ORIGINAL ARTICLE / Musculoskeletal imaging

Interstitial laser photocoagulation for the treatment of osteoid osteoma: Retrospective study on 35 cases

A. Etienne¹,*, É. Waynberger¹, J. Druon²

¹ CHU de Tours, Hôpital Trousseau, Radiology Department, avenue de la République, 37170 Chambry-lès-Tours, France
² CHU de Tours, Hôpital Trousseau, Orthopaedics Department 2, avenue de la République, 37170 Chambry-lès-Tours, France

Abstract
Purpose: The aim of our retrospective study was to evaluate the efficacy of interstitial laser photocoagulation for the treatment of osteoid osteomas and to identify the factors leading to failure of the procedure.

Material and methods: Thirty-five patients received interstitial laser photocoagulation treatment. A minimum of 3 months follow-up was required. The laser fibre was positioned within the nidus under CT guidance, and energy between 500 and 1800 J was delivered at a power of 2 Watts/s. Follow-up was by outpatient appointment and through a questionnaire sent to the patients.

Results: Thirty patients replied to the questionnaire. Mean follow-up was 40 months. The technical success rate was 100%. The primary success rate (no pain at 1 month) was 94.3%. The rate of recurrence was 6%. The rate of complications was 11.4% (a skin burn, patellar enthesopathy, a broken item of material, sacro-iliac fibrous alterations). Factors likely to favour failure of the procedure are the size of the nidus (P = 0.04) and poor positioning of the laser fibre (P = 0.03).

Conclusion: Interstitial laser photocoagulation is an effective and safe treatment for osteoid osteomas.

© 2013 Published by Elsevier Masson SAS on behalf of the Éditions françaises de radiologie.

Introduction

Osteoid osteomas [1] are relatively frequent benign bone tumours [2] (10 to 20% of benign bone tumours), which most often occur during the first 30 years of life (90% of patients are less than 25 years old) with male predominance (sex-ratio 2: 1). The main symptom is
pain, predominantly nocturnal and typically relieved by non-
steroidal anti-inflammatory drugs. The imaging appearance is
often typical [3,4], in particular in a CT scan where the
nidus is hypodense in a reactive osteosclerosis of variable
abundance. MRI reveals the nidus, which has a variable sig-
nal and is enhanced after gadolinium injection, with oedema
of the peripheral cancellous bone and soft tissue [5]. The
nidus is usually less than 2 cm in size, which distinguishes it
from an osteoblastoma [6]. More than 50% of their locations
are in the femur or tibia.

The problem posed by this tumour is disabling pain
[7]. The reference treatment used to be surgical [8,9],
curing patients by complete excision of the nidus. The diffi-
culties of peroperative location of the nidus within the
reactive osteosclerosis often resulted in extensive excisions
responsible for complications (bone fragilisation and frac-
tures). CT-guided minimally invasive therapies were then
developed: first, percutaneous CT-guided excision [10], then
radiofrequency ablation [11—16] and finally interstitial laser
photocoagulation (ILP) [17—23]. The nidus could be located
by CT scanning and the latter two techniques limited fra-
gilisation of the bone.

For ILP treatment, a laser generator (a Dornier Medilas
D Fibertom diode laser from Bernas Medical®) is used at
low energy. The light energy is transmitted to the tumour
through a 400 μm diameter optical fibre and converted into
heat energy on diffusing into the tissue. The rise in tempe-
rate causes denaturation of the proteins and consequently
cell necrosis. The thermal properties of tissues depend on
their water content, making the size of the necrosis pre-
dictable. The study of the thermal properties of bone has
shown that the degree of thermal sensitivity changes very
little between cortical and trabecular bone and bone mar-
row. The necrosis threshold is an exposure to 50 °C for 30s.

We chose this technique because it has several advan-
tages over radiofrequency: it is not necessary to insert a
neutral electrode, no current flows through the patient’s
body, there is no interaction with pacemakers, stimulators
or metal structures, the cost of the laser fibre is lower,
and disposable fibres reduce the risk of contamination. Previ-
ous studies have confirmed that this treatment of osteoid
osteomas is effective and safe [17—23].

The aim of our study was to retrospectively evaluate the
results of this technique in our centre for the treatment of
osteoid osteomas and to identify the factors that might
induce the procedure to fail.

