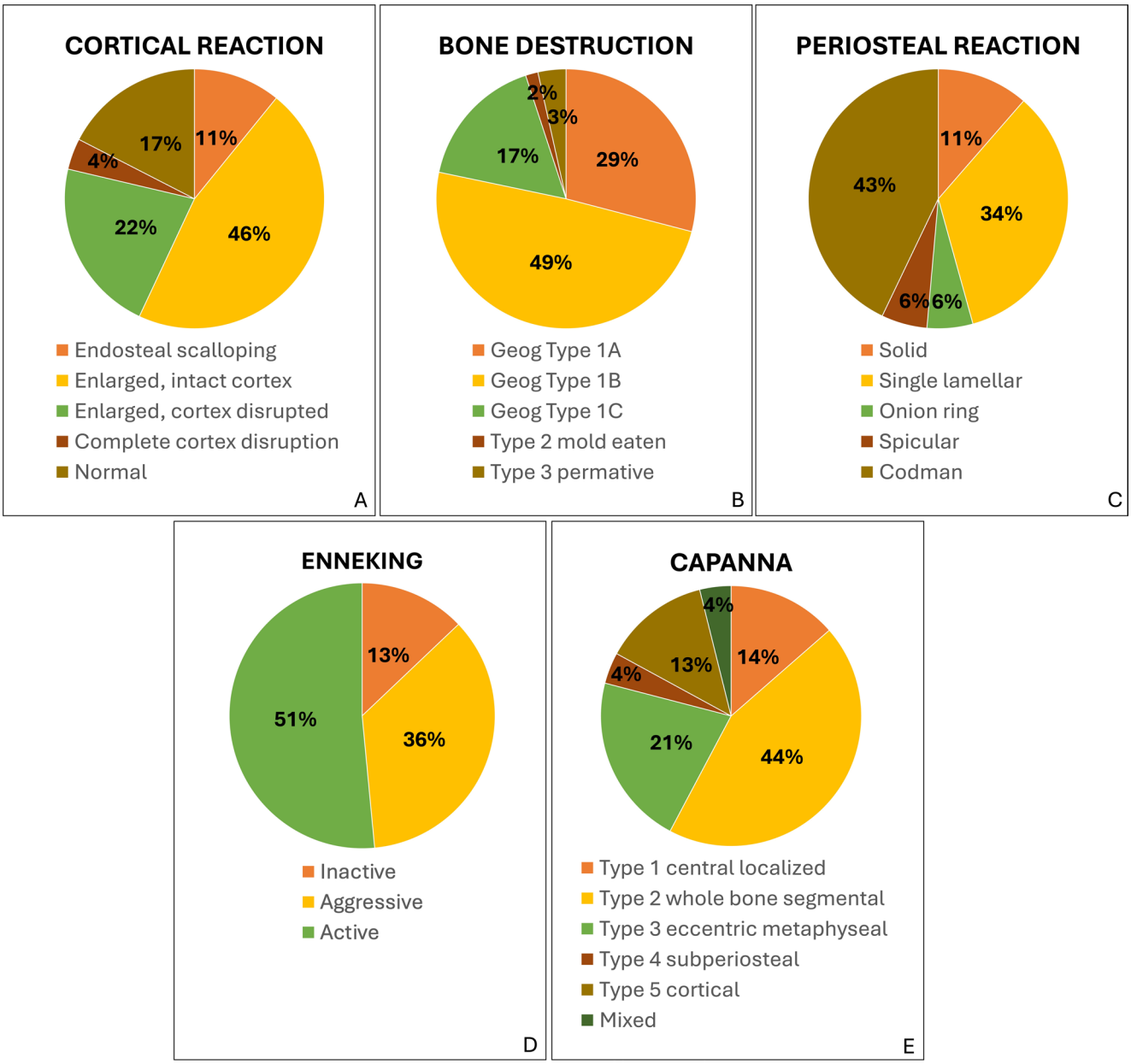


Fig. 4 Distribution of cortical reaction (**A**), bone destruction (**B**), and periosteal reaction (**C**) type, Enneking (**D**) and Capanna (**E**) classifications

For the treatment methods, curettage was performed in all patients. Of these, 122 (47.29%) underwent curettage alone, while 136 (52.71%) received adjuvant treatments. Specifically, 20 (7.75%) underwent burring, 29 (11.24%) underwent cauterization, and 87 (33.72%) received both burring and cauterization in addition to curettage.

