The Development of Postoperative Knee Chondrolysis After Intra-Articular Pain Pump Infusion of an Anesthetic Medication

A Series of Twenty-One Cases

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Background: Postoperative chondrolysis in the knee joint caused by continuous intra-articular pain pumps infusing bupivacaine is a serious complication that severely affects function. We report the clinical course of a series of twenty-one patients who were referred to our clinic with this complication.

Methods: A physical examination and a review of medical records were conducted. The condition of the articular cartilage was determined from operative notes, photographs, magnetic resonance images, and radiographs. Knee function was assessed with the Cincinnati Knee Rating System.

Results: The study group included eighteen female and three male patients ranging in age from fourteen to forty-two years. The index procedures, all done elsewhere, included eighteen anterior cruciate ligament reconstructions, one meniscal repair, one arthroscopy, and one tibial tubercle osteotomy. An intra-articular high-flow-volume pump (200 to 270 mL) was used in ten patients, and a low-flow-volume pump (90 to 120 mL) was used in ten patients; the flow rate in the remaining patient was not documented. The devices used 0.5% bupivacaine in twenty knees and 0.25% in one knee, with 1:200,000 epinephrine added in eleven knees. Knee symptoms affecting daily activities occurred at a mean of 9 ± 7 months after the index procedure. Extensive chondrolysis with loss of articular cartilage of all three knee compartments occurred in six knees. In ten knees, two compartments were affected, and in five knees, one compartment was abnormal. All patients had marked limitations and pain with daily activities, and nineteen patients underwent forty-one subsequent surgical procedures.

Conclusions: Severe postoperative knee chondrolysis occurred after the use of a high or low-flow-volume pump infusing intra-articular bupivacaine, producing disabling knee symptoms. A variety of operative procedures failed to alleviate symptoms. Although this study does not define the incidence of knee chondrolysis after intra-articular bupivacaine pain-pump infusion, the severe complications reported here warrant its use to be contraindicated.

Level of Evidence: Therapeutic Level IV. See Instructions for Authors for a complete description of levels of evidence.

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A commentary by Robert T. Burks, MD, is linked to the online version of this article at jbjs.org.
Knee joint chondrolysis caused by continuous intra-articular bupivacaine administration represents a serious complication in which diffuse chondrocyte death occurs over a relatively short period of time, leading to extensive loss of articular cartilage and progressive joint deterioration. Recent clinical reports have noted an association between rapid chondrolysis and continuous intra-articular pain pumps infusing bupivacaine in both the shoulder\(^1\)\(^2\)\(^3\) and the knee\(^2\)\(^3\)\(^4\). The patients in these studies were typically under the age of fifty years and had undergone operative procedures for the treatment of shoulder instability or knee ligament ruptures. The consequence of major destruction of the articular cartilage results in the eventual requirement for partial or total joint arthroplasty in young patients. Experimental studies have demonstrated a cytotoxic effect of 0.5% and 0.25% bupivacaine and other anesthetic drugs on human and animal articular chondrocytes in vitro and in vivo\(^5\)\(^6\)\(^7\).

We are aware of four reported cases of chondrolysis in the knee joint that were associated with continuous intra-articular pain pumps infusing bupivacaine\(^8\)\(^9\)\(^10\)\(^11\). The first report, from 2009\(^5\), described three cases, and another report, from 2010\(^8\), presented the case of a fourth patient; all four patients were evaluated at our center. After the initial recognition and reporting of these cases, seventeen other patients were referred to our center with this complication. Our purpose is to present the case series of these twenty-one patients to define the clinical course and the results of treatment. All of the index surgical procedures in which pain pumps were used were performed at facilities outside our center.