Material and methods

Patients

Between 3rd October 2001 and 16th November 2011,
35 patients underwent ILP in two different centres: the
paediatric radiology department and the adult radi-
ology department. Our retrospective study did not require
approval by an ethics committee. The age of patients ranged
from 3 to 69 years old (mean: 21.7 years old). Our popu-
lation consisted of 27 males and eight females, giving a
sex-ratio of 3.4:1. The lesions were located in the femur
(n = 19), tibia (n = 7), patella (n = 2), ulna (n = 1), iliac bone
(n = 1), sacrum (n = 1), calcaneus (n = 1), the neck of the talus
(n = 1), humerus (n = 1) and lateral cuneiform bone (n = 1)
(Fig. 1). Nine of these lesions had articular topography: a
lesion of the olecranon groove of the humerus, two of the
patella located respectively at 8 mm and 6 mm from the
patellofemoral joint space, three of the acetabular fossa
in direct contact with the coxo-femoral joint space, a lesion
of the iliac bone 4 mm from the sacro-iliac joint, a sacral
lesion in contact with the L5-S1 zygapophyseal joint 4 mm
from the nerve root where it passes through the foramen
(Fig. 2), and a lesion of the femoral condyle 20 mm from the
femorotibial joint space.

Clinical diagnosis of osteoid osteoma was suspected given
predominantly nocturnal pain, not related to physical acti-
vity, typically relieved by NSAIDs (26 patients had typical
clinical features). Most often there was a considerable delay
in diagnosis, with a mean of 15 months in our study. The cli-
nical suspicion was later confirmed by imaging examinations
[24,25]. All the patients in our study had standard X-rays
and a CT scan and sometimes scintigraphy (n = 10) or MRI
(n = 6). These examinations all showed the nidus, the size of
which was less than 20 mm. Treatment by ILP was decided in
a multidisciplinary musculoskeletal oncology consultative
meeting. When not all the clinical and radiological criteria
were met, a biopsy was performed before or during the ILP
procedure. Five biopsies were performed.

The patients included in our study were treated with ILP
given the clinical symptoms and radiological picture sup-
porting this diagnosis, and a minimum period of 3 months
clinical follow-up was required. The absence of histological
confirmation of the diagnosis was not an exclusion criterion,
nor was prior treatment having been performed.

 Procedure

The treatment was carried out in aseptic surgical conditions
and under general anaesthesia, since entering the nidus is
known to be extremely painful [26,27].

A CT scout scan was performed to verify the absence
of morphological changes compared with the diagnostic CT
scan, and to confirm the treatment parameters (precise
location of the nidus, its situation relative to vulnerable
anatomical features — joints, nerve roots, tendons etc. —
and calculation of the energy required to treat the tumour).
In general, the approach chosen was where the bone
distance to be crossed was the shortest. Exceptionally,
superficial subperiosteal lesions were approached from the
opposite side, with a longer path through the bone for
stabilising the laser fibre, as were lesions near vulnerable
anatomic structures.

A Bonopty 14G needle (Bonopty® Bone Biopsy System,
AprióMed, Uppsala Sweden) was used to cross the corti-
cal bone to the nidus, then an 18G coaxial needle was
inserted into the nidus to protect the 400 μm laser fibre.
Since the fibre was not radiopaque, a marker was put in
place, before inserting it into the 18G needle so that it
extended beyond it by approximately 5 mm into the nidus.
The energy (Dornier Medilas D Fibertom Bernas Medical®
diode laser with a wavelength of 940 nm) was then deli-
vated at 2 Watts/s for a period depending on the size of the
nidus: nidus size × 100 J + 200 J. When the nidus was at a
distance from vulnerable structures, the maximum total energy
of 1200 J was delivered. A 14 mm lesion was treated by
placing the laser at both ends of the lesion (800 J \times 2). A biopsy for histological examination was taken at the start of the procedure when the picture was not typical. One ILP was cancelled in the end because the subperiosteal lesion had increased in size and changed in appearance. It proved to be an osteoblastoma. CT control scans were performed during and at the end of the procedure to ensure correct positioning of the trocar.

The mean duration of the procedure was 1h. Patients stayed in hospital overnight in the orthopaedic surgery department and could resume weight-bearing immediately.

**Evaluation and follow-up**

The patients had appointments with the orthopaedic surgeons at varying intervals.

A questionnaire was sent to patients, or completed by telephone in the absence of a written response, allowing later assessment of the persistence of pain, analgesic consumption, undesirable effects and patient satisfaction. Thirty patients replied to the questionnaire.

