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Efficacy of Sclerotherapy With Polidocanol (Ethoxysclerol) in Primary Aneurysmal Bone Cysts in Children and Adolescents

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Background: Aneurysmal bone cysts (ABC) are rare benign osseous lesions that can be locally aggressive. Traditionally, curettage with or without bone grafting is the treatment of choice. Recent data suggest that percutaneous sclerotherapy is a safe alternative to surgery. We present our experience with percutaneous sclerotherapy. Primary study aims were success rate, risk factors for treatment failure, and complications.

Methods: In this single-center retrospective study (January 2003 to June 2019), 70 patients were treated with percutaneous sclerotherapy for primary ABC at various skeletal sites. Median age was 11 years (range: 3 to 17 y). Median follow-up was 40 months (range 18 to 144 mo). Clinical and radiologic assessments were performed until cyst healing.

Results: Successful healing was seen in 58 of 70 patients (83%) after 1 or more injections with polidocanol. In 12 patients (17%), definitive curettage was performed after previous sclerotherapy, which was considered failure of primary sclerotherapy treatment. Trends toward increased risk for >3 treatments or treatment failure included age younger than 5, epiphyseal plate involvement, and lower leg lesions. The only complication was anaphylaxis in 1 patient shortly after injection of polidocanol/contrast agent and ropivacaine, with full recovery after short resuscitation.

Conclusions: Our results show that percutaneous sclerotherapy with polidocanol has high efficacy in the treatment of primary ABC, with a low complication rate. Our only complication may have been an immediate allergic reaction to polidocanol/contrast agent or ropivacaine. Trends toward increased risk for treatment failure were age younger than 5, epiphyseal plate involvement, and lower leg lesions.

Level of Evidence: Level IV—therapeutic study.

Key Words: aneurysmal bone cysts, percutaneous sclerotherapy, ABC, risk factors, pediatrics, benign tumors

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Aneurysmal bone cysts (ABC) are rare benign osseous lesions of undefined neoplastic nature and can be locally aggressive.[1,2] Contrary to its nomenclature, ABCs are not completely cystic nor aneurysmatic.[3] Upregulation of ubiquitin-specific protease (USP)-6 Tre2 gene was identified in a subset of primary ABCs.[4] ABCs may occur as a primary neoplasm (50% to 70%) or secondary to another primary bone tumor, including giant cell tumor of the bone, chondroblastoma, fibrous dysplasia, chondromyxoid fibroma, or telangiectatic osteosarcoma.[1,5] The annual incidence of primary ABC is estimated at 1.4 new cases per 100,000 individuals.[2] Most patients are younger than 25 years. ABCs mostly affect the metaphysis of long bones.

Clinically, ABCs most commonly present with pain with or without a palpable mass and sometimes a pathologic fracture. On conventional radiographs, ABCs have an osteolytic, eccentric, and expansile appearance with cortical thinning and a soap-bubble appearance due to multichambered cysts (Fig. 1). There is no matrix mineralization. On magnetic resonance (MR) imaging, fluid-fluid levels are seen as a result of sedimentation of old aneurysmatic blood below fatty marrow, resulting from supine position (Fig. 2). Core needle biopsy to establish diagnosis is debatable, because tissue obtained may not be representative of the entire lesion. Also, even after histopathologic examination, diagnosing primary ABC may be challenging as they also arise secondary to more serious diagnoses including malignancies. Frozen section histopathology during biopsy may be helpful to confirm representativeness of the biopsy and show the benign nature. Therefore, in case of any doubt based on radiographic findings, this may be a reasonable first step before proceeding with definitive treatment.[6]

As with most benign lesions, the aim of treatment is to optimize local control while retaining maximum function and minimizing morbidity. Different treatment options exist, but traditionally curettage with or without bone grafting was the treatment of choice.[7–10] Other options include radiofrequency ablation, selective arterial embolization, minimally invasive curopsy (biopsy and curettage in 1 tempo) and recently limited experience is gained with systemic therapy including bisphosphonates and denosumab.[7,11,12] Recent data suggest that percutaneous sclerotherapy is a

