Acta Orthop. Belg., 2011, **77**, 827-833

ORIGINAL STUDY

Radiofrequency ablation of osteoid osteomas : Five years experience

Zafiria G. Papathanassiou, Theodore Petsas, Dionysios Papachristou, Panagiotis Megas

From the University Hospital of Patras, Rio, Greece

The purpose of this study is to retrospectively evaluate the efficacy of radiofrequency ablation as a curative treatment method for benign bone tumours. Twenty-nine osteoid osteomas were treated with radiofrequency ablation. Primary success rate was 89.6% and total secondary success rate was 93.1%. Mean clinical follow-up period was 26.7 months (range : 6-63 months). Statistical analysis of 25 cases of osteoid osteomas with CT follow-up revealed that post-treatment re-ossification does not correlate with clinical outcome (p = 0.14) but is strongly correlated with long-term (≥ 12 months) CT follow-up (p = 0.014). Percutaneous radiofrequency ablation was found to be an effective and safe treatment for osteoid osteomas. CT findings cannot solely differentiate between treatment successes and failures.

Keywords : osteoid osteoma ; radiofrequency ablation technique.

INTRODUCTION

Primary bone tumours are rare, accounting for only 0.2% to 0.5% of human tumours (*1*). The vast majority (71.6%) are benign in nature (*1*). Benign primary bone tumours occur most commonly in skeletally immature patients, arising from cartilage or bone. The diagnostic approach involves plain radiographs, MRI scans and ultimately biopsy. More aggressive tumours may appear radiologically to be similar to malignant tumours. Treatment depends on the anatomical location, symptoms, the natural history of the tumour and the morbidity of treatment and in most cases involves either simple excision or curettage although occasionally it is necessary to perform a complete excision using the same principles as for malignant tumours. With wider margins, there may be greater functional loss but a lesser chance of local recurrence. Conversely, intralesional surgery has less morbidity but a greater risk of local recurrence.

Image-guided radiofrequency ablation (RFA) has emerged as minimally invasive alternative to destroy the tumour, overcome surgical difficulties and potential hazards and preserve the functional ability of the patient. In 1992, Rosenthal *et al* (*11*) were first to describe RFA as a minimally invasive therapeutic option for the treatment of osteoid osteoma. Since then, several studies have described

■ Panagiotis Megas, MD, PhD, Professor of Orthopaedic Surgery.
Orthopaedic Clinic, University Hospital of Patras, Greece.
■ Theodore Petsas MD, PhD, Professor of Radiology.
■ Zafiria G. Papathanassiou, MD, PhD, Radiologist.
Radiology Department, University Hospital of Patras, Greece.
■ Dionysios J. Papachristou, MD, PhD, Assistant Professor.
Department of Anatomy-Histology-Embryology, University of Patras, School of Medicine, Greece ; Assistant Professor (Adjunct), Department of Pathology, University of Pittsburg Medical Center, Pittsburg, PA, USA.
Correspondence : Zafiria G. Papathanassiou, Polikastis 21b, 26442 Patras, Greece. E-mail : papaze@ath.forthnet.gr

No benefits or funds were received in support of this study

the effects of RFA regarding clinical outcome and complications (*3,7-8,12,17-19*).

The aim of our study was to report our experience with RFA concerning technical and clinical success, minor and major complications and especially long-term results after a follow-up period post RFA. In addition, bone tumour parameters and post-treatment imaging and clinical results for osteoid osteomas were statistically correlated.

