Chondroblastoma: Radiofrequency Ablation—Alternative to Surgical Resection in Selected Cases[1]

Leon D. Rybak, MD
Daniel I. Rosenthal, MD
James C. Wittig, MD

Purpose: To demonstrate that radiofrequency (RF) ablation can be used safely and effectively to treat selected cases of chondroblastoma.

Materials and Methods: Approval was obtained from institutional review boards, research was in compliance with HIPAA protocol. The need to obtain informed consent was waived for retrospective review of patient records. The records of patients with biopsy-proved chondroblastoma who were treated with RF ablation at two academic centers from July 1995 to July 2007 were reviewed. RF ablation was performed with a single-tip electrode by using computed tomography for guidance. Lesion characteristics were determined from imaging studies obtained at the time of the procedure. Symptoms were assessed before and 1 day after the procedure. Longer-term follow-up was obtained from medical records.

Results: Thirteen male and four female patients were treated (mean age, 17.3 years). The lesions were located in the proximal humerus ($n = 7$), proximal tibia ($n = 4$), proximal femur ($n = 3$), and distal femur ($n = 3$). The mean volume of the lesions was 2.46 mL. All patients reported relief of symptoms on postprocedure day 1. Three patients were lost to follow-up. Of the 14 patients for whom longer-term (mean, 41.3 months; range, 4–134 months) follow-up was available, 12 had complete relief of symptoms with no need for medications and full return to all activities. The patient who had the largest lesion of the study required surgical intervention because of collapse of the articular surface in the treatment area. Residual viable tumor was found at surgery. Another patient experienced mechanical problems that were thought to be unrelated to the RF ablation and was rendered pain-free after subsequent surgical treatment.

Conclusion: Percutaneous RF ablation is an alternative to surgery for treatment of selected chondroblastomas. Larger lesions beneath weight-bearing surfaces should be approached with caution due to an increased risk of articular collapse and recurrence.

[1] From the Department of Radiology, New York University Hospital for Joint Diseases, 301 E 17th St, 6th Floor, New York, NY 10003-3899 (L.D.R.); the Department of Radiology, Massachusetts General Hospital, Boston, Mass (D.I.R.); and the Department of Orthopedic Surgery, Mount Sinai Medical Center, New York, NY (J.C.W.). From the 2007 RSNA Annual Meeting. Received March 15, 2008; revision requested May 1; revision received July 10; accepted September 18; final version accepted December 10. **Address correspondence to** L.D.R. (e-mail: *Leon.rybak@med.nyu.edu*).

Chondroblastomas are rare bone tumors accounting for approximately 1% of all benign bone lesions. They were first described by Jaffe and Lichtenstein in 1942 (1). Ninety percent of chondroblastomas occur in patients aged 3–25 years. They are more common in male patients (male-to-female ratio, 2:1). Most chondroblastomas occur in the long tubular bones and almost invariably involve the epiphysis or apophysis. They incite inflammatory changes in the surrounding tissues, resulting in pain and decreased range of motion (2,3).

The classic treatment for chondroblastoma is surgical removal. Because of location, the risks of surgery include injury to the articular surface or adjacent open growth plates leading to growth disturbances, decreased range of motion, and premature arthritis. Surgery is curative in most cases, but recurrence rates of 10%–35% have been reported in the literature (4–7).

Radiofrequency (RF) ablation is a well-established technique for the treatment of osteoid osteomas (8–10) and palliation of painful bone metastases (11–13).

Successful treatment of a series of three chondroblastomas by using percutaneous RF ablation was reported in 2001 (14). Since that time, to our knowledge, only two additional reports have been published (15,16). Because of the rarity of the tumor, it is difficult to accumulate substantial clinical experience. The authors undertook this retrospective review at two academic centers to help determine the appropriate role of RF ablation in the treatment of chondroblastoma. The purpose of our study was to demonstrate that RF ablation can be used safely and effectively to treat selected cases of chondroblastoma.

Advances in Knowledge

- Selected chondroblastomas can be safely and effectively treated with percutaneous radiofrequency ablation.
- The size of the lesion and position along a weight-bearing articular surface may determine the feasibility of this procedure.