We assessed the technical success, defined as the positioning of the laser fibre within the nidus so that the desired energy could be delivered, the primary success, in terms of disappearance of pain 1 month after the procedure, the failure, in terms of the persistence of pain 1 month after treatment, the recurrence, in terms of recurrence of symptoms more than 1 month after treatment following initial relief of pain, the complications, and the risk factors for failure of the procedure. The criteria that we considered were age, sex, size of the nidus, the energy delivered, intra- or extra-articular topography, and the positioning of the laser fibre. The position of the laser fibre was determined retrospectively: it was considered as good when the laser fibre was at the centre of the nidus in all three spatial planes, as poor when it was only centred in one spatial plane or was eccentric in all three planes.

We did not perform systematic control imaging examinations in our study where evolution was favourable, except

![Figure 1](image-url)
Interstitial laser photocoagulation for the treatment of osteoid osteoma
Figure 2. a: osteoid osteoma of the left L5/S1 zygapophyseal joint. Bone scintigraphy (TechniScan HDP Tc-99 m): increased uptake in the left sacral ala; b: tomoscintigraphy combined with a CT scan: the focus with increased uptake corresponds to a field of condensation on the scan surrounding a hypodense lesion, the nidus; c: axial T1-weighted MRI of the pelvis, hypointense field in the left sacral ala coming into contact with the joint; the nidus gives an intermediate T1-weighted signal; d: axial STIR sequence: hyperintensity of the left sacral ala peripheral to the nidus and peripheral soft tissues. The nidus is heterogeneous, hyperintense with hypointense areas corresponding to calcifications; e: axial T1-weighted fat sat. sequence after gadolinium injection: enhancement of the nidus, peripheral bone and soft tissue related to the perilesional oedema that can mimic an aggressive lesion; f: scout CT scan during the ILP procedure: hypodense nidus near the nerve roots, calcified in the centre, surrounded by reactive osteosclerosis; g: bonopty needle in place within the nidus.
for seven patients: six of them who were monitored in pediatrics had a CT scan after 6 months; one patient monitored in the adult orthopaedic surgery unit and treated for an LS/S1 zygapophyseal joint lesion had an MRI scan after 4 months.

Results

The technical success rate was 100%.

The mean follow-up of patients was 40 months (3–122 months). Thirty patients replied to the questionnaire, so that the duration of follow-up could be prolonged and information missing from the files completed. Monitoring pain was the main purpose of the follow-up. We did not use a visual analogue scale but considered a binary result: persistence or not of pain, since total absence of pain is expected after treatment.

The primary success rate was estimated at 94.3% (33 primary successes). Two failures occurred, the first in a 17-year-old patient with an intra-articular, 10 mm nidus of the acetabular fossa treated with 1100 J. The second was in a 22-year-old patient who had a 13 mm extra-articular cortical nidus treated with 1200 J.

The rate of recurrence was estimated at 6%, which corresponds to two patients, the recurrences occurring at 2 and 17 months after the initial treatment. They involved a 20-year-old patient and a 17-year-old, whose nidi measured 8 and 12 mm, and were treated respectively with 900 and 1200 J. For the 12 mm nidus, the laser fibre had been poorly positioned. For the 8 mm nidus, it was indeed a recurrence, with the development of a new nidus close to the first.

One of the four patients treated, in whom there had been failure or recurrence, had his pain relieved after a second procedure. Two of the three patients still with pain underwent a third procedure with success. The third patient did not want any additional procedure, was not satisfied with the treatment, and is still taking analgesics after two failures. The characteristics of the osteomas and the therapeutic results are summarised in Table 1.

Complications

The complication rate in our study was 11.4%. The four complications were a skin burn due to migration of the optical fibre requiring covering with a skin flap, a patellar tendon enthesopathy appearing in the ultrasound examination in a female patient treated for a patellar nidus, breakage of an item of material (a Bonopty needle) at the end of the procedure requiring corticotomy, and bone lacunae in contact with the sacro-iliac joint after treatment of a nidus located 4 mm from the joint space, which proved on histological examination to be fibrous tissue. These various complications caused no long-term discomfort.

Histopathology

Only five biopsies were performed for histological confirmation of the diagnosis, and only one was positive. For the other four patients, the histological diagnosis could not be determined because there was not enough lesion tissue.

Failure factors

Only the size of the nidus ($P=0.04$) and the position of the laser fibre ($P=0.03$) were associated significantly with a risk of failure (Table 2).