MATERIAL AND METHODS

From October 2004 to December 2009 29 patients with 29 osteoid osteomas were treated with RFA in the Departments of Interventional Radiology and Orthopaedic Surgery of our institution. Institutional board review approval and informed consent from all patients were obtained prior to intervention. The patient cohort consisted of 20 males and 9 females, aged between 11-39 years (mean : 23 years). The mean maximum diameter of the lesions was 7 mm (range : 4-13 mm). Twenty-five osteoid osteomas were located in long bones ; 15 affected the diaphysis, eight were metaphyseal and two epiphyseal (Table I). Diagnosis of osteoid osteomas was based on a typical clinical history and suggestive imaging features because percutaneous needle biopsy was not diagnostic. In all osteoid osteomas, typical imaging findings on radiography and CT scan included a small (< 1.5 cm) osteolytic area with or without internal calcifications (nidus) surrounded by a sclerotic border ; clinically patients presented with severe pain of sudden offset which worsened at night and reported relief with administration of acetylsalicylic acid or non steroidal anti-inflammatory agents. All patients underwent CT scans alone or in combination with imaging studies such as conventional radiography (17/29, 58.6%), Tc^{99m} bone scintigraphy (4/29, 13.8%), MR Imaging (10/29, 34.5%) and also single photon emission computed tomography (SPECT) (2/29, 6.9%). The mean duration of pain prior to intervention was 8 months (range : 6-60 months). No history of trauma or infection was reported. Strenuous athletic activities were also restricted by pain, local swelling and discomfort. Spinal lesions lacked any neurologic deficits. All tumours were treated with medication except for one case of a tibial osteoid osteoma that was unsuccessfully curetted one year prior to a successful RF ablation.

All procedures were carried out in the CT scan suite (Spiral CT Scan, Somatom, Siemens, Germany and 16 slice-MDCT scanner, LightSpeed, General Electric Healthcare, USA) under epidural anaesthesia or conscious sedation. The optimal approach with the shortest distance to the tumour was planned at the time of the procedure. Drilling from the opposite bone cortex was performed mainly for safety reasons (i.e. adjacent neurovascular structures) or in cases with high index of technical difficulty (i.e. quite oblique initial approaches). In cases with dense cortical bone a threaded guide wire (Kirschner "K" Wire-1.8 mm) followed by a 4.5 mm cannulated drill was used for penetration. Otherwise, where a small amount of cortical bone was present, an 11-gauge bone-marrow biopsy needle was alternatively used. After needle biopsy (when performed), a non cooled-tip RF electrode with a 5-mm exposed tip was introduced inside the nidus. The electrode was connected to the RF generator (RFG-3C ; Radionics, USA) and the temperature was gradually increased (1°C every 2 seconds) up to 85°C-90°C for a total of 4-6 minutes per needle position (Fig. 1c). A total of 90 to 120 minutes (starting from the entrance of the patient into the CT suite) was required for each RFA session.

In cases of larger (> 1 cm) or elongated tumours there were two alternative options : the use of multiple needle positions-maintaining the aforementioned parameters-in order to encompass the entire lesion or the use of a recently developed straight and rigid RF electrode with the advantage of linear deployment for multiple scalable ablations (UNIBLATE, 17G, with active length 1-2,5 cm, RITA Medical Systems). After the RF procedure, patients with lesions in weight-bearing bones were advised to avoid strenuous sports for at least two months. The procedures were considered technically successful if the electrode was placed inside the tumour and if the target temperature was reached and maintained for the selected time.

To assess short-term outcome, all patients were thoroughly examined by an orthopaedic surgeon and an interventional radiologist colleague the 1st day post RFA, the 1st week and the 1st month. Early and late procedure-related complications such as wound problems, infections, haematomas and pain status were recorded. To determine long-term outcome, telephone interviews and CT follow-up imaging (if feasible) were conducted at 6, 12 and 24 months post procedure. The patients were asked about their general condition, medications in current use, and any subsequent interventions. If the patient was free of pain and was not receiving medications, the outcome was considered clinically successful.

Statistical analysis was limited to osteoid osteoma patients for whom more than 6 months of CT follow-up was available. For purposes of analysis, patients were

Table I. — Data of the treated patients (October 2004-December 2009)