Materials and Methods

One author (D.I.R.) has recently taken a position on the scientific advisory board of Covidien (Mansfield, Mass).

Approval was obtained from the institutional review boards at the participating institutions for the retrospective review of the clinical and imaging data included in this report. A waiver of consent was obtained. The study was Health Insurance Portability and Accountability Act compliant. No financial support of any kind was received for this study.

Patients and Procedure

Patients were included for this review if they had undergone RF treatment of a histologically confirmed chondroblastoma at either institution (institution 1, Massachusetts General Hospital; institution 2, New York University Hospital for Joint Diseases). The patient sex and age at the time of the procedure were noted. The nature of the patient's presenting symptoms was recorded as part of a preprocedural history and physical examination. One otherwise eligible patient (institution 1) was excluded because of a highly atypical presentation (multiple synchronous lesions in an individual outside the usual age range).

All patients had been referred by surgeons specializing in orthopedic oncology. The preoperative diagnosis was on the basis of typical imaging and clinical features. Biopsies were performed at the time of treatment but were not part of the selection criteria because, with one exception (noted below), results were not available until after RF ablation. Because this is a relatively new indication for RF ablation with little published data on outcomes, well-established criteria for patient selection were not available. No specific size criteria were employed. Lesions were selected for RF ablation if, in the judgment of the surgeon and the radiologist, the risks of damage to the articular surface, growth plate, or joint with surgical removal were greater than the risks of RF ablation. In most cases, lesions in imminent danger of mechanical collapse were treated with surgery, and augmentation was performed. However, one patient with a large lesion was referred because the surgeon believed that the risk of articular collapse with an open procedure was high enough to warrant an initial attempt with RF ablation.

The records from each institution were reviewed to determine the number of patients with chondroblastoma treated with open surgical excision during the same time period, and the percentage of patients referred for RF ablation was calculated.

All patients were treated by two of the authors (L.D.R. and D.I.R.), both radiologists with experience in RF ablation of osteoid osteomas. Informed consent was obtained.

Due to the painful nature of the lesions, and because precise electrode placement might be compromised by patient movement, all procedures were performed with the patient under general anesthesia. Computed tomography (CT) was used for imaging guidance. The CT scans were limited to the area of the tumor and consisted of helically acquired 3-mm axial sections with 120 kVp and 90–100 mAs depending on the thickness of the body part imaged and the age of the patient. One-millimeter-

Implication for Patient Care

- A minimally invasive alternative to surgery may be available to many patients with chondroblastomas.

Published online before print
10.1148/radiol.2512080500

Radiology 2009; 251:599–604

Abbreviation:
RF = radiofrequency

Author contributions:
Guarantors of integrity of entire study, L.D.R., J.C.W.; study concepts/study design or data acquisition or data analysis/interpretation, all authors; manuscript drafting or manuscript revision for important intellectual content, all authors; manuscript final version approval, all authors; literature research, L.D.R., J.C.W.; clinical studies, L.D.R., D.R., J.C.W.; statistical analysis, L.D.R.; and manuscript editing, L.D.R., D.R., J.C.W.

See Materials and Methods for pertinent disclosures.

thick axial reformations were acquired and used to plan the treatment. Coronal and sagittal reformations at 2–3-mm increments were acquired after the procedure and included in the final examination sent to the picture archiving and communication system workstations.

Access to the lesions was obtained with a 14-gauge hand-operated drill (Bonopty penetration set; RADI Medical Systems, Upssala, Sweden). In every case, a core biopsy was performed before treatment by using a 15- or 16-gauge biopsy needle in a coaxial fashion. These specimens were submitted for permanent pathologic examination. Frozen slices were not used because of the small size of the sample. The biopsy needle was then replaced with the RF probe. Reusable monopolar probes (Covidien) were used at institution 1, and monopolar probes (Cool-Tip; Covidien) were used without cooling at institution 2. With the generator (Covidien) in the manual mode, the output was gradually increased until a temperature of 90°C was achieved and maintained for 6 minutes. These parameters were selected on the basis of the authors' experience with ablation of osteoid osteomas. Additional 6-minute treatments were performed on the basis of the size and geometry of the lesion, placing the exposed probe tip within 6 mm of all portions of the tumor to ensure complete ablation. Multiple small overlapping treatments were thought to offer minimal risk to the articular surface. The "cooled" mode was used in one case at institution 2 where the spherical geometry of the lesion and the match between lesion size and expected coagulation diameter with this technique resulted in reduced RF application time.