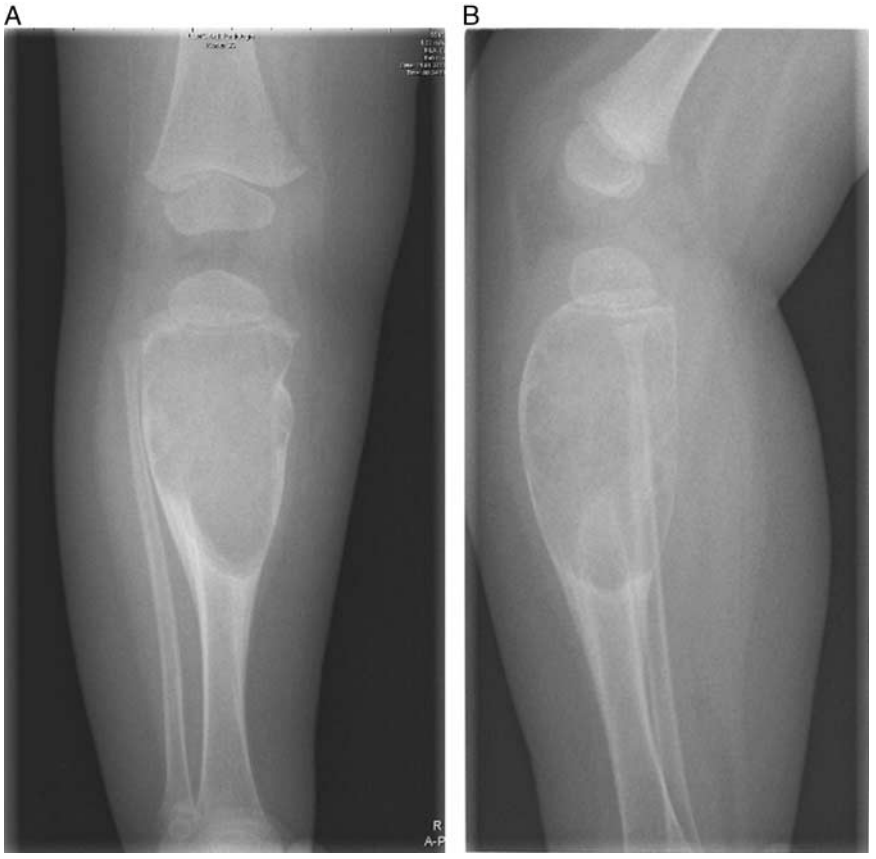

FIGURE 1. Conventional radiographs of the right lower leg in a 2-year-old child in (A) anteroposterior and (B) lateral views demonstrating a large lytic and expansile cyst of the proximal tibia metaphysis. Differential diagnosis of this lesion based only on these plain radiographs includes an aneurysmal bone cyst or a solitary bone cyst.

safe alternative to surgery, with similar recurrence rates and lower risk of damaging surrounding structures, shorter recovery period, and lower bleeding risk.[13,14] Polidocanol is a sclerotherapy agent that has a long history for the treatment of superficial varicosities[15–17] and can be used as a sclerosant directly damaging the endothelial lining of ABCs, hereby triggering the coagulation cascade resulting in thrombotic occlusion of supplying blood vessels and achieving local control in ABC (Fig. 3).[18] Side effects of polidocanol can be hypotension, cardiac arrest, anaphylaxis, and its use is contraindicated during pregnancy.[16,17,19] Doxycycline can also be used as a sclerosant and its safety and efficacy were reported in 20 patients by Shiels et al,[20,21] with a 5% recurrence rate after 2 to 14 injections per patient. Historically, recurrence rate after curettage of ABCs could be as high as 59%, whereas more recent studies have reported local control rates of between 85% and 90% after curettage.[3,8–10]

To date, there is no generally preferred treatment for primary ABCs. Several demographic and clinical characteristics may negatively influence results and identifying such parameters may be helpful in choosing optimal treatment for individual patients. In this study, we present our experience with percutaneous sclerotherapy in primary ABC. Our primary study aims were assessment of success rate, risk factors for treatment failure and complications.

METHODS

Patients were identified by a retrospective review of a prospectively maintained database in our tertiary referral center. Medical records were reviewed and demographic data included sex, age, localization, size, epiphyseal plate involvement, pathologic fracture, treatment, volume of sclerosant injection (mL), and outcome (Table 1). The local medical ethics committee waived the need for informed consent, as this was not required for the use of these patient data under the Medical Research Involving Human Subjects Act (G19-064). Tumor volume was calculated by multiplying maximum dimensions [APxCCxLR (mm)] on MR imaging, if available, or on conventional radiographs. Anesthesiology reports were assessed for potential systemic adverse events.

In all, 106 patients with primary ABC were treated in our tertiary referral center between 2003 and 2019. None of the patients underwent previous treatment elsewhere. Thirty patients with soft tissue or intra-articular extension, nonhealed fracture, or insufficient cortical containment were excluded because of initial treatment