For the reconstruction, grafts were used in 88.33%, cement in 16.67%, and both in 5.00%. Allografts were used in 61.64%, autografts in 22.01%, and both in 26.35%. Fixation was needed in 18 patients: 16 with pathologic fractures and two with high risk of a pathologic fracture. Fixation was performed with plates and screws in six patients, with intramedullary nails in two patients, with posterior instrumentation in two patients, with Kirchner wires in five patients, and with Steinman in one patient. one patient required endoprosthetic reconstruction.

The median disease-free survival was ten months, and the time to first recurrence was 24.22 ± 22.14 months on average. Recurrence was more common for patients younger than five years (34.38% vs. 19.03%, $p=0.046$) and in the case of a pathologic fracture (40.00% vs. 18.42%, $p=0.006$). Moreover, recurrence was less common with the addition of burring and/or cauterisation to curettage (31.97% vs. 11.03%, $p<0.001$). The presence of soft tissue

Table 1 Factors affecting recurrence and time to recurrence

		Recurrence $N=54$	No recurrence $N=204$	*P* value for recurrence	Survival analysis for recurrence
Age	Mean ± standard deviation	15.94 ± 12.95	17.59 ± 12.22	0.1249	-
	<18	36 (20.69%)	138 (79.31%)	0.891	0.184
	>18	18 (21.43%)	66 (78.57%)		
	<5	11 (34.38%)	21 (65.62%)	**0.046**	0.741
	>5	43 (19.03%)	183 (80.97%)		
Presentation	Pathologic fracture +	12 (40.00%)	18 (60.00%)	**0.006**	0.203
	No fracture	42 (18.42%)	186 (81.58%)		
Localization	Flat bones and spine	5 (12.20%)	36 (87.80%)	0.134	0.331
	Long bones	49 (22.58%)	168 (77.42%)		
	Epiphysis	3 (25.00%)	9 (75.00%)	0.206	0.793
	Metaepiphysis	11 (24.44%)	34 (75.55%)		
	Metaphysis	10 (19.23%)	42 (80.76%)		
	Metadiaphysis	21 (30.00%)	49 (70.00%)		
	Diaphysis	4 (10.52%)	34 (89.47%)		
Joint and physis relation	Physis open	36 (22.22%)	126 (77.78%)	0.508	0.375
	Physis closed	18 (18.75%)	78 (81.25%)		
	Adjacent to physis *	20 (23.26%)	66 (76.78%)	0.736	0.697
	Non-adjacent to physis *	16 (21.05%)	60 (78.95%)		
	Adjacent to joint	14 (18.42%)	62 (81.58%)	0.470	0.117
	Non-adjacent to joint	40 (22.47%)	138 (77.53%)		
Bone destruction	Geographical Type IA	13 (17.33%)	62 (82.67%)	0.580	0.531
	Geographical Type IB	30 (23.62%)	97 (76.38%)		
	Geographical Type IC	10 (23.26%)	33 (76.74%)		
	Type II moth eaten	0 (0%)	4 (100%)		
	Type III permeative	1 (11.11%)	8 (88.89%)		
Cortical reaction	Endosteal scalloping	5 (17.86%)	23 (82.14%)	0.768	0.536
	Enlarged, cortex intact	24 (20.17%)	95 (79.83%)		
	Enlarged, cortex destructed	12 (21.43%)	44 (78.57%)		
	Complete destruction	1 (10.00%)	9 (90.00%)		
	Normal	12 (26.67%)	33 (73.33%)		
Periosteal reaction	Solid	0 (0%)	4 (100%)	0.489	0.947
	Single lamellar	4 (33.33%)	8 (66.67%)		
	Onion ring	0 (0%)	2 (100%)		
	Spiculated	1 (50.00%)	1 (50.00%)		
	Sunburst	-	-		
	Codman	3 (20.00%)	12 (80.00%)		
MRI finding	Soft tissue edema	6 (20.69%)	23 (79.31%)	0.973	**0.010**
	No soft tissue edema	48 (20.96%)	181 (79.04%)		
	Fluid– fluid level	39 (21.91%)	139 (78.09%)	0.564	**0.038**
	No fluid– fluid level	15 (18.75%)	65 (81.25%)		
Enneking	Inactive	7 (21.21%)	26 (78.79%)	0.135	0.612
	Active	22 (16.42%)	112 (83.58%)		
	Aggressive	25 (27.47%)	66 (71.53%)		
Capanna	Type I central localized	4 (11.43%)	31 (88.57%)	0.189	0.514
	Type II whole segment	30 (26.32%)	84 (73.68%)		
	Type III eccentric metaphysis	12 (21.82%)	43 (78.18%)		
	Type IV subperiosteal	3 (30.00%)	7 (70.00%)		
	Type V cortical	3 (8.82%)	31 (91.18%)		
	Mixed	2 (20.00%)	8 (80.00%)		
Treatment methods	Curettage alone	39 (31.97)	83 (68.03)	**<0.001**	0.662
	Curettage + Burr / Cautery	15 (11.03)	121 (88.97)		