Discussion

Osteoid osteoma is a benign bone tumour with no risk of malignant degeneration. Spontaneous involution has been described. Its small size, usually less than 2 cm, makes it accessible to ILP treatment. This method is described as safe and effective in the literature, particularly because the volume of necrosis depending on the amount of energy delivered is well controlled. Destruction of the nidus by heating stops the painful phenomena.

There was no technical failure in our study. Thirty-three of the 35 patients initially had their pain relieved. The primary success rate was thus 94.3% and the failure rate 5.7%. Two patients had a recurrence after 2 and 17 months. Pain relief was obtained in one out of four patients who underwent a second procedure. Two of the remaining three underwent a third procedure and obtained relief. These results are not as good as those reported in other studies (Table 3). The largest published series, that of Gangi et al. [28] included 114 patients, the primary success rate was 99.1% ($n=113$), the rate of recurrence 5.3% ($n=6$) and the secondary success rate 100% ($n=6$). The failure was related to a state of agitation during a procedure under local anaesthesia, which only allowed 300 J to be administered. In this study, the laser fibre delivered energy of 2 Watts for 600 s (i.e. 1200 J) for lesions at a distance from vulnerable structures. When this was not the case, the energy delivered was calculated using the formula: nidus size $\times 100 \div 200$, the size of the nidus being in millimetres. Given that the amount of coagulation is limited (particularly by blood flow) to a maximum diameter of 16 mm, six patients whose nidus was between 15 and 24 mm were treated using the laser fibre in several positions in the nidus, delivering an energy total of 2000 to 3000 J.

In our study, a nidus of 14 mm 4 mm from the sacro-iliac joint was treated successfully using two different approaches delivering $2 \times 800$ J.

In the study by Roqueplan et al. [19], the primary success rate was 96% ($n=93/97$), the rate of recurrence 3.1% ($n=3$) and the secondary success rate 66.7% ($n=2/3$).

An alternative treatment to ILP is CT-guided radiofrequency ablation. A radiofrequency generator produces an alternating current delivered via an electrode placed within the nidus. Ionic agitation of the tissues causes a rise in temperature: at more than 60 °C cell damage is irreversible. The series published concerning radiofrequency ablation report primary success rates lower than ours (Table 4).

Rosenthal et al. [11] reported a primary success rate of 89% ($n=112/126$), a failure rate of 11% ($n=14/126$), a recurrence rate of 7% ($n=9/126$), a secondary success rate of 60% ($n=6/10$). Vanderschueren et al. [15] reported an overall success rate of 76% ($n=74/97$), a recurrence rate of 11% ($n=11$), a secondary success rate of 50% for patients with earlier failure and 83% for those who had had a recurrence.
### Table 1  Characteristics of osteoid osteomas and the treatments performed.