**Materials and Methods**

Eighteen female and three male patients were referred to our clinic from May 2007 to December 2011. All patients had undergone knee surgery elsewhere in which a continuous intra-articular pain pump was used postoperatively. The patients demonstrated the following criteria that fulfilled the diagnosis of postoperative knee chondrolysis. First, the postoperative course was abnormal in that, although the recovery was initially uneventful, an unusual onset of knee pain, swelling, and loss of function occurred unexpectedly. Second, there was a diffuse loss of articular cartilage in the knee (grade 3 or 4 according to the Outerbridge classification system\(^12\) or grade 2B according to the Cincinnati articular cartilage knee-rating classification\(^13\)) or loss of cartilage with bone exposure (grade 4 according to the Outerbridge system or grade 3A or 3B according to the Cincinnati articular cartilage knee-rating classification). In addition, descriptions from operative notes, including severe fragmentation and bone exposure or bone loss, were accepted as being indicative of noteworthy cartilage loss. Previous radiographs were reviewed and additional radiographs were made, including standing flexion posteroanterior weight-bearing\(^14\)\(^15\)\(^16\), lateral, and patellofemoral axial views. The radiographs were rated according to the International Knee Documentation Committee (IKDC) rating system\(^17\). A grade was assigned on the basis of joint-space narrowing and the presence of osteophytes, sclerosis, or flattening of the femoral condyles (with grade A indicating normal, grade B indicating nearly normal, grade C indicating abnormal, and grade D indicating severely abnormal). Knees with anterior cruciate ligament reconstructions were rated for knee joint stability with use of IKDC standards. Knee symptoms, functional limitations, and the patient perception of the overall knee condition were assessed for all patients with use of the validated Cincinnati Knee Rating System\(^18\).

Medical records were reviewed to determine the type of pain pump and the flow rate, the anesthetic agent and concentration, whether epinephrine was also used, the time-frame of the onset of the initial symptoms postoperatively, the knee joint compartments affected, subsequent operative procedures and their effect on symptoms, and the condition of the knee menisci. A statistical analysis compared the number of knees with abnormal articular cartilage after use either a high or low-volume pain pump. The Fisher exact test was conducted by an independent statistician. The level of significance was set at p ≤ 0.05.

**Results**

**Index Operation**

Eighteen patients underwent anterior cruciate ligament reconstruction within eight weeks after the injury, one patient had a medial meniscal repair five weeks after the injury, one patient had arthroscopy and debridement ten months after a motor-vehicle accident, and one patient underwent patellar realignment and tibial tubercle osteotomy after approximately five years of symptomatic patellar subluxation (see Appendix). In all patients except one, 0.5% bupivacaine was infused with either a high-volume (200 to 270 mL) or low-volume (90 to 120 mL) pump (see Appendix). In one patient, 0.25% bupivacaine was infused with a low-volume pump. The intra-articular pain pump catheters were introduced into the superior lateral thigh portal in all patients; however, the exact location of the final location in the knee could not be determined. In one patient, the pump volume rate was not documented. In eleven patients, 1:200,000 epinephrine was also infused. At the conclusion of the operative procedure, six patients received an intra-articular bolus injection of bupivacaine, epinephrine, and morphine. The pain pump catheter remained in the knee joint for forty-eight hours in fifteen patients, seventy-two hours in three patients, and ninety-six hours in three patients.