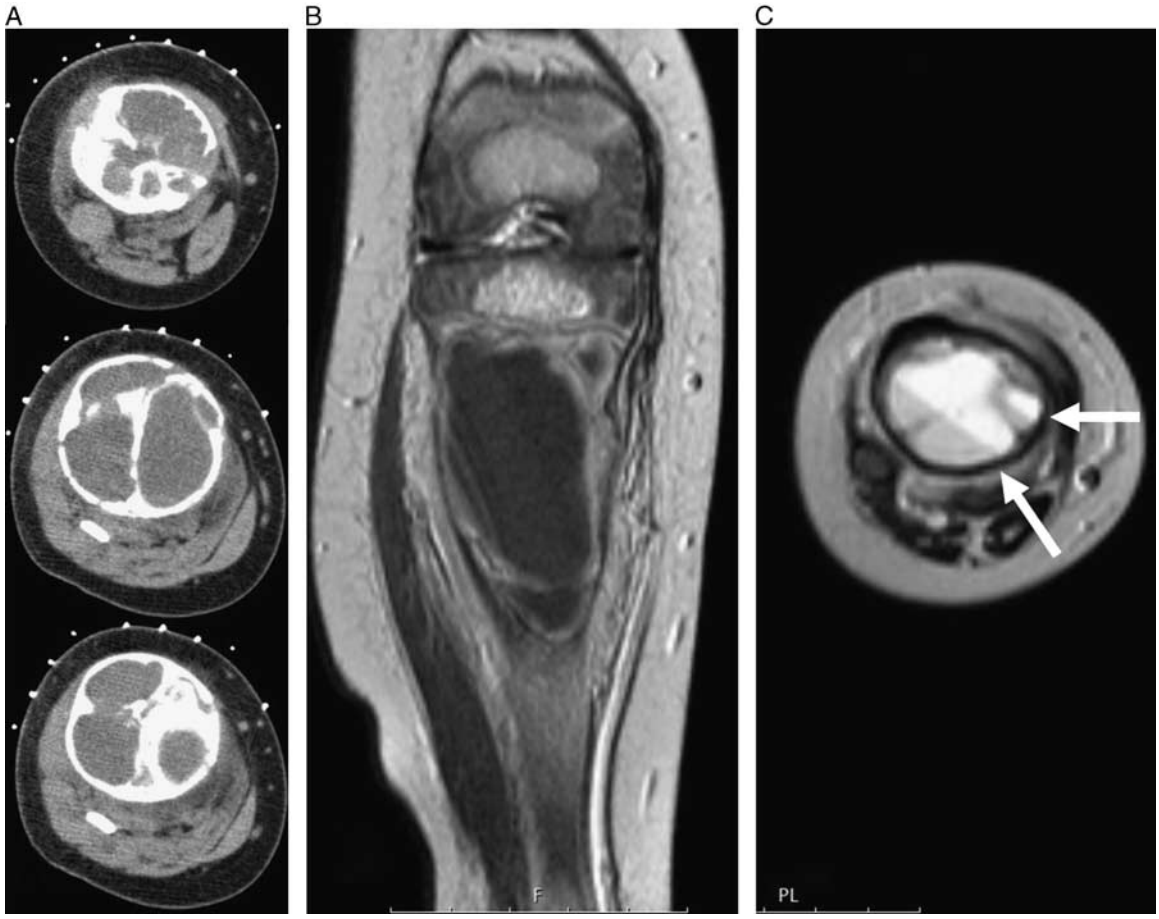

FIGURE 2. (A) Computed tomography images in the axial plane of the same patient demonstrating the proximal tibia metaphysis on several levels showing the multichambered nature of the cyst, consistent with an aneurysmal bone cyst. Magnetic resonance images with (B) coronal T1-weighted TSE sequence and (C) axial T2-weighted TSE sequence demonstrating the multichambered cyst with fluid-fluid levels as typically seen in aneurysmal bone cysts (white arrows). TSE indicates turbo spin echo.

was other than percutaneous sclerotheraphy: 15 curettage, 10 angioembolization and sclerosant injections, 3 curopsy and 2 primary resection (spinous process L1 and spondylodesis; partial scapula resection) (Fig. 4). Seventy were treated with (intended serial) sclerosant injections as primary treatment and were included in this study. Thirty-five were female. Median age was 11 years (range: 3 to 17 y). Median follow-up was 40 months (range: 18 to 144 mo). Standard treatment in our center was percutaneous sclerotherapy.

At first presentation, imaging included conventional radiographs in all and MR imaging in 62/70 patients. Definitive diagnosis was based on radiologic appearance in 50/70 patients. Preoperative core needle biopsy was performed in the other 20 patients and confirmed diagnosis in 10. In the remaining 10 patients, diagnosis was confirmed by excluding other diagnoses. In these patients, perioperative biopsy demonstrated primary ABC as definitive diagnosis.

Treatment consisted of injection of 3% polidocanol (Aethoxysklerol 30 mg/mL, Kressler Pharma, Germany) together with a gel foam absorbable sponge (12 m^2, Pfizer Manufacturing, Belgium) and 2 mL radiopaque contrast agent (Xenetix 300) into the lesion under fluoroscopy and general anesthesia. Approximately 1 mL of 3% polidocanol was injected per 1 mL tumor volume with no maximum per injection. In multilocular cysts, multiple needles were used to inject the sclerosant into different chambers. Percutaneous sclerotherapy procedures were completed in case of optimal filling of all cystic components of the ABC without venous filling. After injection, the core needle was blocked to prevent sclerosant backflow. During follow-up of the first patients, pain and sometimes fever was seen postoperatively, but this was not recorded on a routine basis. Therefore, we started with preoperative injection of bupivacaine 7.5% or lidocaine 2% subperiosteally at the injection site. This resulted in less postoperative pain.

Clinical improvement was determined by pain reduction and improved range of motion. Radiologic improvement was determined by sclerosis within the lesion and absence of increase in size (Fig. 3). In the absence of clinical and/or radiologic response, repeat sclerosant injection was given after 8 to 12 weeks and repeated at similar intervals as necessary. No further intervention was