Procedure reports were reviewed to determine probe size and the number of treatments performed. The total time of RF application was calculated by multiplying the number of treatments by 6 minutes.

All patients were transferred to the postoperative anesthesia care unit and discharged after a few hours. Patients with lesions along weight-bearing surfaces were discharged with partial or non–weight-bearing precautions and told to consult their orthopedist for activity modifications. The patients were instructed to use pain medications as necessary. They were contacted by phone on postprocedure day 1 to assess subjective (no formal quantitative scale used) changes in the level of their preprocedural pain, and the results were recorded.

CT Imaging

The CT scan obtained at the onset of the procedure was retrospectively reviewed at each institution by the operator who performed the ablations. Lesion size and anatomic location were noted. Assessment of lesion size in all three planes (x = anteroposterior, y = transverse, and z = craniocaudal) was performed with a picture archiving and communication system (AGFA; Agfa-Gevaert Group, Mortsel, Belgium) at institution 1 and with another picture archiving and communication system (Siemens Medical Systems, Erlangen, Germany) at institution 2. Lesion volume was calculated by assuming simple cubic geometry ($x \cdot y \cdot z$). Note was made of the status of the growth plate (open or closed). Any contact between the lesion and an open growth plate was noted.

Clinical Analysis

The records were reviewed for reported pain relief on postprocedure day 1. When available, longer-term follow-up with regard to pain levels was obtained from the medical records. The records were also reviewed for any new symptoms or limitations on activity that could be attributed to the procedure and, specifically, damage to the growth plate.

Complications

Procedure reports were reviewed for any complications at the time of ablation. When available, the medical records were reviewed for any recurrent symptoms or additional treatments required.

Results

Patients and Procedures

Patient and procedure-related details are presented in the Table. From 1995

Summary of Patient Characteristics and Procedural Details

Patient No./Age (y)/Sex	Lesion Location*	Lesion Dimensions (cm)	Lesion Volume (mL)	Probe Size (cm)	No. of Treatments	Time of RF Ablation (min)
1/22/M	PH	0.9 × 0.9 × 0.9	0.73	0.8	1	6
2/12/F	PH	0.6 × 1.0 × 1.2	0.72	0.5	1	6
3/18/M	PH	1.2 × 0.9 × 1.2	1.30	0.5	1	6
4/17/M	PH	1.2 × 1.3 × 1.5	2.34	0.5	1	6
5/14/M	PH	1.0 × 1.1 × 1.3	1.43	1.0	1	6
6/27/M	PH	0.7 × 0.8 × 0.8	0.49	1.0	2	12
7/13/F	PH	1.0 × 0.9 × 1.2	1.08	1.0	1	6
8/16/M	PT	1.3 × 1.4 × 1.6	2.91	0.5	3	18
9/17/M	PT	2.5 × 2.0 × 2.1	10.50	0.8	12	72
10/16/M	PT	1.6 × 1.5 × 1.4	3.36	0.8	4	24
11/15/M	PT	1.6 × 1.5 × 1.5	3.60	2.0	1	6
12/26/F	PF	0.9 × 0.9 × 0.9	0.73	0.5	1	6
13/30/M	PF	1.7 × 1.6 × 1.7	4.62	0.5	7	42
14/14/F	PF	0.9 × 0.8 × 1.4	1.01	1.0	3	18
15/10/M	DF	1.2 × 1.7 × 1.2	2.49	0.8	6	36
16/14/M	DF	1.4 × 1.5 × 1.3	2.73	1.0	4	24
17/14/M	DF	1.3 × 1.3 × 1.1	1.86	1.0	1†	6

Note.—Mean patient age was 17.3 years, mean lesion volume was 2.46 mL, mean number of treatments was 2.94, and mean RF ablation time was 17.6 minutes.