Magnetic resonance imaging and operative records showed that the condition of the articular cartilage at the time of the index operation was entirely normal in seventeen patients. Three patients had small areas of cartilage surface fissuring or...
<table>
<thead>
<tr>
<th>Case</th>
<th>Time to Onset of Noteworthy Knee Symptoms After Index Operation (mo)</th>
<th>Time from Index Operation to First Follow-up Operative Procedure (mo)</th>
<th>Follow-up Operative Procedures (in Chronological Order)*</th>
<th>Compartments With Abnormal Articular Cartilage**†</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6</td>
<td>30</td>
<td>1. Arthroscopic chondroplasty PF, MTF, LTF; partial LM</td>
<td>PF, MTF, LTF</td>
<td>ACLR contralateral knee without pain pump 60 months before index operation, no problems</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>25</td>
<td>1. Arthroscopic debridement</td>
<td>MTF</td>
<td>Proximal-distal extensor mechanism realignment, Fulkerson tibial tubercle osteotomy in contralateral knee without pain pump 49 mo before index operation, no problems</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>12</td>
<td>1. Arthroscopic debridement, partial MM</td>
<td>PF, MTF</td>
<td>ACLR contralateral knee without pain pump 31 mo after index operation, no problems</td>
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<td>4</td>
<td>9</td>
<td>None</td>
<td>2. Arthroscopic debridement</td>
<td>MTF</td>
<td>ACLR contralateral knee without pain pump 6 mo after index operation, no problems</td>
</tr>
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<td>5</td>
<td>5</td>
<td>20</td>
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<td>PF, MTF, LTF</td>
<td>ACLR contralateral knee with pain pump 11 mo after index operation, no problems</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>33</td>
<td>1. Arthroscopic chondroplasty, lysis adhesions</td>
<td>PF, MTF, LTF</td>
<td>ACLR contralateral knee without pain pump 90 mo before index operation, no problems</td>
</tr>
<tr>
<td>7</td>
<td>24</td>
<td>53</td>
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<td>PF</td>
<td>ACLR contralateral knee without pain pump 60 months before index operation, no problems</td>
</tr>
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<td>57</td>
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<td>PF, MTF, LTF</td>
<td>ACLR contralateral knee without pain pump 60 months before index operation, no problems</td>
</tr>
<tr>
<td>9</td>
<td>3</td>
<td>29</td>
<td>2. Arthroscopic debridement</td>
<td>PF, MTF</td>
<td>ACLR contralateral knee without pain pump 60 months before index operation, no problems</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
<td>20</td>
<td>1. Arthroscopic chondroplasty MTF</td>
<td>PF, MTF</td>
<td>ACLR contralateral knee without pain pump 60 months before index operation, no problems</td>
</tr>
<tr>
<td>11</td>
<td>4</td>
<td>9</td>
<td>1. Revision ACLR B-PT-B autograft, chondroplasty PF, microfracture MFC 2. ACI biopsy 3. Arthroscopic chondroplasty PF, MFC 4. Osteochondral autograft trochlea, MFC; medial meniscus transplant; revision ACLR allograft 5. Arthroscopic debridement, lysis adhesions</td>
<td>PF, MTF</td>
<td>ACLR contralateral knee with pain pump 60 months before index operation, no problems</td>
</tr>
<tr>
<td>12</td>
<td>6</td>
<td>7</td>
<td>1. Arthroscopic debridement</td>
<td>PF, MTF, LTF</td>
<td>ACLR contralateral knee without pain pump 60 months before index operation, no problems</td>
</tr>
<tr>
<td>13</td>
<td>7</td>
<td>15</td>
<td>1. Arthroscopic chondroplasty LFC, MFC; HTO opening wedge</td>
<td>PF, MTF</td>
<td>ACLR contralateral knee without pain pump 60 months before index operation, no problems</td>
</tr>
<tr>
<td>14</td>
<td>12</td>
<td>16</td>
<td>1. Arthroscopic debridement, partial MM</td>
<td>PF, MTF</td>
<td>ACLR contralateral knee without pain pump 60 months before index operation, no problems</td>
</tr>
<tr>
<td>15</td>
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<td>None</td>
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<tr>
<td>16</td>
<td>5</td>
<td>14</td>
<td>1. Arthroscopic debridement</td>
<td>PF, MTF, LTF</td>
<td>ACLR contralateral knee without pain pump 60 months before index operation, no problems</td>
</tr>
</tbody>
</table>
fragmentation on one joint surface. One patient (Case 2) who had sustained multiple patellar dislocations for two years before a realignment procedure had limited areas of fissuring on the undersurface of the patella and trochlea; however, the tibiofemoral cartilage surfaces were normal.

**Symptoms and Findings at First Evaluation**

The patients reported the onset of noteworthy knee symptoms a mean of 9 ± 7 months (range, three to twenty-four months) after the index procedure (Table I). The onset of symptoms occurred between three and twelve months postoperatively in seventeen