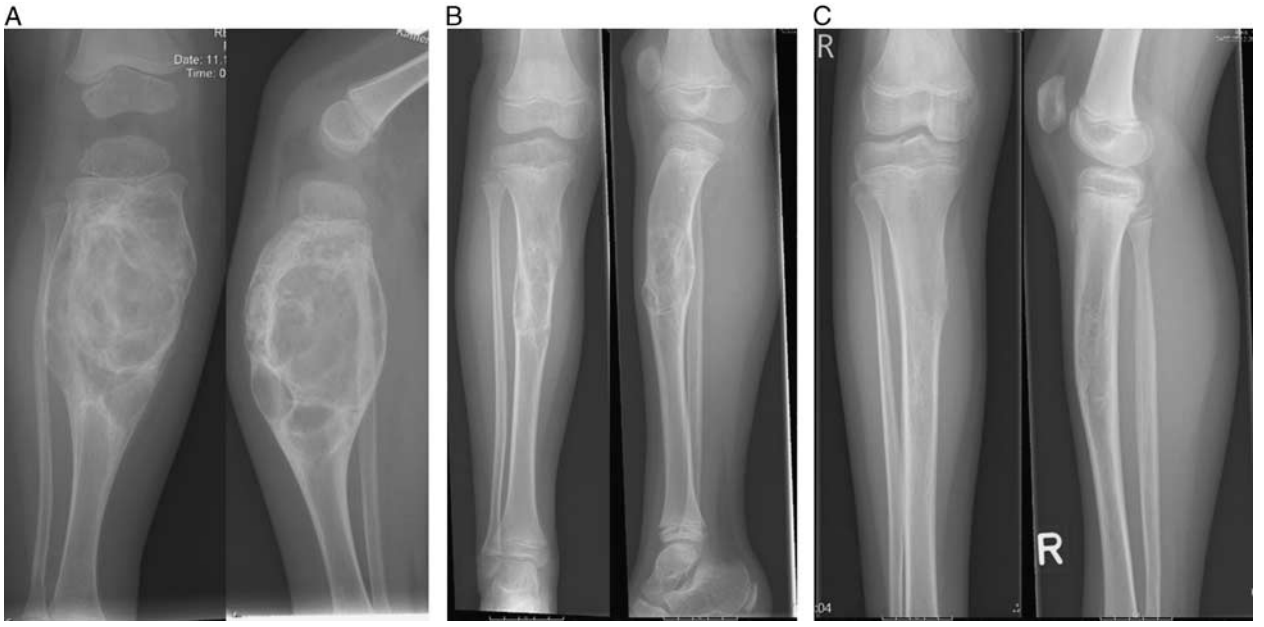

FIGURE 3. Conventional radiographs of the same patient during follow-up, after 1 percutaneous sclerotherapy injection. A, Demonstrates some cortical thickening and peripheral and central sclerosis of the lesion, but with persistent expansion 2 months after treatment. B, Demonstrates normal cortical thickness, slight remaining expansion during growth, and sclerosis of the previously lytic lesion at 5 years follow-up. C, Demonstrates complete resolution of the lytic cyst with almost full remodeling of the proximal tibia during growth at 10 years follow-up. Alignment in the coronal plane is normal and there is a small remaining angulation in the sagittal plane, with only slightly increased slope of the tibia plateau. Over the years during follow-up, this is spontaneously remodeling and the child will be followed until skeletal maturity.

considered in case of complete pain resolution, restored cortical thickness, increasing sclerosis within the lesion, and arrested growth of the lesion. We considered the need for >3 injections as a suboptimal sclerotherapy result. Local progression or residual disease was diagnosed if symptoms reappeared and/or with an increasing area of radiolucency within the lesion after treatment. In case of progression or insufficient radiologic improvement after repeated injections, curettage was performed as definitive treatment; we defined this as sclerotherapy treatment failure.

Patients were advised to avoid contact sports during the period of active treatment. All patients were called 2 weeks after treatment and were followed up at the outpatient clinic after 6 weeks and every 3 months for 2 years and every 6 months thereafter until the lesion was healed. Clinical examination and biplanar radiographs were performed at each outpatient visit.

Switch to curettage as definitive treatment was considered as failure of percutaneous sclerotherapy treatment. Relapse-free survival (RFS) was calculated for all patients treated with (repeated) sclerotherapy, and with definitive curettage as the primary end point. We considered the need for >3 repeated injections as suboptimal sclerotherapy result; results of this small group are presented separately.

TABLE 1. Patient and Tumor Characteristics

	n = 70
Sex (female/male)	35/35
Age at diagnosis, median (range) (y)	11; 3-17
Follow-up, median (range) (mo)	40; 18-144
Epiphyseal involvement (n; %)	7; 10
Pathologic fracture at diagnosis (n; %)	16; 23
Localization, n (%)	
Proximal humerus	14 (20)
Proximal tibia	10 (15)
Pelvis	9 (13)
Foot	8 (11)
Proximal femur	8 (11)
Distal fibula	7 (10)
Clavicle	2 (3)
Distal tibia	3 (5)
Proximal fibula	3 (5)
Costa	2 (3)
Scapula	1 (1)
Proximal ulna	1 (1)
Distal femur	1 (1)
Hand	1 (1)

Statistical Analysis

Continuous data were reported using median and range. Categorical data were presented by frequency and proportion and were compared using χ^2 or Fisher exact test. RFS was presented as Kaplan-Meier survival curve. Time to relapse (ie, need for more extensive treatment, being curettage) was calculated from first injection to curettage as definitive treatment or until last follow-up. Univariate and multivariate Cox regression analyses were performed to