** Adjacency to the physis is only evaluated in patients with an open physis* (*n = 162*).

*** Chi-square and Fisher's exact tests were used to compare categorical variables between groups. Kaplan-Meier analysis was performed for recurrence-free survival. Differences were considered statistically significant for p value < 0.05.*

edema or fluid-fluid levels in MRI sections was also investigated in relation to recurrence. While these findings did not significantly impact the recurrence rate, the time until recurrence was significantly shorter in cases with soft tissue oedema (median 5 vs. 12 months, $p=0.010$) or fluid-fluid levels (median 6 vs. 12 months, $p=0.038$).

The relationship between growth plate status and recurrence was also investigated. Out of 258 patients, the physis was open in 162 (62.79%). A total of 86 (33.33%) lesions were adjacent to the physis, while 76 (29.46%) lesions were adjacent to the joints. No significant difference in recurrence rates was observed between lesions adjacent to the physis and those non-adjacent to the physis (23.26% vs. 21.05%, $p=0.736$). There was also no significant difference in recurrence rates between lesions adjacent to the joint and those not adjacent to the joint (18.42% vs. 22.47%, $p=0.47$). Factors affecting recurrence were summarised in Table 1.

Discussion

The most commonly reported symptoms of ABCs are pain, swelling, a palpable mass, pathological fractures, and limping [6, 7, 20, 21]. Our study found that pain was the most frequent symptom, consistent with the literature, occurring in 79.07% of cases. However, despite pain being the most common symptom in patients under 5 years of age, the number of patients presenting with pathological fractures was significantly higher compared to other age groups. This suggests that ABCs may have a shorter doubling time in younger individuals, emphasising the need for early diagnosis and treatment in this age group. Alternatively, younger children may be less effective in verbalising pain, especially in the early stages of the disease.

There are various treatment methods available for ABCs. The primary treatment method has been curettage with or without grafting [7, 9, 10, 19, 20]. In addition, adjuvant methods such as burring, electrocauterization, cryotherapy, argon laser coagulation, phenol, cement, hydrogen peroxide, and embolisation are available [4, 11, 12, 22]. Sclerotherapy using substances like polidocanol and doxycycline is also employed [13–15, 23]. In our study, electrocauterization and/or high-speed burring was applied in 52.7% of patients as an adjuvant treatment method to enhance the effectiveness of curettage. The purpose of high-speed burring is to augment curettage by mechanically disrupting the lesion down to the surrounding healthy bone. Similarly, electrocauterization aims to kill residual tumour cells through the heat effect [4, 7, 24, 25]. Various adjuvant treatment methods have evolved to reduce recurrence; however, there is no consensus in the literature on their exact effects on the recurrence rate.