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**TABLE I (continued)**

<table>
<thead>
<tr>
<th>Case</th>
<th>Time to Onset</th>
<th>Time from Index</th>
<th>Follow-up Operative</th>
<th>Compartments With Abnormal Articular Cartilage**†</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>of Noteworthy Knee Symptoms After Index Operation (mo)</td>
<td>Operation to First Follow-up Operative Procedure (mo)</td>
<td>Procedures (in Chronological Order)*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>3</td>
<td>17</td>
<td>1. Revision ACLR B-PT-B allograft, MM, hardware removal, chondroplasty</td>
<td>PF, MTF</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>6</td>
<td>78</td>
<td>Partial knee replacement, MTF</td>
<td>PF, MTF</td>
<td>ACLR contralateral knee without pain pump 100 mo before index operation, no problems</td>
</tr>
<tr>
<td>6.</td>
<td>12</td>
<td>96</td>
<td>Arthroscopy, partial MM</td>
<td>PF, MTF</td>
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</tr>
<tr>
<td>10.</td>
<td>9</td>
<td>49</td>
<td>Arthroscopic chondroplasty</td>
<td>PF, MTF</td>
<td></td>
</tr>
<tr>
<td>11.</td>
<td>22</td>
<td>22</td>
<td>Arthroscopic debridement</td>
<td>MTF</td>
<td></td>
</tr>
</tbody>
</table>

*ACI = autologous chondrocyte implantation, ACLR = anterior cruciate ligament reconstruction, B-PT-B = bone-patellar tendon-bone, HTO = high tibial ostectomy, LFC = lateral femoral condyle, LM = lateral meniscus, LTF = lateral tibiofemoral, MFC = medial femoral condyle, MM = medial meniscus, MTF = medial tibiofemoral, PF = patellofemoral. †Designated by operative notes (grades 3 or 4 according to the Outerbridge system or grades 2B, 3A, or 3B according to the Cincinnati articular cartilage knee-rating system**20**)) or radiographs (grade C or D according to the IKDC system) in patients who did not undergo follow-up operations.

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Bar graph showing the distribution of patient responses to the Cincinnati Knee Rating System symptom-rating scale at the time of the first evaluation at the authors’ center, performed at a mean of sixty-nine months after the index procedure and the use of an intra-articular pain pump. The scale shows the highest level of activity possible without the patient experiencing the symptoms of pain, swelling, and giving-way.
patients, at fifteen months postoperatively in one patient, and between twenty-two and twenty-four months postoperatively in three patients. The mean amount of time from the index procedure to the first evaluation at our clinic was 69 ± 38 months (range, five to 142 months). The Cincinnati Knee Rating System ratings for pain, swelling, and full giving-way at the time of this evaluation are shown in Figure 1. All patients except one had moderate to severe knee joint pain with daily activities and had given up sports and recreational activities. Of the fifteen patients who were working, only four were able to do so without limitations. Ten patients rated the overall condition of the knee as poor and eleven rated it as fair according to the patient perception scale.

Fourteen of the eighteen anterior cruciate ligament reconstructions were rated as normal or nearly normal according to the IKDC system, and four were rated as abnormal or severely abnormal with a residual grade-2 or 3 pivot-shift test. Fourteen knees had a normal range of motion equal to that on the contralateral side. Flexion was limited to 105° to 130° in five knees. Two knees had limitations of both flexion and extension (5° to 98°, 10° to 130°). Moderate to severe crepitus was present in the patellofemoral compartment in seventeen knees and in the tibiofemoral compartment in eight knees. Nine patients had an antalgic gait with limitation of knee flexion and a painful extended knee position during stance phase, and a mild varus thrust was observed in four knees. One patient required crutch support for walking. Quadriceps muscle atrophy was visibly discernible in fifteen patients, in whom 2.5 to 5 cm of loss of thigh circumference as compared with the contralateral side was measured 15 cm proximal to the superior aspect of the patella.

**Follow-up Operations**

At the time of writing, a total of forty-one operative procedures had been performed in nineteen knees after the index procedure (Table I). All but three of these operative procedures had been performed elsewhere before the time of presentation to our center. The mean time from the index procedure to the first follow-up operation was 32 ± 24 months (range, seven to
ninety-six months). Eleven patients had multiple subsequent procedures. At the time of the first follow-up operative procedure, the articular cartilage had markedly deteriorated in all nineteen knees. Two knees (Cases 4 and 15) did not undergo surgery after the index operation but were evaluated at our clinic twenty-three and seventy-seven months after the index procedure, at which time radiographs demonstrated marked joint narrowing (IKDC grades C and D) in the medial tibiofemoral and patellofemoral compartments.