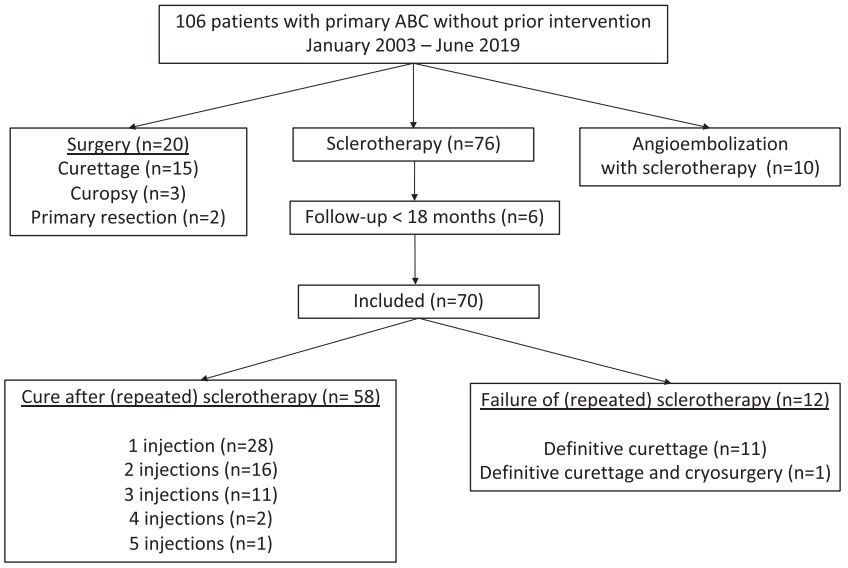

FIGURE 4. Flowchart of patients treated for primary aneurysmal bone cysts (ABC) at our tertiary referral center

assess risk factors for sclerotherapy treatment failure (ie, with curettage as primary endpoint). Age, localization, epiphyseal plate involvement, and pathologic fracture were included. All statistical analyses were performed using SPSS version 25.0 (IBM, Armonk, NY).

RESULTS

At follow-up, clinical and/or radiologic resolution of primary ABC was seen in 58/70 patients after 1 or more injections with polidocanol (83%). Number of injections with polidocanol required to achieve clinical and/or radiologic cure ranged from 1 to 5 (Table 2). Three patients needed 4 or 5 injections. In 12 patients, definitive curettage was performed after failing to achieve satisfactory clinical and/or radiologic improvement after (repeated) sclerotherapy. After curettage, 1 patient developed local recurrence, treated with repeat curettage and cryosurgery resulting in full recovery. RFS was 99% after 1 year, 94% after 2 years, 90% after 3 years, and 75% after 5 years.

Relevant patient and tumor characteristics of patients requiring >3 injections and/or curettage as definitive treatment are listed in Table 3. In univariate Cox regression analysis, several factors were identified resulting in a potentially higher risk of requiring definitive curettage, including lower leg localization, epiphyseal plate involvement, pathologic fracture, and age younger than 5 (Table 4). In a multivariate model, lower leg localization and epiphyseal plate involvement increased risk for sclerotherapy treatment failure. Approximately one-third of all lower leg lesions required definitive curettage (including proximal and distal tibia and fibula) after median 2 injections (range: 1 to 3). Overall, lesions with failed sclerotherapy eventually requiring definitive curettage were larger lesions (Table 5), suggesting that larger size may negatively influence percutaneous sclerotherapy outcome. The amount of polidocanol used per injection was not a prognostic factor for treatment failure.

TABLE 2. Number of (Repeated) Percutaneous Injections to Achieve Cure and Median Amount of Polidocanol Used Per Injection in Milliliter

	Patients (%)	Median Polidocanol/ Injection, (Range) (mL)
1 injection	28 (48.2)	6.0 (2-23)
2 injections	16 (27.6)	6.0 (2-22)
3 injections	11 (19.0)	8.0 (3-12)
4 injections	2 (3.5)	9.0 (6-18)
5 injections	1 (1.7)	10 (10-10)
Total	58 (83)	

TABLE 3. Patient and Tumor Characteristics in Case of Suboptimal Result After Sclerotherapy (ie, Requiring >3 Percutaneous Injections) and in Case of Failure of Sclerotherapy (ie, Requiring Curettage as Definitive Treatment to Cure)

Location	No. Injections >3 to Cure (n = 3), n/N (%)	Treatment Failure (Definitive Curettage) (n = 12), n/N (%)
Distal tibia	—	1/3 (33)
Proximal fibula	—	1/3 (33)
Proximal tibia	—	3/10 (30)
Distal fibula	—	2/7 (29)
Pelvis	1/9 (11)	2/9 (20)
Foot	—	1/8 (13)
Proximal femur	1/8 (13)	1/8 (13)
Proximal humerus	1/14 (7)	1/14 (6)
Clavicle	—	—
Scapula	—	—
Costa	—	—
Proximal ulna	—	—
Distal femur	—	—
Hand	—	—
Epiphyseal plate involvement	1/7 (14)	2/7 (29)
Pathologic fracture at diagnosis	—	3/16 (19)