N°/age/ sex	Localisation		D_{max} mm	Success 1st RFA	Relapse (months post RFA)	2nd RFA	Clinical F-UP (months)	CT F-UP (months)	Hosp/tion (hours)
1/19/M	femur	Diaph	4	yes	–	–	63	≥ 12	24 h
2/18/M	femur	Diaph	4	yes	–	–	55	≥ 12	24 h
3/35/M	acetabulum	–	9	no	2 mo	NP	57	≥ 12	24 h
4/27/M	femur	Diaph	7	no	6 mo	NP	40	< 12	24 h
5/24/M	acetabulum	–	9	yes	–	–	48	≥ 12	24 h
6/38/F	femur	Diaph	5	yes	–	–	48	≥ 12	24 h
7/31/M	femur	Metaph	10	yes	–	–	46	≥ 12	24 h
8/26/M	tibia	Epiph	8	yes	–	–	45	≥ 12	24 h
9/19/M	tibia	Metaph	8	yes	–	–	40	< 12	24 h
10/18/M	tibia	Metaph	10	yes	–	–	38	≥ 12	24 h
11/20/M	tibia	Diaph	6	yes	–	–	35		24 h
12/24/M	femur	Diaph	7	yes	–	–	33	< 12	24 h
13/38/M	femur neck	Metaph	7	yes	–	–	21	< 12	24 h
14/17/M	femur	Diaph	4	yes	–	–	21	≥ 12	24 h
15/24/F	femur	Metaph	5	yes	–	–	19	< 12	24 h
16/12/F	tibia	Diaph	6	yes	–	–	18	≥ 12	24 h
17/11/F	femur	Metaph	6	yes	–	–	18		24 h
18/20/M	femur	Diaph	5	yes	–	–	18		24 h
19/20/M	femur	Metaph	6	yes	–	–	17		24 h
20/28/M	humerus	Diaph	4	yes	–	–	14	≥ 12	24 h
21/39/M	tibia	Epiph	8	yes	–	–	13	≥ 12	24 h
22/24/F	femur	Diaph	8	no	4 mo	yes	8 (post 2nd RFA)	≥ 12	48 h
23/21/M	femur	Diaph	5	yes	–	–	12	≥ 12	24 h
24/33/F	femur	Diaph	7	yes	–	–	10	≥ 12	24 h
25/12/F	S 1	–	12	yes	–	–	10	< 12	24 h
26/14/M	tibia	Diaph	5	yes	–	–	7	< 12	24 h
27/11/F	S 1	–	13	yes	–	–	6	< 12	24 h
28/18/M	humer neck	Metaph	11	yes	–	–	6	< 12	24 h
29/25/F	femur	Diaph	5	yes	–	–	6	< 12	24 h

* : NP : Not performed.

categorized by age, sex, tumour size and location, presence of calcifications, clinical outcome and length of CT follow-up. Evaluation was performed with Kendall's t-test (SPSS 10.0 for Windows /SPSS, Inc, Chicago, IL, USA) and differences with a p value less than 0.05 were considered statistically significant.

RESULTS

Radiofrequency ablation was technically feasible in all patients (33/33, 100%). The CT guidance provided accurate control of bone and adjacent soft tissues during and immediately after the ablation.

CT scan proved to be successful in detecting and characterizing 27 out of 29 lesions (93.1%). Two intra-articular hip joint osteoid osteomas due to lack of perinidal sclerosis on CT scan, were additionally imaged with SPECT Tc 99^m in order to localize precisely the osteoblastic activity of the tumours (Fig. 1a,b).

Conscious sedation was used in 14 older patients and epidural anaesthesia in 15 patients younger than 23 years old to obtain better stability and anxiety control. According to our institution policy all RF ablations of liver or kidney masses have to be performed under conscious sedation and approximately 50 to 60 of these treatments take place annually, we are experienced in pain management during interventions. For this reason, conscious sedation along with local anaesthesia with 1% lidocaine solution at the skin entry site, was preferred in older patients. One minor and two major complications occurred : a mild skin burn, a delayed degenerative hip joint arthritis due to cartilage damage and a septic arthritis with cutaneous fistula-due to infection along the needle tract that was surgically treated. There were no fractures or neurovascular injuries during the procedure.

Complete pain relief was achieved after a mean time of 2 days (range : 1-5 days) in all patients. Non steroidal anti-inflammatory drugs were prescribed for the 1st week and rapidly discontinued. Hospitalization lasted from 24 hours (28/29 patients) to 48 hours (1/29 patients) with a mean duration of 24.8 hours (Table I). Resumption of daily and sporting activities was completed within 7-10 days (mean : 8 days) and 70 days (mean : 40 days) respectively. No cast, physical therapy, or other external support was needed for recovery. Twenty-six patients remained pain-free at follow-up, corresponding to 89.6% (26/29) primary success of the technique. Three patients with osteoid osteomas (one intra-articular cancellous and two extra-articular cortical) had recurrent pain after a variable duration ; at two, six and four months post RFA respectively (mean = 4 months) (Table I). One patient underwent surgical wide resection, one decided to continue oral analgesic and anti-inflammatory medication and the other underwent a second successful percutaneous RF ablation four months after the first procedure. As a result, the overall secondary clinical success of RFA reached 93.1% (27/29). Clinical follow-up ranged from 6 to 63 months (mean : 26.7 months) (Table I).