<table>
<thead>
<tr>
<th>No.</th>
<th>Age (years)</th>
<th>Sex</th>
<th>Site of nidus</th>
<th>Size of nidus (mm)</th>
<th>Energy delivered (Joules)</th>
<th>Result at 1 month</th>
<th>Recurrence</th>
<th>Follow-up period (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20</td>
<td>M</td>
<td>Tibia</td>
<td>8</td>
<td>900</td>
<td>S</td>
<td>Yes</td>
<td>108</td>
</tr>
<tr>
<td>2</td>
<td>18</td>
<td>M</td>
<td>Calcaneus</td>
<td>10</td>
<td>1200</td>
<td>S</td>
<td>No</td>
<td>45</td>
</tr>
<tr>
<td>3</td>
<td>17</td>
<td>M</td>
<td>Femur</td>
<td>10</td>
<td>1100</td>
<td>F</td>
<td>No</td>
<td>92</td>
</tr>
<tr>
<td>4</td>
<td>69</td>
<td>M</td>
<td>Tibia</td>
<td>6</td>
<td>720</td>
<td>S</td>
<td>No</td>
<td>65</td>
</tr>
<tr>
<td>5</td>
<td>17</td>
<td>M</td>
<td>Femur</td>
<td>7</td>
<td>840</td>
<td>S</td>
<td>No</td>
<td>22</td>
</tr>
<tr>
<td>6</td>
<td>21</td>
<td>M</td>
<td>Tibia</td>
<td>9</td>
<td>1200</td>
<td>S</td>
<td>No</td>
<td>20</td>
</tr>
<tr>
<td>7</td>
<td>35</td>
<td>F</td>
<td>Femur</td>
<td>6</td>
<td>1200</td>
<td>S</td>
<td>No</td>
<td>24</td>
</tr>
<tr>
<td>8</td>
<td>17</td>
<td>M</td>
<td>Femur</td>
<td>12</td>
<td>1200</td>
<td>S</td>
<td>No</td>
<td>39</td>
</tr>
<tr>
<td>9</td>
<td>70</td>
<td>M</td>
<td>Humerus</td>
<td>6</td>
<td>1200</td>
<td>S</td>
<td>No</td>
<td>32</td>
</tr>
<tr>
<td>10</td>
<td>24</td>
<td>F</td>
<td>Patella</td>
<td>4</td>
<td>1200</td>
<td>S</td>
<td>No</td>
<td>36</td>
</tr>
<tr>
<td>11</td>
<td>23</td>
<td>M</td>
<td>Ulna</td>
<td>4</td>
<td>1200</td>
<td>S</td>
<td>No</td>
<td>36</td>
</tr>
<tr>
<td>12</td>
<td>38</td>
<td>M</td>
<td>Femur</td>
<td>5</td>
<td>500</td>
<td>S</td>
<td>No</td>
<td>3</td>
</tr>
<tr>
<td>13</td>
<td>24</td>
<td>F</td>
<td>Femur</td>
<td>15</td>
<td>1200</td>
<td>S</td>
<td>No</td>
<td>36</td>
</tr>
<tr>
<td>14</td>
<td>28</td>
<td>M</td>
<td>Femur</td>
<td>7</td>
<td>960</td>
<td>S</td>
<td>No</td>
<td>3</td>
</tr>
<tr>
<td>15</td>
<td>18</td>
<td>M</td>
<td>Tibia</td>
<td>2</td>
<td>600</td>
<td>S</td>
<td>No</td>
<td>88</td>
</tr>
<tr>
<td>16</td>
<td>18</td>
<td>M</td>
<td>Femur</td>
<td>8</td>
<td>900</td>
<td>S</td>
<td>No</td>
<td>86</td>
</tr>
<tr>
<td>17</td>
<td>12</td>
<td>F</td>
<td>Femur</td>
<td>5</td>
<td>600</td>
<td>S</td>
<td>No</td>
<td>86</td>
</tr>
<tr>
<td>18</td>
<td>24</td>
<td>M</td>
<td>Tibia</td>
<td>5</td>
<td>800</td>
<td>S</td>
<td>No</td>
<td>96</td>
</tr>
<tr>
<td>19</td>
<td>13</td>
<td>M</td>
<td>Ilium</td>
<td>14</td>
<td>1600</td>
<td>S</td>
<td>No</td>
<td>122</td>
</tr>
<tr>
<td>20</td>
<td>13</td>
<td>F</td>
<td>Femur</td>
<td>6</td>
<td>800</td>
<td>S</td>
<td>No</td>
<td>3</td>
</tr>
<tr>
<td>21</td>
<td>18</td>
<td>F</td>
<td>Tibia</td>
<td>9</td>
<td>1000</td>
<td>S</td>
<td>No</td>
<td>57</td>
</tr>
<tr>
<td>22</td>
<td>7</td>
<td>M</td>
<td>Femur</td>
<td>7</td>
<td>750</td>
<td>S</td>
<td>No</td>
<td>37</td>
</tr>
<tr>
<td>23</td>
<td>7</td>
<td>F</td>
<td>Tibia</td>
<td>11</td>
<td>700</td>
<td>S</td>
<td>No</td>
<td>34</td>
</tr>
<tr>
<td>24</td>
<td>3</td>
<td>M</td>
<td>Femur</td>
<td>11</td>
<td>600</td>
<td>S</td>
<td>No</td>
<td>24</td>
</tr>
<tr>
<td>25</td>
<td>6</td>
<td>M</td>
<td>Femur</td>
<td>12</td>
<td>900</td>
<td>S</td>
<td>No</td>
<td>27</td>
</tr>
<tr>
<td>26</td>
<td>17</td>
<td>M</td>
<td>Cuneiform</td>
<td>8</td>
<td>900</td>
<td>S</td>
<td>No</td>
<td>23</td>
</tr>
<tr>
<td>27</td>
<td>13</td>
<td>M</td>
<td>Femur</td>
<td>8</td>
<td>700</td>
<td>S</td>
<td>No</td>
<td>20</td>
</tr>
<tr>
<td>28</td>
<td>13</td>
<td>M</td>
<td>Femur</td>
<td>6</td>
<td>850</td>
<td>S</td>
<td>No</td>
<td>10</td>
</tr>
<tr>
<td>29</td>
<td>17</td>
<td>M</td>
<td>Femur</td>
<td>12</td>
<td>1200</td>
<td>S</td>
<td>Yes</td>
<td>44</td>
</tr>
<tr>
<td>30</td>
<td>35</td>
<td>M</td>
<td>Femur</td>
<td>7</td>
<td>1200</td>
<td>S</td>
<td>No</td>
<td>12</td>
</tr>
<tr>
<td>31</td>
<td>16</td>
<td>M</td>
<td>Patella</td>
<td>6</td>
<td>1200</td>
<td>S</td>
<td>No</td>
<td>15</td>
</tr>
<tr>
<td>32</td>
<td>21</td>
<td>M</td>
<td>Talus</td>
<td>8</td>
<td>1200</td>
<td>S</td>
<td>No</td>
<td>43</td>
</tr>
<tr>
<td>33</td>
<td>23</td>
<td>M</td>
<td>Sacrum</td>
<td>7</td>
<td>1100</td>
<td>S</td>
<td>No</td>
<td>6</td>
</tr>
<tr>
<td>34</td>
<td>22</td>
<td>F</td>
<td>Femur</td>
<td>4</td>
<td>1200</td>
<td>S</td>
<td>No</td>
<td>3</td>
</tr>
<tr>
<td>35</td>
<td>22</td>
<td>M</td>
<td>Femur</td>
<td>13</td>
<td>1200</td>
<td>F</td>
<td>No</td>
<td>3</td>
</tr>
</tbody>
</table>