* DF = distal femur, PF = proximal femur, PH = proximal humerus, PT = proximal tibia.

† A cooled probe was used in this case.

to 2007, 10 patients were included from the first institution. This includes three previously published cases (14). From 2004 to 2007, another seven patients were identified at the second institution. There were 13 male and four female patients aged 10–30 years (mean age, 17.3 years).

In 14 of the 17 patients, chondroblastoma had been suspected before ablation on the basis of typical symptoms and imaging features. In two patients—one at each institution—the presumptive diagnosis had been osteoid osteoma, but biopsy results revealed chondroblastoma. In one patient, histologic confirmation was available with biopsy results before treatment.

During the same time period, 43 chondroblastomas were treated surgically at the combined institutions; thus, the 17 patients treated with RF ablation represent 28% of the total (17 of 60 patients). The records of these surgically treated cases were not all available for review, and a detailed comparison between the two patient groups is not possible.

Probe sizes used at institution 1 were 5 mm ($n = 6$) and 8 mm ($n = 4$), and those at institution 2 were 1 cm ($n = 6$) and 2 cm ($n = 1$). The range of individual treatments required within a given procedure was one to 10 (mean, 2.94). The total RF application time ranged from 6 to 72 minutes (mean, 17.6 minutes).

Figure 1

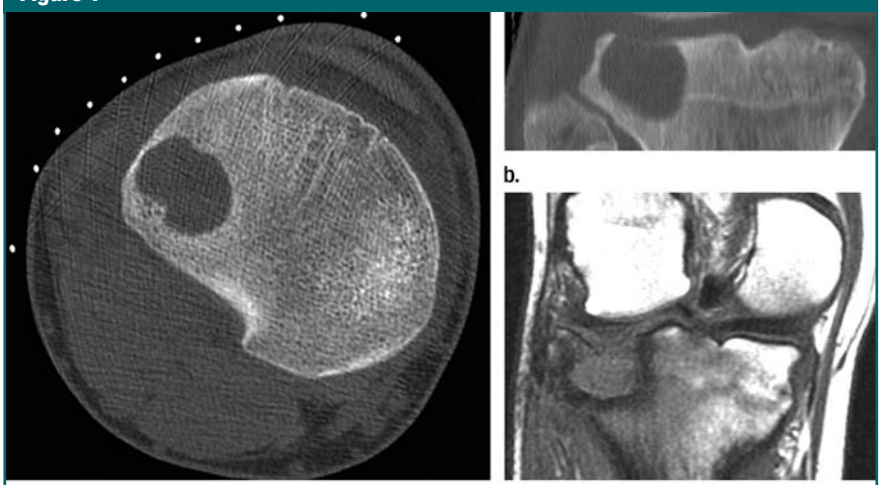

Figure 1: Images in 17-year-old adolescent boy with subsequent collapse of the articular surface after RF ablation of a large lesion in lateral tibial plateau. **(a)** Axial CT scan and **(b)** reconstructed coronal CT scan obtained immediately before the procedure demonstrate a large lytic lesion in the posterolateral aspect of the tibial plateau with marked thinning of the articular surface. **(c)** Coronal T1-weighted MR image obtained 9 months after RF ablation demonstrates collapse of the subchondral surface with marked surrounding low-signal-intensity edema.

Figure 2

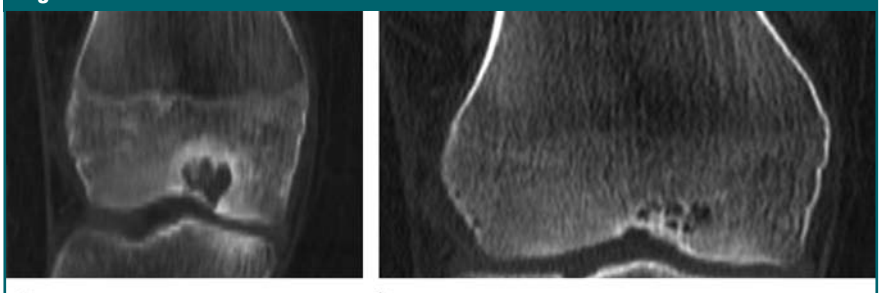

Figure 2: CT scans in 14-year-old adolescent boy demonstrate healing of a lesion after RF ablation. **(a)** Coronal reconstructed CT scan of the knee obtained 3 months after ablation demonstrates a small lytic lesion with sclerotic margins along the inner margin of the medial femoral condyle with thinning of the articular surface. **(b)** CT scan obtained 24 months later demonstrates healing in the area of the lesion with in-growth of bone and small residual cystic change.