By comparing follow-up CT scans with the pre-treatment ones, imaging changes were classified into one of the two following groups defined as : a) complete or partial ossification of the treated nidus with or without change (decrease) of the size of the nidus and b) absence of internal ossification with or without change (decrease) of the size of the nidus (Fig. 1d, e). Of the 25 cases 10 exhibited partial or complete internal ossification while the remaining 15 cases did not show any changes.

Statistical analysis of bone tumour parameters regarding 25 cases of osteoid osteomas with available CT-follow-up, like complete, partial or absent ossification of the treated nidus, patient age and sex, tumour size and location, pre-existing calcifications, clinical outcome and CT follow-up, revealed that :

- Absent and/or minimal post RFA ossification does not correlate with clinical outcome and as result it does not necessarily indicate clinical failure ($p = 0.14$).
- Detection of post RFA ossification showed an intense positive correlation with CT follow-up that exceeded one year (≥ 12 months) ($p = 0.014$).

The increased size of osteoid osteomas (maximum diameter > 7 mm) showed an intense negative correlation with the cortical ($p = 0.001$), extra-articular ($p = 0.003$) and diaphyseal location ($p = 0.001$).

DISCUSSION

For many years surgery with either curettage or en bloc resection was considered as the treatment of choice for benign bone tumours (2). However certain drawbacks like inaccurate pre-operative localization and difficulties in achieving complete eradication, especially in lesions with complex anatomy, resulted in extended bone excision to ensure complete tumour removal. This often requires additional procedures (internal fixation and