S: success; F: failure.

### Table 2  Risk factors for failure.

<table>
<thead>
<tr>
<th></th>
<th>Successes (n = 31)</th>
<th>Failures (n = 4)</th>
<th>Total (n = 35)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex: male (%)</td>
<td>23 (77)</td>
<td>4 (100)</td>
<td>27 (80)</td>
<td>NS</td>
</tr>
<tr>
<td>Mean age in years (standard deviation)</td>
<td>22.0 (15.1)</td>
<td>19.0 (2.4)</td>
<td>21.7 (14.2)</td>
<td>NS</td>
</tr>
<tr>
<td>Size of the nidus in mm (standard deviation)</td>
<td>7.6 (3.0)</td>
<td>10.7 (2.2)</td>
<td>7.9 (3.1)</td>
<td>P = 0.04&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Mean energy in J (standard deviation)</td>
<td>974.0 (260.8)</td>
<td>1100.0 (141.4)</td>
<td>989.0 (281.8)</td>
<td>NS</td>
</tr>
<tr>
<td>Intra-articular topography (%)</td>
<td>9 (29)</td>
<td>1 (25)</td>
<td>10 (28)</td>
<td>NS</td>
</tr>
<tr>
<td>Poor laser position (%)</td>
<td>5 (16)</td>
<td>3 (75)</td>
<td>8 (23)</td>
<td>P = 0.03&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup> Mann-Whitney test.

<sup>b</sup> Fisher exact test.
Table 3  Result of laser treatment procedures of osteoid osteomas.

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Primary successes (%)</th>
<th>Failures (%)</th>
<th>Recurrences (%)</th>
<th>Secondary successes (%)</th>
<th>Complications (%)</th>
<th>Histological confirmation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gangi et al. (2007) [28]</td>
<td>114</td>
<td>113 (99)</td>
<td>1 (1)</td>
<td>6 (5)</td>
<td>6 (100)</td>
<td>1 (1)</td>
<td>67/88 (76)</td>
</tr>
<tr>
<td>Roqueplan et al. (2010) [19]</td>
<td>100</td>
<td>99/7/96 (96)</td>
<td>2/97 (2)</td>
<td>3/97 (3)</td>
<td>2/3 (67)</td>
<td>4 (4)</td>
<td>10 (64)</td>
</tr>
<tr>
<td>Witt et al. (2000) [18]</td>
<td>23</td>
<td>22 (96)</td>
<td>1 (4)</td>
<td>1 (4)</td>
<td>2 (100)</td>
<td>2 (9)</td>
<td>—</td>
</tr>
<tr>
<td>Zouari et al. (2008) [17]</td>
<td>15</td>
<td>15 (100)</td>
<td>0 (0)</td>
<td>1 (7)</td>
<td>1 (100)</td>
<td>1 (7)</td>
<td>—</td>
</tr>
</tbody>
</table>

Table 4  Result of radiofrequency treatment procedures of osteoid osteomas.