CT Imaging Findings

The lesions were located in the proximal humerus ($n = 7$), proximal tibia ($n = 4$), proximal femur ($n = 3$), and distal femur ($n = 3$). The maximum lesion dimension ranged from 0.8 to 2.5 cm (mean, 1.4 cm). Lesion volume ranged from 0.49 to 10.5 mL (mean, 2.46 mL). In 12 patients, the growth plate was assessed as being closed at imaging. In the remaining five patients, the growth plate was open. In one of these five patients, the lesion contacted a portion of the growth plate.

Clinical Outcomes

All patients reported complete relief of their typical preprocedural pain on postprocedure day 1. Unfortunately, the use of pain medications was not recorded. Three patients were lost to follow-up; thus, longer-term clinical follow-up (mean, 41.3 months; range, 4–134 months) was available in 14 patients. Twelve patients have reported continued relief of pain with no further use of medications. The other two patients are described in the paragraphs to follow.

One patient who had been treated for a lesion of the femoral head reported recurrent hip pain on return to competitive athletics. Subsequent imaging demonstrated a labral tear and cartilage wear, which was confirmed at arthroscopy. The patient was treated with arthroscopic débridement with good pain relief.

One patient developed recurrent

pain approximately 9 months after treatment of a tibial lesion. This patient had the largest lesion treated in this series, with dimensions of 2.5 × 2.0 × 2.1 cm (transverse × anteroposterior × craniocaudal) and a volume of 10.5 mL. Magnetic resonance (MR) imaging demonstrated collapse of the articular surface over the lesion in the lateral tibial plateau (Fig 1). The patient required an open curettage and packing. During surgery, viable tumor was found. The patient remains largely pain free and has resumed playing soccer with mild occasional discomfort.

Imaging Outcomes

The lack of uniform imaging follow-up makes it difficult to draw meaningful conclusions. However, several instances of dramatic healing in the area were noted, one of which is included in Figure 2.

Complications

No complications attributable to the procedures were noted. Of the five patients with open growth plates at the procedure, longer-term follow-up (mean, 25 months; range, 5–45 months) was available in four patients. At clinical examination, none of these four patients were reported to have growth disturbances related to the lesion or damage to the growth plates sustained at the procedure.

Discussion

Our results reaffirm the impression that treatment of chondroblastoma with RF ablation is a reasonable alternative to surgery in selected cases.

The success rate for initial pain relief in our series was 100% (17 of 17 patients), with continued pain relief and no further need for intervention related to the lesion in 93% (13 of 14 patients) at longer-term follow-up. There was one recurrence (6%), which is less than would be anticipated based on rates of 10%–35% reported in several of the larger surgical series (4–6). The characteristics of our patient population and the anatomic distribution of the lesions are consistent with those in the literature for chondroblastoma. However, the lesions in the present series ranged from 0.8 to 2.5 cm (mean, 1.4 cm) in greatest diameter, which is smaller than the average range of 3–5 cm noted previously in both the radiologic and surgical literature (2,3). We believe, therefore, that the procedure is effective and safe for smaller lesions.

We would also argue that the delayed collapse of the articular cortex in the largest lesion of our series was due to residual viable tumor. It therefore represents an adverse outcome, but not a complication of the procedure. Thus, no complications directly attributable to the procedure were encountered.

Our results form an interesting contrast with the study by Tins et al (16), in which two of four relatively large (mean volume, 22.3 mL) lesions sustained damage to the articular surface (chondrolysis, osteonecrosis, collapse), with no evidence of residual tumor. In an effort to treat the tumors completely, Tins et al used larger multi-tined expandable probes. We chose (with one exception) to use single-tined noncooled probes, creating multiple small overlapping ablation zones—each not exceeding 1 cm in diameter.