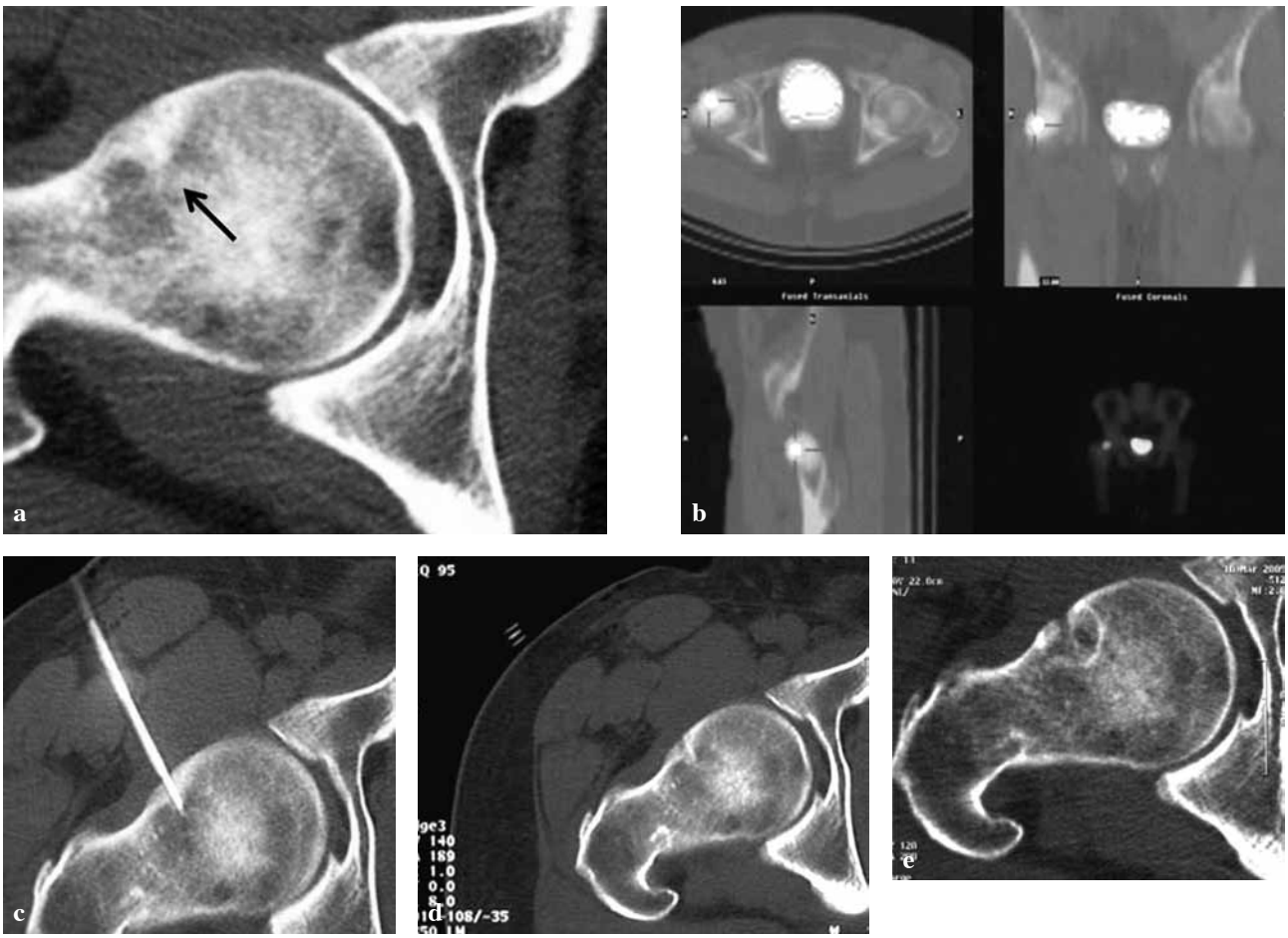

Fig. 1a-e. — A 38 year-old female with an intra-articular femoral head osteoid osteoma. On axial CT scan (a) the lesion is not characteristic of an osteoid osteoma and only mild sclerosis is shown at the frontal aspect of the femoral head (arrow). Subsequent SPECT with Tc 99^{m} (b) verifies the anatomic location of the tumor. After creating a frontal access route, the RF electrode (c) was inserted and ablation was performed at target temperature of 85°C for 6 minutes. On the 12 month CT follow-up (d-e), there are no signs of internal ossification. Only a well delineated periphery of the induced thermo-necrosis is shown. The patient presents so far (18 months post RFA) an uneventful clinical course.

bone grafting), prolonged hospitalization and avoidance of exercising and weight bearing. In addition, secondary fractures are not uncommon (*5,14,20*).

Recent advances in minimally invasive therapies provide additional tools for the management of benign bone neoplasms. In thermal ablation, cells are heated to temperatures above 60°C until death. This can be achieved by radiofrequency (RF) or laser energy (ILT), microwaves and high intensity ultrasound (US). Image-guided RF ablation (RFA) is used in interventional oncology to coagulate and destroy tumour tissues by the direct application of RF-generated heat. Coagulative necrosis is induced from electromagnetic sources with frequencies less than 30 MHz, with most available devices functioning between 375 and 500 kHz (*6*).

Due to the benign nature as well as the reduced or absent growth potential and the small size of osteoid osteomas these tumours are amenable to RFA interventions. In the present study, RFA proved to be effective with a clinical success rate of 89.6% (30/33) for the initial RF session and a secondary overall clinical success rate of 93.1% % (31/33) which are in line with the results reported in

literature (*12,17-18*). Pain recurrence occurred in three osteoid osteomas (10%) ; one intra-articular medullary lesion and two extra-articular cortical lesions at two, six and four months post RFA, respectively (mean : 4 months). Failure was attributed to inadequate RF electrode positioning in the cortical lesions whilst articular damage was the main reason for pain relapse in the intra-articular case. Pain relapse of the two cortical osteoid osteomas was successfully managed with curettage and a repeated RF session by changing the access route, respectively. Even though cartilage is relatively resistant to heat, extra care should be taken in subchondral intra-articular lesions. Pain relapse that was reported two months post RFA seemed different from the previous characteristic pain of an osteoid osteoma. Imaging and clinical signs of degenerative hip joint arthritis were evident 6 months post procedure. The pain was treated with oral analgesic and anti-inflammatory medication.