In the study by Wang et al. [18], which included 31 patients, a recurrence rate of 3.2% were observed following the use of curettage, bone grafting, and burring. In a case series of 40 patients, Gibbs et al. [25], reported local control rates of up to 90% were achieved in patients who underwent curettage and high-speed burring. In another study by Döring et al. [26], which included 90 patients with primary ABC, it was concluded that burring after curettage resulted in superior recurrence-free survival compared to curettage alone. Consistent with these studies, our study found that the recurrence rate was lower in the patient group that received electrocauterization and/or burring as an adjuvant treatment compared to the curettage-alone group (11.03% vs. 31.97%, $p<0.001$). On the other hand, there were studies indicating that adjuvant treatment methods have no significant effect on the recurrence rate. Lin et al. [27] concluded in their study that adding burr to curettage did not affect recurrence. In the study by Gettleman et al. [17], adjuvant treatment methods such as high-speed burr, coagulation, liquid nitrogen, and/or hydrogen peroxide were used in 70.5% of cases (91 out of 129). They reported that there was no significant difference in recurrence rate between the groups that received and did not receive adjuvant treatment. In another study, Levanon et al. [28], reported that cryoablation, as an adjuvant treatment method, had no significant effect on the recurrence rate. In this study, the group that underwent curettage and burring was compared with the group that received additional cryoablation, with recurrence rates reported as 9.1% vs. 7.1%, respectively ($p=0.553$). However, this study did not include a curettage-alone group, and all patients underwent burring. The patient group that underwent curettage and burring in the study by Levanon et al. appears to have similar recurrence rates to the group in our study that underwent burring and/or electrocauterization after curettage (9.1% vs. 11.03%). Differences among studies in the literature may be due to variations in the follow-up durations, differences in the sizes of study groups, the implementation of surgical techniques, and differences between surgeons.

Several authors have documented a higher rate of tumour recurrence in younger age groups [17, 27, 29]. We found a significantly higher recurrence rate in patients under five years of age, which was consistent with previous series. Various explanations have been proposed for this situation. One possibility is that the clinical and pathological behaviour of ABCs in younger patients is more aggressive. Another factor contributing to the high recurrence rate may be surgeons' excessive caution in preventing growth arrest in very young patients [17, 27, 30]. Some authors have also theorized that the increased biological activity of growth plates raises the risk of recurrence in young patients [25, 31]. However, our study found no significant relationship between physeal status or physeal contact and recurrence. In terms of findings