TABLE 4. Potential Individual Risk Factors for Sclerotherapy Treatment Failure in Aneurysmal Bone Cysts With Definitive Curettage as End Point

	n	Failure	Hazard Ratio	95% Confidence Interval	*P*
Univariate Cox regression analysis					
Lower leg	23	7	3.6	1.1-12	0.04
Epiphyseal plate involvement	7	2	2.1	0.45-9.9	0.34
Pathologic fracture	16	3	1.8	0.44-6.9	0.42
Age under 5	10	4	1.5	0.39-5.9	0.54
Multivariate Cox regression analysis					
Lower leg	23	7	3.6	1.0-12	0.04
Epiphyseal plate involvement	7	2	2.0	0.43-9.7	0.37

There was 1 major complication, being hypovolemic shock due to anaphylaxis shortly after injecting the mixture of polidocanol/Xenetix 300 and ropivacaine in a 5-year-old healthy patient. Resuscitation included 1 no-shock block for pulseless electrical activity with adrenalin, resulting in bradycardia for which additional phenylephrine and atropine were given. Given the hypothesis of an allergic reaction to one of the agents, hydrocortisone, clemastine, and ranitidine were given. Return of spontaneous circulation was seen after 6 minutes. The intended treatment was discontinued and the patient recovered uneventfully; definitive curettage was performed at a later stage with no further recurrences nor complications. Four months earlier, the same patient underwent percutaneous sclerotherapy with the same agents and had a short course of hypotension. The patient was evaluated by a pediatrician/allergist, who explained the event as hypotension due to increased bioavailability of ropivacaine, or immediate (type I/IgE mediated) allergic reaction to either polidocanol or Xenetix 300, Querbet, Villepente, France. To date, no allergy tests were performed, with the pragmatic advise to avoid all agents until the age of 10 years, followed by epicutaneous skin tests. In several other patients, a brief drop in blood pressure (RR) was recorded during the intervention. One patient demonstrated a tension drop to RR 60/30 mm Hg shortly after injection of polidocanol/Xenetix 300 and ropivacaine, which normalized after a bolus of ephedrine. One patient demonstrated a tension drop to RR 70/20 mm Hg shortly after the injection that was only noted by the anaesthesiologist but needed no further medical attention. Two patients received a bolus of ephedrine shortly after induction and 2 received a bolus of ephedrine shortly before the end of general anesthesia; there was no direct relation with the sclerosant injection. There were no other major or minor complications in the other patients.

TABLE 5. Influence of the Size of the Lesion on Failure Rate of Percutaneous Injection (ie, When Definitive Curettage Was Required to Achieve Cure)

	n	Estimated Mean Tumor Volume (mm^3)	Mean Polidocanol Per Injection (mL)
Cured after (repeated) sclerotherapy	58	55,084	9.4
Not cured after (repeated) sclerotherapy	12	70,460	8.9

DISCUSSION

In this study, we present our experience with percutaneous sclerotherapy in primary ABC. Primary study aims were evaluating success rate, risk factors for treatment failure and complications.

In our study, clinical and radiologic resolution of ABC was seen in 58/70 (83%) patients after 1 or more injections with polidocanol after a median follow-up of 3 years. Puri et al[3] recently published a smaller retrospective study (56 patients) with similar success rate after 1 or more polidocanol injections (84%) and progression-free survival of 100%, 98%, and 93% after 2, 3, and 5 years. They presented a similar injection technique but with a maximum of 6 mL sclerosant, whereas polidocanol volume in our study was based on lesion volume without a maximum. In a smaller series with 19 patients, Batisse et al[22] reported similar success rates of 85% complete ossification and 95% pain-free patients after 3 months. In both series, percutaneous sclerotherapy with polidocanol demonstrated a safe and effective minimally invasive technique for primary ABC treatment. Another retrospective study comparing healing rates after polidocanol injection with curettage and bone grafting, demonstrated excellent local control after both interventions, without statistically significant difference (93% vs. 85%).[14] Also, promising reports on the use of doxycycline as sclerosing agent in ABC treatment are published by Shiels et al.[20,21] In a preliminary study, the authors reported 20 patients with a recurrence rate of 5% after 2 to 14 doxycycline foam injections and with a minimum follow-up of 24 months.[20] In a second study from the same authors, focussing on ABC affecting the epiphyseal plate, they reported mainly the same patients included in the same study period: none of the patients with focal involvement of the epiphyseal plate demonstrated diffuse epiphyseal growth arrest; only patients with intraepiphyseal or transepiphyseal ABC had epiphyseal growth arrests.[21] Overall, sclerosant injection therapy has many advantages over conventional surgery, including lower complication risk and less surgical morbidity and is therefore recommended as treatment of first choice.

Our study is the first to report on trends toward increased risk for treatment failure after (repeated) percutaneous sclerotherapy. Several trends were identified, including age younger than 5, epiphyseal plate involvement, and lower leg lesions. Young age and open growth plates were also identified as risk factors for recurrence after curettage with a high-speed burr.[23] At a younger age and/or with epiphyseal plate involvement, this increased failure risk may be explained by higher remaining growth potential, especially adjacent to epiphyseal plates, resulting in more active and growing lesions. A larger tumor

volume may be more difficult to treat completely with this minimally invasive technique. However, during follow-up of larger lesions, they often partially resolve, and only the remaining cystic part requires repeat injection. It is difficult to explain our finding of higher failure risk in lower leg lesions, but the expansile character in regions with less soft tissue coverage (when compared with upper leg and upper extremity) and maybe orthostasis resulting in a higher intralesional pressure may play a role in this. In the literature, risk factors for failure of sclerosant injection therapy have not been described, and it would be interesting if future studies will be able to confirm our findings on trends toward a higher risk for failure of sclerosant therapy.