Location of Chondrolysis
The review of medical records and radiographs that were made at the time of our evaluation showed extensive chondrolysis in all three knee compartments (patellofemoral, medial tibiofemoral, lateral tibiofemoral) in six knees. In ten knees, the patellofemoral and medial tibiofemoral compartments were affected, but the lateral tibiofemoral compartment was normal. In two knees extensive chondrolysis involved only the patellofemoral compartment, and in three other knees extensive chondrolysis involved only the medial tibiofemoral compartment. There was no significant difference between the use of a high or low-flow pain pump with regard to the number of knee compartments that were rated as abnormal.

Association Between Condition of the Menisci and Chondrolysis
There appeared to be no association between the condition of the menisci and the deterioration of the articular cartilage surfaces (see Appendix). Typically, the meniscal structures, if not previously removed, appeared normal on subsequent arthroscopy or magnetic resonance imaging.

Operations in the Contralateral Knee
Five patients (Cases 1, 2, 6, 7, and 19) underwent the same procedure in the contralateral knee as in the involved knee (anterior cruciate ligament reconstruction in four knees and a patellar realignment procedure in one knee) without the use of a pain pump. In three of these patients, the operation without the pain pump had been performed first. One patient (Case 10) underwent the same procedure in the contralateral (right) knee as in the involved (left) knee (anterior cruciate ligament reconstruction), and in the right knee, a pain pump was used. In all six of these patients, there were no postoperative complications or chondrolysis development following the operations on the contralateral knees. The contralateral knees were asymptomatic, and radiographs were normal.

Illustrative Case Reports
CASE 3. A fourteen-year-old girl sustained an anterior cruciate ligament tear while playing basketball and underwent an anterior cruciate ligament reconstruction. The articular cartilage was pristine in all knee compartments at the time of surgery. A continuous-infusion low-volume pain pump that delivered 100 mL of 0.5% bupivacaine and 1:200,000 epinephrine was used for forty-eight hours postoperatively. Six months later, the patient complained of pain and severe crepitus in the knee joint. Twelve months after the original operation, she underwent an arthroscopic evaluation and partial medial meniscectomy. The operative records indicated extensive articular cartilage loss in the patellofemoral and medial tibiofemoral joints. Eleven years after the index operation, she had severe symptoms with daily activities and a walking tolerance of five minutes. A second arthroscopic debridement showed diffuse loss of articular cartilage in the medial tibiofemoral and patellofemoral joints (Figs. 2-A through 2-D). She was expected to require a total knee replacement.

CASE 5. A nineteen-year-old woman sustained a patellofemoral contusion as the result of a motor-vehicle accident. Ten months later, she underwent an arthroscopic procedure on the right knee for the treatment of persistent anterior knee pain. At the time of
surgery, there was mild softening in the patellar articular cartilage. A continuous-infusion high-volume pain pump that delivered 270 mL of 0.5% bupivacaine was used for forty-eight hours postoperatively. Five months postoperatively, the patient had an onset of severe patellar pain, grinding, and popping. Twenty months after the original procedure, an arthroscopic examination showed diffuse articular cartilage fragmentation and bone exposure in the patellofemoral and medial tibiofemoral compartments. The lateral tibiofemoral compartment was normal, and both medial and lateral menisci were normal (Fig. 3). The patient underwent autologous chondrocyte implantation in the patellofemoral and medial tibiofemoral compartments before she was evaluated at our center. This procedure failed to provide relief of the symptoms and, at the time of the latest follow-up at the age of twenty-five years, the patient had severe pain, had a walking tolerance of forty-five minutes, and was expected to require a total joint arthroplasty.

CASE 12. A seventeen-year-old girl sustained anterior cruciate ligament and lateral meniscal tears while playing soccer and underwent anterior cruciate ligament reconstruction and lateral meniscal repair. The articular cartilage was normal in all knee compartments. A continuous-infusion high-volume pain pump that delivered 200 mL of 0.5% bupivacaine and 1:200,000 epinephrine was used for forty-eight hours postoperatively. Six months later, the patient complained of severe knee symptoms, including grinding, cracking, and pain. She underwent arthroscopic debridement, at which time diffuse articular cartilage loss was noted in all knee compartments (Cincinnati articular cartilage rating grades 2B and 3). Fourteen months after the index operation, anteroposterior radiographs showed narrowing of both the medial and lateral tibiofemoral compartments and the patient complained of severe pain in the medial compartment (see Appendix). She underwent a valgus-producing opening-wedge proximal tibial osteotomy and osteochondral allografting.