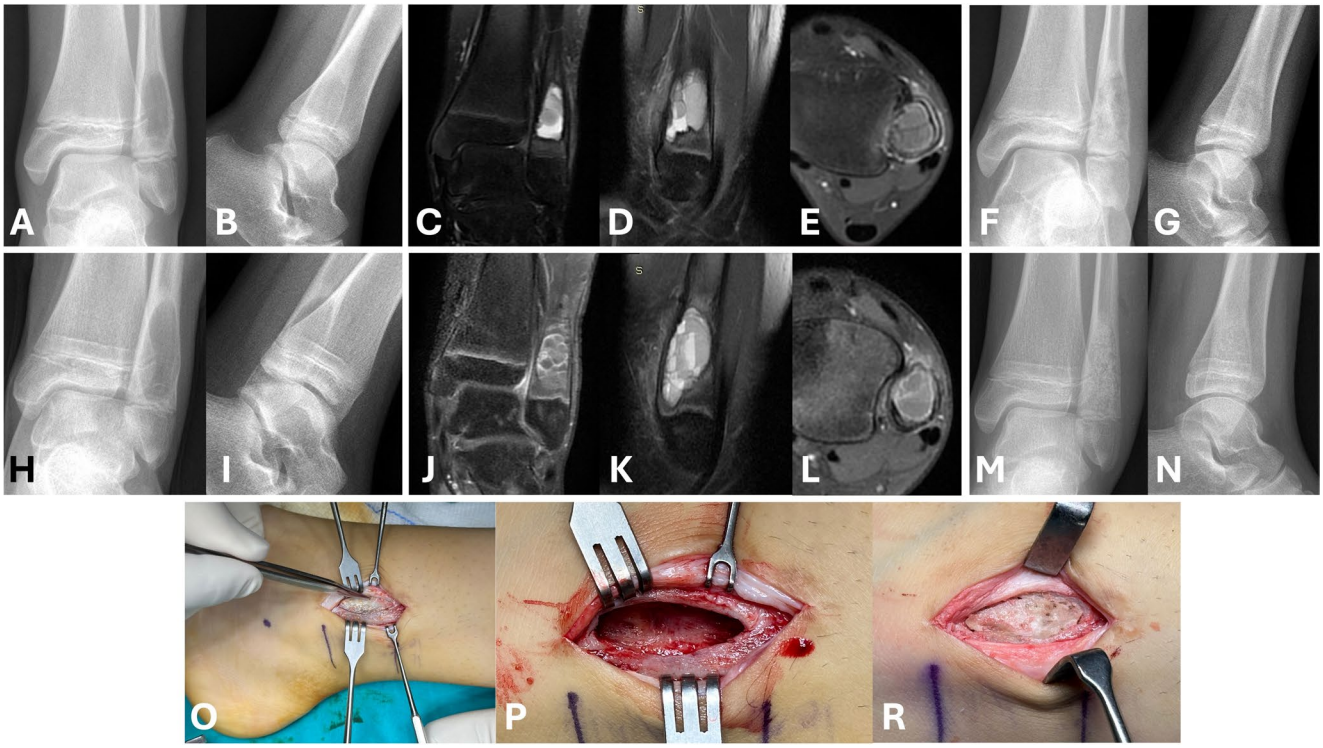


Fig. 5 Illustration of the medical and surgical history of a 12-year-old female patient with a distal fibular aneurysmal bone cyst (**ABC**) and a recurrence in the postoperative first year
(**A** & **B**) depict preoperative anteroposterior and lateral X-rays revealing a metaphyseal lesion in the distal fibula. (**C**, **D** & **E**) show preoperative MRI images highlighting the fluid-fluid levels characteristic of ABC. (**F** & **G**) display postoperative anteroposterior and lateral X-rays demonstrating the lesion filled with graft material following the initial surgery, which included curettage and cauterization. (**H** & **I**) present anteroposterior and lateral X-rays indicating the recurrence of the lesion. (**J**, **K** & **L**) provide preoperative MRI images confirming the recurrence. (**M** & **N**) show postoperative anteroposterior and lateral X-rays after the second surgery, which involved curettage, burring, and cauterization, and again depict the lesion filled with graft material. (**O**, **P** & **R**) include intraoperative images showing the bone lid, the space after curettage, burr and cauterization, and the reapplication of the bone lid after grafting

on this topic, our study aligns with the results of Gettleman et al. [17]. They documented that patients aged six years or younger had an increased recurrence rate; however, no significant association was found with physeal contact.

Fluid-fluid levels (FFL) within a bony lesion were first reported as a feature of aneurysmal bone cyst by Hudson et al. [32, 33]. FFL occur when fluids of different densities accumulate within a cystic structure [33, 34]. Although aneurysmal bone cysts and telangiectatic osteosarcoma are the most common bone lesions with fluid-fluid levels, these levels can be found in various bone and soft tissue lesions [33, 35]. Liquefaction due to tumour necrosis and intratumoral haemorrhage are possible mechanisms in the pathophysiology of FFL formation [33]. Van Dyck et al. reported FFL in 37% of ABCs in their series [34]. Davies et al. documented that 84% of ABCs contained FFL [36]. Our findings are consistent with the literature, as we observed FFL in 68.9% of our series. One noteworthy finding in our study is the shorter time to recurrence in the presence of soft tissue edema and fluid-fluid levels. Figure 5 shows an example case with these specific radiologic findings. Currently, no publication in the literature supports our findings regarding the relationship between recurrence time and the presence of FFL. The first possible reason may be that in lesions containing FFL, intraoperative bleeding control is more challenging, which may reduce the effectiveness of the applied curettage. The second possible reason is that ABCs with FFL may exhibit a more aggressive pattern. Evaluating this issue histopathologically in larger patient groups would provide valuable insights.

The study has several limitations. As a retrospective analysis, it lacks access to the specific criteria used for intraoperative decisions such as curettage, cauterisation, burring, grafts, cement, and fixation. Additionally, the study does not include sclerotherapy, preventing an assessment of its impact on recurrence in ABC treatment. Furthermore, the absence of USP6 and CDH11 oncogenes, specific to primary ABCs, limits diagnostic accuracy and differentiation [37]. Lastly, given the extensive 30-year period covered, changes in diagnostic and treatment practices over time may affect the evaluation of early versus late cases.