<table>
<thead>
<tr>
<th></th>
<th>n</th>
<th>Primary successes (%)</th>
<th>Failures (%)</th>
<th>Recurrences (%)</th>
<th>Secondary successes (%)</th>
<th>Complications (%)</th>
<th>Histological confirmation</th>
</tr>
</thead>
<tbody>
<tr>
<td>De Berg et al. (1995) [13]</td>
<td>38</td>
<td>38 (100)</td>
<td>0 (0)</td>
<td>1 (6)</td>
<td>1 (100)</td>
<td>0 (0)</td>
<td>—</td>
</tr>
<tr>
<td>Hoffmann et al. (2010) [12]</td>
<td>10</td>
<td>8 (80)</td>
<td>2 (20)</td>
<td>0 (0)</td>
<td>2/2 (100)</td>
<td>0 (0)</td>
<td>—</td>
</tr>
<tr>
<td>Martel et al. (2009) [29]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a Failures.

Complications

No severe complication such as fracture or infection occurred in our study.

There were four minor complications: breakage of a piece of equipment, a patellar enthesopathy, a bone lacuna and a skin burn. Our rate of complications was 11.4%.

Ten percent of osteoid osteomas occur in the spine, most often in the posterior arch. In our centre, they are still often treated surgically, for fear of root or spinal cord lesions. We treated a nidal in contact with the L5/S1 zygopophyseal joint and 4 mm from the nerve root passing through the foramen with 1100 J, without a cooling technique and without causing neurological complications.

The spontaneous cooling effect of the flow of epidural blood and CSF has been suggested by Dupuy et al. [30] but remains difficult to assess in practice, so that some authors feel justified in using additional cooling procedures.

In the series by Gangi et al. [28], 12 spinal osteoid osteomas were treated without neurological complications. Five of them were within 8 mm of the nerve roots and a slow perfusion of epidural or periradicular physiological saline was used to protect them. Similarly, for the nidi in contact with neurological or vascular structures and for intra- or juxta-articular nidi an injection of physiological saline was given. In this series, only one complication occurred, a case of reflex sympathetic dystrophy. The same authors [31] also advocate the use of epidurography using atmospheric air or carbon dioxide.

Treatment of osteomas of the hands or feet was initially controversial because of the risk of vascular, tendon and cutaneous complications. We treated three tarsal lesions (lateral cuneiform, neck of the talus, calcaneus) with no complications. Several studies recommend using protective systems in these situations. Zouari et al. [17] have treated 15 lesions of the hands and feet using ILP. When the distance between the lesion and the skin, tendon or nerve structure was less than 15 mm for the carpus or tarsus and 12 mm for the phalanges, an injection of physiological saline was given to increase the space between them. No complications were reported.

In the series by Roqueplan et al. [19], the rate of complications was 4% and included contusion of the peroneal nerve resulting in a deficit of the extensor of the thumb, a haematoma at the site of puncture, a superficial abscess, and a case of tendinitis.

For radiofrequency ablations, Rosenthal et al. [11] described 3.2% of complications, two related to the anaesthesia (cardio-respiratory arrest, inhalation) and two relating to the procedure (reflex sympathetic dystrophy and cellulitis). Vanderschueren et al. [15] reported two complications (a skin burn and breakage of a piece of equipment), i.e. a complication rate of 2.1%.

These complication rates are lower than those described for surgical treatment or CT-guided percutaneous resections (Table 5). For surgical treatment, Sluga et al. [9] described 3% of fractures after curettage and 4.5% after block resection. Sans et al. [10] reported a complication rate of 24%, including two fractures and chronic focal osteomyelitis after CT-guided percutaneous resection.

CT-guided minimally invasive treatments reduce the length of hospital stay to less than 24 h as against 4.8 days for percutaneous ablation [10] and 5 days following surgery [9]. Similarly, no period without weight-bearing is required,
which means that children need not interrupt their schooling and the period off work for adults is reduced.

**Histopathology**

In our study, of the five biopsies performed, only one confirmed the diagnosis of osteoid osteoma, the others not providing any information. Nevertheless, we think that the majority of these biopsies did in fact correspond to osteoid osteomas. Akhlaghpooor et al. [33] recommend surgical treatment in cases presenting atypically. In their study of 39 patients, the rate of histological confirmation was 69.2% from the bone fragments from normal drilling. In the literature, the rate of diagnostic confirmation in radiofrequency ablation with a biopsy at the beginning of the procedure is between 36 and 100% [11-13,15], and 100% after surgery.