We believe, therefore, that there is a delicate balance between the probability of complete tumor ablation and the risk of articular damage, particularly with larger lesions along a weight-bearing surface. The use of multi-tined probes (and presumably other large-volume treatment devices such as clustered or water-cooled probes) may produce more complete tumor necrosis but may also result in higher risks to the articular surface. Perhaps this risk can be decreased through the use of simultaneous percutaneous augmentation. In a recent report, Petsas et al (15) followed ablation of two femoral head lesions with multi-tined probes with percutaneous placement of bone graft. They demonstrated healing at follow-up, with no collapse of the articular surface.

In view of the possibility of residual tumor, a standardized follow-up protocol after RF ablation is desirable. Late recurrences have been reported following surgery, and yearly follow-up for at least 5 years is recommended in the surgical literature (4–7). Unfortunately, as the authors of this article were early in their experience with RF ablation of chondroblastomas, the imaging follow-up was left to the discretion of the referring surgeons and the vagaries of reimbursement policies. Although some dramatic instances of healing in the area of the ablation have been noted, given the wide variation with respect to both the timing of the imaging and the modality employed, no meaningful conclusions can be drawn from this information at this time.

The authors acknowledge that there were many limitations to this study. The procedures were performed at two different institutions by two different operators. Because our study was retrospective, we could not control the entrance criteria. The small size of the lesions treated clearly represents a selection bias. Furthermore, short-term pain relief was assessed subjectively, rather than with use of a standardized tool, and the use of analgesic medications was not restricted. Three patients were lost to follow-up.

However, because of the rarity of chondroblastoma, it is unlikely that a randomized, statistically significant case-controlled study comparing RF ablation with surgery is feasible.

Despite the limitations of the data, we believe that our experience supports the contention that RF ablation can be an alternative to surgery in the treatment of chondroblastoma. The size of the lesion and position along a weight-bearing surface should be taken into consideration when considering RF ablation.

References

1. Jaffe HL, Lichtenstein L. Benign chondroblastoma of bone: a reinterpretation of the so-called calcifying or chondromatous giant cell tumor. Am J Pathol 1942;18:969–983.

2. Resnick D. Bone and joint disorders. Fourth ed. Philadelphia, Pa: Saunders; 2002.

3. Robbin MR, Murphey MD. Benign chondroid neoplasms of bone. Semin Musculoskelet Radiol 2000;4(1):45–58.

4. Atalar H, Basarir K, Yildiz Y, Erekul S, Saglik Y. Management of chondroblastoma: retrospective review of 28 patients. J Orthop Sci 2007;12(4):334–340.

5. Lin PP, Thenappan A, Deavers MT, Lewis VO, Yasko AW. Treatment and prognosis of chondroblastoma. Clin Orthop Relat Res 2005;438:103–109.

6. Ramappa AJ, Lee FY, Tang P, Carlson JR, Gebhardt MC, Mankin HJ. Chondroblastoma of bone. J Bone Joint Surg Am 2000; 82(8):1140–1145.

7. Suneja R, Grimer RJ, Belthur M, et al. Chondroblastoma of bone: long-term results and functional outcome after intralesional curettage. J Bone Joint Surg Br 2005;87(7):974–978.

8. Rosenthal DI, Alexander A, Rosenberg AE, Springfield D. Ablation of osteoid osteomas with a percutaneously placed electrode: a new procedure. Radiology 1992;183(1): 29–33.

9. Rosenthal DI, Hornicek FJ, Wolfe MW, Jennings LC, Gebhardt MC, Mankin HJ. Percutaneous radiofrequency coagulation of osteoid osteoma compared with operative treatment. J Bone Joint Surg Am 1998; 80(6):815–821.

10. Rosenthal DI, Hornicek FJ, Torriani M, Gebhardt MC, Mankin HJ. Osteoid osteoma: percutaneous treatment with radiofrequency energy. Radiology 2003;229(1):171–175.

11. Callstrom MR, Charboneau JW, Goetz MP, et al. Painful metastases involving bone: feasibility of percutaneous CT- and US-guided radio-frequency ablation. Radiology 2002; 224(1):87–97.