The study benefits from several notable strengths. It includes a large sample size, which enhances the reliability of the results. Patient records are well-maintained and highly accessible, contributing to the robustness of the data. Additionally, all surgeries were performed by expert senior surgeons at a tertiary centre, ensuring high-quality procedural standards. The study also spans a 30-year period, providing valuable insights into long-term outcomes and the evolution of diagnostic and treatment strategies.

Conclusion

In conclusion, this study finds that aneurysmal bone cysts in patients under the age of five and those with pathological fractures are at a higher risk for recurrence. Electrocauterization or high speed burring as local adjuvant therapy leads to low recurrence rates. Therefore, early diagnosis—preferably before the occurrence of fractures—and effective local treatment are crucial for preventing recurrence.

Acknowledgements Authors thank to the radiology and pathology departments of the university for their support.

Author contributions MOK: Conceptualization, Writing, Review & Editing OEB: Data Collection, Literature review, Writing MDS: Data Collection, Data Analysis, Writing MÖ: Data analysis, Literature review, Editing KB: Review & Editing, Literature review HYY: Conceptualization, Supervision, Review & Editing The authors reviewed and approved the final manuscript to ensure accuracy and adherence to research standards.

Funding Open access funding provided by the Scientific and Technological Research Council of Türkiye (TÜBİTAK). Open access funding provided by the Scientific and Technological Research Council of Türkiye (TÜBİTAK). There is no funding source.

Data availability The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declarations

Competing interests The authors declare no competing interests.

Use of AI Artificial intelligence (AI) tools were used solely for language editing purposes in the preparation of this manuscript. No AI tools were employed for data analysis, study design, or interpretation of results.

Ethics The study is approved by the Ethics Committe (ID: İ04-362-24).

Consent to participate Not applicable.

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by/4.0/.

References

1. Batisse F, Schmitt A, Vendeuvre T, Herbreteau D, Bonnard C (2016) Aneurysmal bone cyst: A 19-case series managed by percutaneous sclerotherapy. Orthop Traumatol Surg Res 102:213–216. https://doi.org/10.1016/j.otsr.2015.11.016
2. Kaiser CL, Yeung CM, Raskin KA, Lozano-Calderon SA (2019) Aneurysmal bone cyst of the clavicle: a series of 13 cases. J Shoulder Elb Surg 28:71–76. https://doi.org/10.1016/j.jse.2018.06.036
3. Leithner A, Windhager R, Lang S, Haas OA, Kainberger F, Kotz R (1999) Aneurysmal bone cyst. A population based epidemiologic study and literature review. Clin Orthop Relat Res:176–179
4. Dormans JP, Hanna BG, Johnston DR, Khurana JS (2004) Surgical treatment and recurrence rate of aneurysmal bone cysts in children. Clin Orthop Relat Res 205–211. https://doi.org/10.1097/01.blo.0000126336.46604.e1
5. Tsagozis P, Brosjö O (2015) Current strategies for the treatment of aneurysmal bone cysts. Orthop Rev (Pavia) 7:6182. https://doi.org/10.4081/or.2015.6182
6. van Geloven TPG, van der Heijden L, Laitinen MK, Campanacci DA, Döring K, Dammerer D, Badr IT, Haara M, Beltrami G, Kraus T, Scheider P, Soto-Montoya C, Umer M, Fiocco M, Coppa V, de Witte PB, van de Sande MAJ, EPOS Study Group (2023) Do's and don'ts in primary aneurysmal bone cysts of the proximal femur in children and adolescents: retrospective multicenter EPOS study of 79 patients. J Pediatr Orthop 43(1):37–45. https://doi.org/10.1097/BPO.0000000000002267
7. Park HY, Yang SK, Sheppard WL, Hegde V, Zoller SD, Nelson SD, Federman N, Bernthal NM (2016) Current management of aneurysmal bone cysts. Curr Rev Musculoskelet Med 9:435–444. https://doi.org/10.1007/s12178-016-9371-6
8. Brosjö O, Pechon P, Hesla A, Tsagozis P, Bauer H (2013) Sclerotherapy with polidocanol for treatment of aneurysmal bone cysts. Acta Orthop 84:502–505. https://doi.org/10.3109/17453674.2013.850013
9. James AG, Coley BL, Higinbotham NL (1948) Solitary, unicameral, bone cyst. Arch Surg (1920) 57:137–147. https://doi.org/10.1001/archsurg.1948.01240020140011
10. Campanacci M, Capanna R, Picci P (1986) Unicameral and aneurysmal bone cysts. Clin Orthop Relat Res:25–36
11. Erol B, Topkar MO, Caliskan E, Erbolukbas R (2015) Surgical treatment of active or aggressive aneurysmal bone cysts in children. J Pediatr Orthop B 24:461–468. https://doi.org/10.1097/bpb.0000000000000173
12. Crowe MM, Houdek MT, Moran SL, Kakar S (2015) Aneurysmal bone cysts of the hand, wrist, and forearm. J Hand Surg Am 40:2052–2057. https://doi.org/10.1016/j.jhsa.2015.06.108
13. Shiels WE 2nd, Mayerson JL (2013) Percutaneous Doxycycline treatment of aneurysmal bone cysts with low recurrence rate: a preliminary report. Clin Orthop Relat Res 471:2675–2683. https://doi.org/10.1007/s11999-013-3043-2
14. Deventer N, Deventer N, Gosheger G, de Vaal M, Vogt B, Budny T (2021) Current strategies for the treatment of solitary and