Percutaneous sclerosant therapy is generally considered a safe procedure with a low complication rate. Several sclerosant agents exist, including polidocanol used as standard treatment in our center, and doxycycline as reported by one other group.[20,21] Tsagozis and Brosjö[24] described different treatment modalities in their review, and concluded that sclerotherapy is a cost-effective procedure that may be done in an outpatient setting with good functional outcome, sometimes requiring multiple procedures; and that curettage is often effective as a single procedure, but cannot be performed in an outpatient setting and may result in higher morbidity including growth disturbances. Complications after polidocanol injections may include hypopigmentation, injection site necrosis, pulmonary embolism, osteomyelitis, allergic reactions, and anesthetic complications.[14,18,25] None of these complications were reported in the recent study of Puri et al.[3] We only reported 1 (major) complication. This healthy 5-year-old patient, without known allergies, sustained a cardiac arrest shortly after injecting polidocanol/Xenetix 300 and ropivacaine. Fortunately, return of spontaneous circulation was seen after short resuscitation and the patient completely recovered. We did not proceed with the planned procedure and definitive curettage was performed at a later date. Over the course of our study period, 2 other patients demonstrated transient hypotension shortly after injection of polidocanol/contrast agent. Recently, a first case involving severe life-threatening hypersensitivity reaction after polidocanol injection was reported.[19] Therefore, we advise to perform this procedure under general anesthesia, to include the injection of polidocanol/contrast agent in the formal time-out procedure and to announce this to the anesthesiologist shortly before injecting, in analogy with announcing cementation in total hip and knee arthroplasty. In this way, the anesthesiologist may anticipate potential tension drops. After curettage, the complication rate can be as high as 10%, and includes intraoperative hemorrhage, growth disturbances and infection.[24,26]

Recently, some experience has been gained with the use of denosumab, a receptor activator of nuclear factor kappa-B ligand inhibitor, as systemic targeted therapy for ABC.[10,11,27] Kurucu and colleagues treated 9 pediatric ABC patients with denosumab (70 mg/m^2 monthly) for a median of 12 months (range: 6 to 14 mo). Clinically, all patients experienced pain reduction and radiologically, tumor volume reduction ranged from 18% to 82%.[28] Palmerini and colleagues treated 9 ABC patients (median age 17 y, range: 14 to 42 y) with denosumab (120 mg monthly) for a median of 8 months (range: 3 to 61 mo). Clinically, all patients experienced pain reduction and radiologically, replacement of cystic formations with solid bony tissue was seen.[29] Complications of denosumab treatment for ABC included rebound hypercalcemia and asymptomatic hypocalcemia. Recently, a small therapeutic study has been conducted on denosumab as potential treatment for recurrent ABC, axial localization, or pathologic fracture (NCT03415477), but results have not yet been published. Currently, an open-label multicenter phase 2 study on the efficacy of denosumab in giant cell-rich tumors of the bone (including ABC) is conducted and still recruiting patients (NCT03605199). None of our patients received denosumab.

Limitations

One of the limitations of our study is that preoperative biopsy was performed in only 20 of 70 patients, confirming the histologic diagnosis in only 10 of these 20. However, in all patients, perioperative biopsy was performed, confirming the diagnosis of primary ABC in all patients and ruling out other diagnoses including telangiectatic osteosarcoma. In addition, we feel that preoperative biopsy may not always be representative of the final diagnosis because of sample error in the large cystic areas.

In conclusion, our study affirmed a high success rate of percutaneous sclerotherapy in ABC treatment in children, with a low complication rate. Younger age at diagnosis, epiphyseal involvement, larger tumor volume, and lower leg localization (the tibia and fibula) demonstrated a trend toward higher risk for failure of percutaneous sclerotherapy. Finally, injection of polidocanol/contrast agent should be announced before the anesthesiologist to be able to anticipate the uneventful event of tension drops.

REFERENCES

1. Fletcher CDMBJ, Hogendoorn PCW, Mertens F. Soft tissue and bone tumours–aneurysmal bone cyst. *WHO Classification of Tumours, 5th Ed, Vol 3: Soft Tissue and Bone Tumours*. 2020;3:348–349.
2. Leithner A, Windhager R, Lang S, et al. Aneurysmal bone cyst. A population based epidemiologic study and literature review. *Clin Orthop Relat Res*. 1999;363:176–179.
3. Puri A, Hegde P, Gulia A, et al. Primary aneurysmal bone cysts. *Bone Joint J*. 2020;102-B:186–190.
4. Oliveira AM, Hsi BL, Weremowicz S, et al. USP6 (Tre2) fusion oncogenes in aneurysmal bone cyst. *Cancer Res*. 2004;64:1920–1923.
5. Mascard E, Gomez-Brouchet A, Lambot K. Bone cysts: Unicameral and aneurysmal bone cyst. *Orthop Traumatol Surg Res*. 2015;101(suppl): S119–S127.
6. Mohaidat ZM, Al-Gharaibeh SR, Aljararhih ON, et al. Challenges in the diagnosis and treatment of aneurysmal bone cyst in patients with unusual features. *Adv Orthop*. 2019;2019:2905671.
7. Muratori F, Mondanelli N, Rizzo AR, et al. Aneurysmal bone cyst: A review of management. *Surg Technol Int*. 2019;35:325–335.
8. Mendenhall WM, Zlotecki RA, Gibbs CP, et al. Aneurysmal bone cyst. *Am J Clin Oncol*. 2006;29:311–315.
9. Mankin HJ, Hornicek FJ, Ortiz-Cruz E, et al. Aneurysmal bone cyst: A review of 150 patients. *J Clin Oncol*. 2005;23:6756–6762.