12. Goetz MP, Callstrom MR, Charboneau JW, et al. Percutaneous image-guided radiofrequency ablation of painful metastases involving bone: a multicenter study. J Clin Oncol 2004;22(2):300–306.

13. Simon CJ, Dupuy DE. Percutaneous minimally invasive therapies in the treatment of bone tumors: thermal ablation. Semin Musculoskelet Radiol 2006;10(2):137–144.

14. Erickson JK, Rosenthal DI, Zaleske DJ, Gebhardt MC, Cates JM. Primary treatment of chondroblastoma with percutaneous radio-frequency heat ablation: report of three cases. Radiology 2001;221(2):463–468.

15. Petsas T, Megas P, Papathanassiou Z. Radiofrequency ablation of two femoral head chondroblastomas. Eur J Radiol 2007;63(1): 63–67.

16. Tins B, Cassar-Pullicino V, McCall I, Cool P, Williams D, Mangham D. Radiofrequency ablation of chondroblastoma using a multitined expandable electrode system: initial results. Eur Radiol 2006;16(4):804–810.

Radiology 2009

This is your reprint order form or pro forma invoice

(Please keep a copy of this document for your records.)

Reprint order forms and purchase orders or prepayments must be received 72 hours after receipt of form either by mail or by fax at 410-820-9765. It is the policy of Cadmus Reprints to issue one invoice per order. **Please print clearly**.

Author Name _____
Title of Article _____
Issue of Journal_____ Reprint # _____ Publication Date _____
Number of Pages_____ KB # _____ Symbol Radiology
Color in Article? Yes / No (Please Circle)

Please include the journal name and reprint number or manuscript number on your purchase order or other correspondence.

Order and Shipping Information

Reprint Costs **(Please see page 2 of 2 for reprint costs/fees.)**

_____ Number of reprints ordered $_____
_____ Number of color reprints ordered $_____
_____ Number of covers ordered $_____
Subtotal $_____
Taxes $_____

(*Add appropriate sales tax for Virginia, Maryland, Pennsylvania, and the District of Columbia or Canadian GST to the reprints if your order is to be shipped to these locations*.)

First address included, add $32 for each additional shipping address $_____

TOTAL $_____

Shipping Address **(cannot ship to a P.O. Box) Please Print Clearly**

Name _____
Institution _____
Street _____
City _____ State _____ Zip _____
Country _____
Quantity_____ Fax _____
Phone: Day _____ Evening _____
E-mail Address _____

Additional Shipping Address* **(cannot ship to a P.O. Box)**

Name _____
Institution _____
Street _____
City _____ State _____ Zip _____
Country _____
Quantity _____ Fax _____
Phone: Day _____ Evening _____
E-mail Address _____

** Add $32 for each additional shipping address*

Payment and Credit Card Details

Enclosed: Personal Check _____
Credit Card Payment Details _____

Checks must be paid in U.S. dollars and drawn on a U.S. Bank.

Credit Card: __ VISA __ Am. Exp. __ MasterCard
Card Number _____
Expiration Date_____
Signature: _____

Please send your order form and prepayment made payable to:

Cadmus Reprints
P.O. Box 751903
Charlotte, NC 28275-1903

Note: Do not send express packages to this location, PO Box.

FEIN #:541274108

Invoice or Credit Card Information

Invoice Address **Please Print Clearly**

Please complete Invoice address as it appears on credit card statement

Name _____
Institution _____
Department _____
Street _____
City _____ State _____ Zip _____
Country _____
Phone _____ Fax _____
E-mail Address _____

Cadmus will process credit cards and *Cadmus Journal Services* will appear on the credit card statement.

If you don't mail your order form, you may fax it to 410-820-9765 with your credit card information.

Signature _____ Date _____

Signature is required. By signing this form, the author agrees to accept the responsibility for the payment of reprints and/or all charges described in this document.