aneurysmal bone cysts: A review of the literature. J Bone Oncol 30:100384. https://doi.org/10.1016/j.jbo.2021.100384
15. Puri A, Hegde P, Gulia A, Parikh M (2020) Primary aneurysmal bone cysts. Bone Joint J 102–B(2):186–190. https://doi.org/10.1302/0301-620X.102B2.BJJ-2019-1083.R1
16. Bavan L, Wijendra A, Kothari A (2021) Efficacy of treatment interventions for primary aneurysmal bone cysts: a systematic review. Bone Jt Open 2:125–133. https://doi.org/10.1302/2633-1462.22.Bjo-2020-0168
17. Gettleman BS, Padilla AN, Kumar S, Wren TAL, Miller J, Pawel BR, Tolo VT, Christ AB (2024) Use of surgical adjuvants does not decrease recurrence of aneurysmal bone cysts in surgical intervention with pediatric patients. J Pediatr Orthop 44:e79–e83. https://doi.org/10.1097/bpo.0000000000002536
18. Wang EH, Marfori ML, Serrano MV, Rubio DA (2014) Is curettage and high-speed burring sufficient treatment for aneurysmal bone cysts? Clin Orthop Relat Res 472:3483–3488. https://doi.org/10.1007/s11999-014-3809-1
19. Bakarman KA (2024) Diagnosis and current treatment of aneurysmal bone cysts. Cureus 16(2):e53587. https://doi.org/10.7759/cureus.53587
20. Restrepo R, Zahrah D, Pelaez L, Temple HT, Murakami JW (2022) Update on aneurysmal bone cyst: pathophysiology, histology, imaging and treatment. Pediatr Radiol 52:1601–1614. https://doi.org/10.1007/s00247-022-05396-6
21. Mascard E, Gomez-Brouchet A, Lambot K (2015) Bone cysts: unicameral and aneurysmal bone cyst. Orthop Traumatol Surg Res 101:S119–127. https://doi.org/10.1016/j.otsr.2014.06.031
22. van Geloven TPG, van de Sande MAJ, van der Heijden L (2023) The treatment of aneurysmal bone cysts. Curr Opin Pediatr 35(1):131–137. https://doi.org/10.1097/MOP.0000000000001205
23. Strohm JA, Strohm PC, Kühle J, Schmal H, Zwingmann J (2023) Management of juvenile and aneurysmal bone cysts: a systematic literature review with meta-analysis. Eur J Trauma Emerg Surg 49(1):361–372. https://doi.org/10.1007/s00068-022-02077-9
24. Karaca MO, Özyıldıran M, Alizade R, Başarır K, Yıldız HY (2024) Chondromyxoid fibroma: A retrospective evaluation of 31 cases. Jt Dis Relat Surg 35(2):377–385. https://doi.org/10.52312/jdrs.2024.1620
25. Gibbs CP Jr., Hefele MC, Peabody TD, Montag AG, Aithal V, Simon MA (1999) Aneurysmal bone cyst of the extremities. Factors related to local recurrence after curettage with a high-speed burr. J Bone Joint Surg Am 81:1671–1678. https://doi.org/10.2106/00004623-199912000-00003
26. Döring K, Puchner S, Vertesich K, Funovics PT, Hobusch G, Sulzbacher I, Chiari C, Windhager R (2022) Results in the surgical treatment of aneurysmal bone cysts - A retrospective data analysis. Orthop Traumatol Surg Res 108(4):103095. https://doi.org/10.1016/j.otsr.2021.103095