Apart from inaccurate needle positioning inside the nidus, a large size (≥ 10 mm) of osteoid osteomas has also been proved to act as an independent risk factor for incomplete RF ablation with a significantly higher recurrence rate. Tumour location, calcifications, coagulation time as well as patient gender were not found to serve as risk factors (*7,16*). In the present study, only four osteoid osteomas measured above 10 mm and they were successfully ablated by performing two RF sessions with overlapping fields.

RFA treatment of spinal osteoid osteomas is not always advisable due to the impending risk of harming the noble structures in the spinal canal (*12*). Moreover, there is a controversy in opinions regarding the safety of the method for these lesions (*4,9*). However, in our patient group, there were two osteoid osteomas located at the left wing of the S1 vertebra surrounded by an intact cortex and mild perinidal sclerosis that acted as effective insulators during RFA.

It is also well known that needle biopsy results in primary bone neoplasms may have a substantial false-negative rate ; especially in osteoid osteomas, non-diagnostic biopsy findings are not uncommon even after surgical excision (*13*). Therefore, if clinical and imaging findings were suggestive of an osteoid osteoma the patients were not excluded from this study. Even though bone scintigraphy (Tc^{99m}) is an easily accessible examination, it was not performed on a routine basis because a negative bone scan does not exclude the diagnosis of this tumour in the presence of a high index of clinical and CT scan suspicion (*10*). In the present study, advanced radionuclide imaging (SPECT) facilitated the accurate localization of the osteoblastic activity of two intra-articular osteomas that lacked perinidal sclerosis.

In our patient group, there were differences in the CT appearance of 25 osteoid osteomas (with available CT follow-up) between patients with successful and unsuccessful RF ablation. However, there was no significant correlation ($p = 0.14$) between clinical outcome and post RFA CT healing pattern ; a finding which is in line with a recent study by Vanderschueren *et al* (*15*). There were only three recurrences (3/25, 12%) which showed no signs of ossification post RFA and in the remaining 22 successfully treated patients only ten (10/22, 45%) showed evidence of internal ossification while the remaining 12 patients (12/22, 55%) exhibited no change post RFA. As a result, absence of internal ossification after RFA does not necessarily suggest clinical failure since it was also observed in clinically successful cases. Even though ossification is usually expected within the first year post RFA (*15*), in this study a clear positive correlation ($p = 0.014$) was found between the ossification pattern and the long-term CT follow-up (≥ 12 months) which could be attributed to the prolonged procedure of bone restoration.

By further analyzing the results, the authors came up with a strong negative correlation between the size of osteoid osteomas (> 7 mm in its largest diameter) and the cortical ($p = 0.001$), extra-articular ($p = 0.003$) and diaphyseal location ($p = 0.001$). As a result, small osteoid osteomas (≤ 7 mm) showed a great tendency to grow in intra-cortical, extra-articular and diaphyseal locations. The latter observation can be justified by the fact that cancellous bone contains primarily bone marrow which has a rich blood supply, contains large concentrations of cytokines, prostaglandins and growth factors and hosts considerable amounts of

stem cells. As a result, a fertile micro-environment that favours tumour growth is present.

In conclusion, percutaneous RFA is a minimally invasive therapeutic option for osteoid osteomas, which provides immediate pain relief and low rates of complications and recurrences on long-term follow-up. It can be considered as the treatment of choice mostly for appendicular, spinal osteoid osteomas (in selected cases) and for surgical recurrences as well. Meticulous planning and special care are necessary in cases of intra-articular osteoid osteomas treated with RFA.

The determination of an adverse clinical outcome should be based on clinical evaluation and not on the imaging pattern. Absence of post RFA ossification does not correlate with treatment failure and should not be included in the selection criteria for patients who may benefit from a subsequent RF session.