10. Grahneis F, Klein A, Baur-Melnyk A, et al. Aneurysmal bone cyst: A review of 65 patients. *J Bone Oncol*. 2019;18:100255.
11. Dürr HR, Grahneis F, Baur-Melnyk A, et al. Aneurysmal bone cyst: Results of an off label treatment with denosumab. *BMC Musculoskelet Disord*. 2019;20:456.
12. Skubitz KM, Peltola JC, Santos ER, et al. Response of aneurysmal bone cyst to denosumab. *Spine (Phila Pa 1976)*. 2015;40:E1201–E1204.
13. Oliveira M, Meohas W, Silva RR, et al. Percutaneous treatment of aneurysmal bone cyst with calcitonin and methylprednisolone. *Acta Ortop Bras*. 2018;26:314–319.
14. Varshney MK, Rastogi S, Khan SA, et al. Is sclerotherapy better than intralesional excision for treating aneurysmal bone cysts? *Clin Orthop Relat Res*. 2010;468:1649–1659.
15. Brodersen JP, Geismar U. Catheter-assisted vein sclerotherapy: a new approach for sclerotherapy of the greater saphenous vein with a double-lumen balloon catheter. *Dermatol Surg*. 2007;33:469–475.
16. Campos W Jr, Torres IO, da Silva ES, et al. A prospective randomized study comparing polidocanol foam sclerotherapy with surgical treatment of patients with primary chronic venous insufficiency and ulcer. *Ann Vasc Surg*. 2015;29:1128–1135.
17. Rabe E, Otto J, Schliephake D, et al. Efficacy and safety of great saphenous vein sclerotherapy using standardised polidocanol foam (ESAF): A randomised controlled multicentre clinical trial. *Eur J Vasc Endovasc Surg*. 2008;35:238–245.
18. Rastogi S, Varshney MK, Trikha V, et al. Treatment of aneurysmal bone cysts with percutaneous sclerotherapy using polidocanol. A review of 72 cases with long-term follow-up. *J Bone Joint Surg Br*. 2006;88:1212–1216.
19. Gupta G, Pandit RS, Jerath N, et al. Severe life-threatening hypersensitivity reaction to polidocanol in a case of recurrent aneurysmal bone cyst. *J Clin Orthop Trauma*. 2019;10:414–417.
20. Shiels WE 2nd, Mayerson JL. Percutaneous doxycycline treatment of aneurysmal bone cysts with low recurrence rate: A preliminary report. *Clin Orthop Relat Res*. 2013;471:2675–2683.
21. Shiels WE 2nd, Beebe AC, Mayerson JL. Percutaneous doxycycline treatment of juxtaphyseal aneurysmal bone cysts. *J Pediatr Orthop*. 2016;36:205–212.
22. Batisse F, Schmitt A, Vendeuvre T, et al. Aneurysmal bone cyst: A 19-case series managed by percutaneous sclerotherapy. *Orthop Traumatol Surg Res*. 2016;102:213–216.
23. Gibbs CP Jr, Hefele MC, Peabody TD, et al. Aneurysmal bone cyst of the extremities. Factors related to local recurrence after curettage with a high-speed burr. *J Bone Joint Surg Am*. 1999;81:1671–1678.
24. Tsagozis P, Brosjö O. Current strategies for the treatment of aneurysmal bone cysts. *Orthop Rev (Pavia)*. 2015;7:6182.
25. Park HJ, Kwon SY, Cho SG, et al. Giant cell tumor with secondary aneurysmal bone cyst shows heterogeneous metabolic pattern on (18)F-FDG PET/CT: A case report. *Nucl Med Mol Imaging*. 2016;50:348–352.
26. Wang EH, Marfori ML, Serrano MV, et al. Is curettage and high-speed burring sufficient treatment for aneurysmal bone cysts? *Clin Orthop Relat Res*. 2014;472:3483–3488.
27. Lipplaa A, Dijkstra S, Gelderblom H. Challenges of denosumab in giant cell tumor of bone, and other giant cell-rich tumors of bone. *Curr Opin Oncol*. 2019;31:329–335.
28. Kurucu N, Akyuz C, Ergen FB, et al. Denosumab treatment in aneurysmal bone cyst: Evaluation of nine cases. *Pediatr Blood Cancer*. 2018;65:4.
29. Palmerini E, Ruggieri P, Angelini A, et al. Denosumab in patients with aneurysmal bone cysts: A case series with preliminary results. *Tumori*. 2018;104:344–351.