27. Lin PP, Brown C, Raymond AK, Deavers MT, Yasko AW (2008) Aneurysmal bone cysts recur at juxtaphyseal locations in skeletally immature patients. Clin Orthop Relat Res 466:722–728. https://doi.org/10.1007/s11999-007-0080-8
28. Levanon E, Merose O, Segal O, Dadia S, Sternheim A, Levin D, Sher O, Gortzak Y (2024) Does cryotherapy decrease the local recurrence rate in the treatment of an aneurysmal bone cyst? A comparative assessment. J Orthop Res 42(6):1369–1375. https://doi.org/10.1002/jor.25775
29. Bavan L, Eastley N, Stevenson J, Mifsud M, Bayliss L, Mahmoud S, Baker G, Cusick L, Nail R, Rankin K, Crooks S, Cool P, Williams D, Kandarakis G, Duncan R, Kothari A, ABC Study Group (2024) Aneurysmal bone cysts: A UK wide tumor center experience. J Surg Oncol 129(3):601–608. https://doi.org/10.1002/jso.27499
30. Ramírez AR, Stanton RP (2002 Jul-Aug) Aneurysmal bone cyst in 29 children. J Pediatr Orthop 22(4):533–539
31. Zehetgruber H, Bittner B, Gruber D, Krepler P, Trieb K, Kotz R, Dominkus M (2005) Prevalence of aneurysmal and solitary bone cysts in young patients. Clin Orthop Relat Res 439:136–143. https://doi.org/10.1097/01.blo.0000173256.85016.c4
32. Hudson TM (1984) Fluid levels in aneurysmal bone cysts: a CT feature. AJR Am J Roentgenol 142(5):1001–1004. https://doi.org/10.2214/ajr.142.5.1001
33. Tsukamoto S, Errani C, Facchini F, Papagelopoulos P, Mavrogenis AF (2021) Fluid-fluid levels in musculoskeletal tumor imaging. Curr Med Imaging 17(2):157–165. https://doi.org/10.2174/1573405616666200806173258
34. Van Dyck P, Vanhoenacker FM, Vogel J, Venstermans C, Kroon HM, Gielen J, Parizel PM, Bloem JL, De Schepper AM (2006) Prevalence, extension and characteristics of fluid-fluid levels in bone and soft tissue tumors. Eur Radiol 16(12):2644–2651. https://doi.org/10.1007/s00330-006-0250-1
35. Bazzocchi A, Spinnato P, Mercatelli D, Aparisi Gómez MP (2019) Fluid-Fluid levels in aneurysmal bone cysts. J Pediatr 204:317. https://doi.org/10.1016/j.jpeds.2018.08.081
36. Davies AM, Cassar-Pullicino VN, Grimer RJ (1992) The incidence and significance of fluid-fluid levels on computed tomography of osseous lesions. Br J Radiol 65(771):193–198. https://doi.org/10.1259/0007-1285-65-771-193
37. Oliveira AM, Perez-Atayde AR, Inwards CY, Medeiros F, Derr V, Hsi BL, Gebhardt MC, Rosenberg AE, Fletcher JA (2004) USP6 and CDH11 oncogenes identify the neoplastic cell in primary aneurysmal bone cysts and are absent in so-called secondary aneurysmal bone cysts. Am J Pathol 165(5):1773–1780. https://doi.org/10.1016/S0002-9440(10)63432-3

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.