RB-1/01/09

Radiology 2009

Black and White Reprint Prices

Domestic (USA only)						
# of Pages	50	100	200	300	400	500
1-4	$239	$260	$285	$303	$323	$340
5-8	$379	$420	$455	$491	$534	$572
9-12	$507	$560	$651	$684	$748	$814
13-16	$627	$698	$784	$868	$954	$1,038
17-20	$755	$845	$947	$1,064	$1,166	$1,272
21-24	$878	$985	$1,115	$1,250	$1,377	$1,518
25-28	$1,003	$1,136	$1,294	$1,446	$1,607	$1,757
29-32	$1,128	$1,281	$1,459	$1,632	$1,819	$2,002
Covers	$149	$164	$219	$275	$335	$393

International (includes Canada and Mexico)						
# of Pages	50	100	200	300	400	500
1-4	$299	$314	$367	$429	$484	$546
5-8	$470	$502	$616	$722	$838	$949
9-12	$637	$687	$852	$1,031	$1,190	$1,369
13-16	$794	$861	$1,088	$1,313	$1,540	$1,765
17-20	$963	$1,051	$1,324	$1,619	$1,892	$2,168
21-24	$1,114	$1,222	$1,560	$1,906	$2,244	$2,588
25-28	$1,287	$1,412	$1,801	$2,198	$2,607	$2,998
29-32	$1,441	$1,586	$2,045	$2,499	$2,959	$3,418
Covers	$211	$224	$324	$444	$558	$672

Color Reprint Prices

Domestic (USA only)						
# of Pages	50	100	200	300	400	500
1-4	$247	$267	$385	$515	$650	$780
5-8	$297	$435	$655	$923	$1194	$1467
9-12	$445	$563	$926	$1,339	$1,748	$2,162
13-16	$587	$710	$1,201	$1,748	$2,297	$2,843
17-20	$738	$858	$1,474	$2,167	$2,846	$3,532
21-24	$888	$1,005	$1,750	$2,575	$3,400	$4,230
25-28	$1,035	$1,164	$2,034	$2,986	$3,957	$4,912
29-32	$1,186	$1,311	$2,302	$3,402	$4,509	$5,612
Covers	$149	$164	$219	$275	$335	$393

International (includes Canada and Mexico))						
# of Pages	50	100	200	300	400	500
1-4	$306	$321	$467	$642	$811	$986
5-8	$387	$517	$816	$1,154	$1,498	$1,844
9-12	$574	$689	$1,157	$1,686	$2,190	$2,717
13-16	$754	$874	$1,506	$2,193	$2,883	$3,570
17-20	$710	$1,063	$1,852	$2,722	$3,572	$4,428
21-24	$1,124	$1,242	$2,195	$3,231	$4,267	$5,300
25-28	$1,320	$1,440	$2,541	$3,738	$4,957	$6,153
29-32	$1,498	$1,616	$2,888	$4,269	$5,649	$7028
Covers	$211	$224	$324	$444	$558	$672

Minimum order is 50 copies. For orders larger than 500 copies, please consult Cadmus Reprints at 800-407-9190.

Reprint Cover

Cover prices are listed above. The cover will include the publication title, article title, and author name in black.

Shipping

Shipping costs are included in the reprint prices. Domestic orders are shipped via FedEx Ground service. Foreign orders are shipped via a proof of delivery air service.

Multiple Shipments

Orders can be shipped to more than one location. Please be aware that it will cost $32 for each additional location.

Delivery

Your order will be shipped within 2 weeks of the journal print date. Allow extra time for delivery.

Tax Due

Residents of Virginia, Maryland, Pennsylvania, and the District of Columbia are required to add the appropriate sales tax to each reprint order. For orders shipped to Canada, please add 7% Canadian GST unless exemption is claimed.

Ordering

Reprint order forms and purchase order or prepayment is required to process your order. Please reference journal name and reprint number or manuscript number on any correspondence. You may use the reverse side of this form as a proforma invoice. Please return your order form and prepayment to:

Cadmus Reprints
P.O. Box 751903
Charlotte, NC 28275-1903

Note: Do not send express packages to this location, PO Box.
FEIN #:541274108

Please direct all inquiries to:

Rose A. Baynard
800-407-9190 (toll free number)
410-819-3966 (direct number)
410-820-9765 (FAX number)
baynardr@cadmus.com (e-mail)

Reprint Order Forms and purchase order or prepayments must be received 72 hours after receipt of form.