Fig. 3
Case 5. Arthroscopic photographs of the knee of a twenty-one-year-old woman, made nineteen months after postoperative pain pump infusion. There is widespread cartilage loss in the patellofemoral (upper left) and medial tibiofemoral (upper right and lower left) compartments. The lateral compartment (lower right) and both menisci are unaffected.
of the medial and lateral femoral condyles (see Appendix) before she was evaluated at our center. At the time of writing, forty months after the original operation, the patient, at twenty-one years of age, was experiencing pain and swelling with daily activities and was expected to require a total knee replacement.

Discussion

The occurrence of chondrolysis following knee surgery is an extremely rare event. Two previous reports described eight patients with knee chondrolysis following accidental irritation with 1% chlorhexidine during arthroscopy that resulted in tricompartmental joint chondrolysis. Arthroscopic partial or complete lateral meniscectomy and subsequent deterioration of the lateral tibiofemoral compartment that was incorrectly labeled as chondrolysis has been reported in six athletes. Those reports involved deterioration of only the lateral tibiofemoral compartment and not widespread knee chondrolysis.

To our knowledge, only four cases of chondrolysis in the knee have been previously reported following the use of continuous intra-articular pain pumps infusing bupivacaine. These four patients were evaluated at our clinic and are included in the present series (Cases 4, 10, 12, and 13). In the twenty-one knees in the present series, we could not identify other possible causes for the development of chondrolysis, such as the use of a thermal wand or probe, infection, introduction of toxic substances, trauma, and rheumatoid or other inflammatory joint diseases.

All twenty-one patients had the common feature of complete or nearly complete loss of articular cartilage in the involved compartments. Of interest, fifteen patients had loss of articular cartilage in only one or two knee compartments, possibly because of the location of the intra-articular catheter. There appeared to be no association between the condition of the menisci and the subsequent development and location of the chondrolysis. The meniscal structures appeared to be resistant to the infused bupivacaine. In these patients, a total of forty-one subsequent operative procedures were performed, although most failed to alleviate severe symptoms and functional limitations. The indications for procedures such as osteotomy, osteochondral allografting, and even multiple arthroscopic debridements appear to be questionable in knees with severe diffuse chondrolysis.

Several reports have described rapid chondrolysis of the shoulder in >100 patients following the use of intra-articular infusion pain pumps. To our knowledge, Hansen et al. were the first to report this complication in a 2007 study of twelve shoulders that underwent capsular procedures in which high-flow pumps infusing 0.25% bupivacaine and epinephrine were used for forty-eight hours postoperatively. Scheffel et al. systematically reviewed 100 cases of postoperative glenohumeral chondrolysis from sixteen studies. The most common factor for the development of chondrolysis was the use of a pain pump, which was reported in the cases of forty-eight patients who did not undergo thermal capsulorrhaphy. The studies used both high and low-volume flow-rate pumps (2 to 6.25 mL/hr) that infused various local anesthetics with or without epinephrine. Hasan et al. used published data from the studies by Anderson et al. and Hansen et al. to calculate significant differences in the incidence of chondrolysis between shoulders that received treatment with a pain pump and those that did not receive this treatment. The likelihood that chance alone could explain the observed distribution of chondrolysis in the two studies was extremely remote (p < 0.0001 in both investigations). An association between the use of thermal probes and the development of glenohumeral chondrolysis has been reported by several authors. Historically, the injection of gentian violet into the glenohumeral joint during rotator cuff repair and infection with Propionibacterium acnes have also led to shoulder chondrolysis.