**Risk factors for failure or recurrence**

Two failures occurred in our study. Re-examination of the images showed poor positioning of the laser fibre.

As far as the recurrences are concerned, the laser fibre had been incorrectly positioned in the first patient, whereas in the second (occurring at 17 months), it was a case rather of the appearance of a new nidus close to the first.

Mean nidus size was 7.6 mm for the patients who obtained long-term pain relief and 10.7 mm for the patients with failure or recurrence.

These patients underwent a second treatment. Three of these failed: in two cases the laser fibre was positioned incorrectly because of persistent approach problems. As for the third patient, the laser was well positioned but with the formation of air bubbles within the nidus. The pain was initially relieved but recurred 13 months later, when imaging showed the appearance of two nidi at the superior and inferior poles of the first lesion, with increased uptake in scintigraphy. They were successfully treated by placing the laser fibre in two positions delivering $2 \times 1200$ J. The osteoma of the acetabular fossa was finally successfully treated with a third procedure, the laser fibre having been correctly positioned.

For our statistical analysis of risk factors for failure we grouped together patients with primary failure and those with recurrence (four patients). The size of the nidus and poor positioning of the laser fibre are significant factors for failure ($P=0.04$ and $P=0.03$ respectively). The age, sex, intra or extra-articular topography and energy delivered were not significant.

These results are consistent with those of Vanderschueren et al. [34] who have studied the risk factors for failure of radiofrequency thermocoagulation. Treatment failure seems to occur more often in young patients, especially where the nidus is large and the laser electrode poorly positioned. The use of a single electrode position seems to be the most important factor for failure. Their conclusion is that using multiple trajectories reduces the risk of failure, especially when the nidus is larger than 10 mm. The location, calcification of the nidus, coagulation time, size of the lesion, the learning curve and previous treatments are not independent risk factors. Poor positioning could be explained by difficulties of approach (the proximity of nerve structures, for example) or poor visualisation of the nidus, particularly when previous treatment has been performed.

The main limitations of our study for evaluating the factors for failure or recurrence are the limited size of our sample, the low number of patients with failure of the procedure, retrospective analysis of the position of the laser fibre, which was not performed blind, and the variable character of the energy delivered, initially calculated using the formula cited above, then systematically of 1200 J.

**The place of post-therapeutic imaging**

We did not perform systematic control imaging examinations in our study if the condition evolved favourably, except in seven patients. Of the six control scans at 6 months, three showed a completely ossified nidus, two a decrease in the size of the nidus (5 mm as against 11 mm and 4 mm as against 8 mm previously), and one a bone lacuna. The control MRI at 4 months of the patient treated for an osteoma of the L5/S1 zygapophyseal joint showed a reduction in STIR hyperintensity, fat recovery on the T1-weighted sequence with bone hyperintensity, and a clear decrease in enhancement of the nidus, the peripheral bone and soft tissue after gadolinium injection. The scans of the four patients with failure or recurrence all revealed stable or reduced nidus size.

Vanderschueren et al. [35] compared the imaging (CT and MRI) appearance of patients treated with and without success by thermocoagulation. In CT, it was possible to see complete ossification of the nidus, persistence of a small nidus, a reduction in the diameter of the nidus, unchanged diameter and thermal necrosis. Complete ossification of the nidus or persistence of a small nidus was seen in 58% of the patients treated with success, but not in the cases where the treatment had failed. The absence of ossification of the nidus was not correlated with failure of the treatment.
CT cannot therefore be used to evaluate the activity of the lesion after treatment. The value of MRI also appears to be limited, since oedema and enhancement can persist (69% of oedema persists in successfully treated patients). MRA sequences with subtraction, which distinguishes the nidus from peripheral bone oedema, could improve post-treatment evaluation of osteoid osteoma.

Clinical examination retains a central role in assessing the response to treatment, identifying patients who might benefit from a second procedure.

Conclusion

Interstitial laser photocooagulation is an effective and safe treatment for osteoid osteomas. In the case of failure or recurrence, treatments can be repeated. The main factors for failure seem to be the size of the nidus, sometimes requiring the use of several trajectories, and the position of the trocar in the three spatial planes.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

References