REFERENCES

1. **Baena-Ocampo Ldel C, Ramirez-Perez E, Linares-Gonzalez LM, Delgado-Chavez R.** Epidemiology of bone tumors in Mexico City : retrospective clinicopathologic study of 566 patients at a referral institution. *Ann Diagn Pathol* 2009 ; 13 : 16-21.
2. **Campanacci M, Ruggieri P, Gasbarini A, Ferraro A, Campanacci L.** Osteoid osteoma. Direct visual identification and intralesional excision of the nidus with minimal removal of bone. *J Bone Joint Surg* 1999 ; 81-B : 814-820.
3. **Cribb GL, Goude W, Cool P *et al.*** Percutaneous radiofrequency thermocoagulation of osteoid osteomas : factors affecting therapeutic outcome. *Skeletal Radiol* 2005 ; 34 : 702-706.
4. **Gangi A, Alizadeh H, Wong L *et al.*** Osteoid osteoma : Percutaneous laser ablation and follow-up in 114 patients. *Radiology* 2007 ; 242 : 293-301.
5. **Ghanem I.** The management of osteoid osteoma : updates and controversies. *Curr Opin Pediatr* 2006 ; 18 : 36-41.
6. **Goldberg NS, Dupuy DE.** Image-guided radiofrequency tumor ablation : challenges and opportunities – part I. *J Vasc Interv Radiol* 2001 ; 12 :1021-1032.
7. **Kjar R, Powell GJ, Schilcht SM *et al.*** Percutaneous radiofrequency ablation for osteoid osteoma : experience with a new treatment. *Med J Aust* 2006 ; 184 :563-565.
8. **Lindner NJ, Ozaki T, Roedl R *et al.*** Percutaneous radiofrequency ablation in osteoid osteoma. *J. Bone Joint Surg* 2001 ; 83-B : 391-396.
9. **Martel J, Bueno A, Nieto-Morales ML, Ortiz EJ.** Osteoid osteoma of the spine : CT-guided monopolar radiofrequency ablation. *Eur J Radiol* 2009 ; 71 :564-569.
10. **Papathanassiou ZG, Megas P, Petsas T *et al.*** Osteoid osteoma : diagnosis and treatment. *Orthopedics* 2008 ; 31 : 1118-1127.
11. **Rosenthal DI, Alexander A, Rosenberg AE, Sprongfield D.** Ablation of osteoid osteomas with percutaneously placed electrode : a new procedure *Radiology* 1992 ; 183 :29-33.
12. **Rosenthal DI, Hornicek FJ, Torriani M, Gebhart MC, Mankin HJ.** Osteoid osteoma : Percutaneous treatment with radiofrequency energy. *Radiology* 2003 ; 229 :171-175.
13. **Sim FH, Dahlin CD, Beabout JW.** Osteoid osteoma : diagnostic problems. *J Bone Joint Surg* 1975 ; 57-A : 154-159.
14. **Sluga M, Windhager R, Pfeiffer M, Dominkus M, Kotz R.** Peripheral osteoid osteoma. Is there still a place for traditional surgery ? *J Bone Joint Surg* 2002 ; 84-B : 249-251.
15. **Vanderschueren GM, Taminiau AH, Obermann WR *et al.*** The healing pattern of osteoid osteomas on computed tomography and magnetic resonance imaging after thermo coagulation. *Skeletal Radiol* 2007 ; 36 : 813-821.
16. **Vanderschueren GM, Taminiau AH, Obermann WR *et al.*** Osteoid Osteoma : Factors for increased risk of unsuccessful thermal coagulation. *Radiology* 2004 ; 233 : 757-762.
17. **Vanderschueren GM, Taminiau AHM, Obermann WR, Bloem JL.** Osteoid osteoma : clinical results with thermocoagulation. *Radiology* 2002 ; 224 : 82-86.
18. **Venbrux AC, Montague BJ, Murphy KPJ *et al.*** Image-guided percutaneous radiofrequency ablation for osteoid osteomas. *J Vasc Interv Radiol* 2003 ; 14 : 375-380.
19. **Woertler K, Vestring T, Boettner F *et al.*** Osteoid osteoma : CT-guided percutaneous radiofrequency ablation and follow-up in 47 patients. *J Vasc Intervent Radiol* 2001 ; 12 : 717-722.
20. **Yildiz Y, Bayracki K, Altay M, Saglik Y.** Osteoid osteoma : the results of surgical treatment. *Int Orthop* 2001 ; 25 : 119-122.