Single intra-articular injections of bupivacaine for controlling postoperative pain following joint surgery have been used for many years without any recognized or reported clinical problems. However, it should be noted this represents an off-label use, as the United States Food and Drug Administration has not approved the intra-articular use of bupivacaine or any other local anesthetic. Hoenecke et al. recommended a continuous infusion of 0.25% bupivacaine at a rate of 2 mL/hr for forty-eight hours following anterior cruciate ligament patellar tendon autograft reconstruction. The pain pumps that were used in these cases and the pain ratings were reported. There was no subsequent follow-up information on those patients.

The true incidence of knee chondrolysis after the use of continuous intra-articular pain pumps is unknown. It is feasible that other cases of chondrolysis occurred but were missed or were not reported because of the amount of time that elapsed from the surgical procedure to the onset of knee symptoms. In this study, Hansen et al. reported a rate of chondrolysis of 63% (twelve of nineteen) following various operative procedures. Provencher et al. recommended that the term chondrolysis be applied to cases of knee joint chondrolysis that occurred within twelve months after an operative procedure or cartilage insult, the occurrence of noteworthy joint pain and evidence of severe articular cartilage loss. In the
present study, seventeen (81%) of twenty-one patients had severe symptoms and cartilage loss within twelve months. Four patients noticed increased symptoms within the first year, but fifteen to twenty-four months elapsed before they were fully symptomatic and, at that point, the chondrolysis had progressed with diffuse loss of cartilage and bone exposure in the joints. Hasan and Fleckenstein \(^{16}\) reported similar results in the shoulder joint, with the majority of patients experiencing the onset of symptoms at a mean of ten months (range, one to thirty-four months) postoperatively.

In vitro and in vivo studies have shown that local anesthetics such as bupivacaine and lidocaine are chondrotoxic to human and animal articular chondrocytes \(^{17,18}\). Chu et al. reported that the exposure of bovine articular chondrocytes to 0.5\% bupivacaine resulted in the death of 99\% of all chondrocytes exposed in a culture medium \(^{19}\). Human and bovine articular chondrocyte cytotoxicity has been reported after exposure to 0.5\% and 0.25\% bupivacaine, with time and dose-dependent effects \(^{20}\). Piper and Kim confirmed these results and showed that bupivacaine was more cytotoxic than ropivacaine \(^{21}\). Anz et al., in a co-culture model involving canine cartilage, reported a deleterious effect of 0.5\% bupivacaine, with nearly 100\% decrease in cell viability \(^{22}\). Lo et al., in a bovine culture model of articular cartilage, showed that bupivacaine, lidocaine, and ropivacaine had deleterious effects on chondrocyte viability that were dependent on the dose and duration of exposure \(^{23}\). Grishko et al. reported that exposure of human chondrocytes to bupivacaine, lidocaine, and ropivacaine damaged mitochondrial DNA and led to cell apoptosis \(^{24}\).

The devastating clinical course of knee chondrolysis in our series included moderate to severe pain with daily activities in twenty of twenty-one patients at the time of the latest follow-up. One patient who had a unicompartmental joint replacement procedure elsewhere was able to perform light swimming and bicycling activities without pain. All patients had given up sports activities that involved running or other strenuous activities, and all rated the overall knee condition as poor or fair. A variety of operative procedures performed prior to referral to our center had not been successful in alleviating pain and improving function. These included proximal tibial osteotomy, autologous chondrocyte implantation, osteochondral allografts, partial femoral condylar replacement, and multiple arthroscopic debridement and chondroplasty procedures (Table I). At the time of writing, one patient who was thirty years of age had undergone a total knee arthroplasty and three patients who ranged from twenty-seven to thirty-one years of age had had a medial unicondylar joint replacement. The other patients were attempting to manage the condition for as long as possible before total knee replacement. The results of this case series show that the association between intra-articular pain pump administration of an anesthetic agent and severe knee chondrolysis warrants the use of pain pumps to be contraindicated.

### Appendix

**Tables showing data on the patients and procedures as well as the condition of the menisci and the effect on articular cartilage surfaces and radiographs for a patient who underwent proximal tibial osteotomy are available with the online version of this article as a data supplement at jbjs.org.**

### References

15. Chu CR, Izzo NJ, Papas NE, Fu FH. In vitro exposure to 0.5\% bupivacaine is cytotoxic to bovine articular chondrocytes. Arthroscopy. 2006 Jul;22(7):693-9.