Chondrolysis of the Glenohumeral Joint After Infusion of Bupivacaine Through an Intra-articular Pain Pump Catheter: A Report of 18 Cases

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Purpose: To report on our experience of patients who received infusion of bupivacaine with epinephrine after arthroscopic glenoid labral repair surgery and in whom glenohumeral joint chondrolysis subsequently developed, as well as to determine the incidence of such chondrolysis in our surgeons’ patient populations. Methods: A retrospective chart review of 18 patients diagnosed with chondrolysis was carried out. All patients were from 2 experienced orthopaedic surgeons’ practices. Details of their clinical course were obtained and summarized. These data were compared with all other arthroscopies completed by the 2 surgeons to determine the incidence of chondrolysis. Results: All 18 patients diagnosed with glenohumeral joint chondrolysis received postoperative infusion of bupivacaine with epinephrine through an intra-articular pain pump catheter (IAPPC). None of the patients received thermal energy as part of their procedure. None of the patients had evidence of glenohumeral joint infection, although an extensive workup was frequently undertaken. Clinically, patients presented with a stiff, painful shoulder. Examination showed decreased range of motion of the affected shoulder. Radiographs and magnetic resonance imaging showed joint space narrowing, as well as subchondral sclerosis and cyst formation. Of the 18 patients, 14 have since undergone repeat arthroscopic procedures, and 5 have received a humeral head–resurfacing operation. Within the same time period, there were 113 arthroscopies, with 45 pain pumps used. Chondrolysis developed in 16 of 32 patients with high-flow IAPPCs and 2 of 12 patients with low-flow IAPPCs (1 patient’s IAPPC flow rate was not documented). Conclusions: Although we cannot establish a causal link, the development of glenohumeral chondrolysis may be related to the intra-articular infusion of bupivacaine with epinephrine postoperatively. We thus caution against the use of IAPPCs. Level of Evidence: Level IV, therapeutic case series.

Chondrolysis is characterized by rapid destruction of the articular cartilage surface in a joint. It is the result of chondrocyte lysis and dissolution of the cartilage matrix. Radiographs of affected joints show joint space narrowing and, if severe, subchondral sclerosis and cyst formation. Magnetic resonance imaging (MRI) will show similar findings, including loss of articular cartilage on both the glenoid and humeral surfaces of the joint. Clinical examination shows painful, limited range of motion, often with crepitus.

There have been several recent case reports of glenohumeral chondrolysis after shoulder arthroscopy. Thermal energy devices have been implicated in the development of chondrolysis and articular cartilage damage has been reported in association with loose or prominent suture anchors and/or tacks. Most notably, there have been 3 published articles linking the development of chondrolysis to the intra-articular infusion of bupivacaine postoperatively. All 18 patients in this series received bupivacaine with epinephrine intra-articularly after their procedure. The purpose of
this series was to review the clinical courses of 18 patients in whom chondrolysis of the glenohumeral joint developed after arthroscopic shoulder labral repair surgery and use of an intra-articular pain pump catheter (IAPPC), as well as to determine the incidence of chondrolysis associated with IAPPC use in our surgeons’ patient populations. We hypothesize that the development of chondrolysis in these patients may be related to postoperative infusion of bupivacaine with epinephrine through an IAPPC.

METHODS

A retrospective chart review of 18 patients diagnosed with chondrolysis after arthroscopic labrum repair surgery for symptomatic glenohumeral instability was undertaken. The single inclusion criterion was a known diagnosis of chondrolysis, given by the attending orthopaedic surgeon, after arthroscopic stabilization surgery. Symptoms of increasing pain (particularly with movement) and decreased range of motion, as well as radiographic evidence of joint space narrowing, were used to aid in the diagnosis. Details pertaining to each patient, including the surgical procedure he or she underwent, as well as his or her clinical course postoperatively, were compiled, and radiographs and MRI studies were obtained.

These patients had their arthroscopic surgeries between May 31, 2004, and December 7, 2005, and have had follow up since that time. The same 2 experienced orthopaedic surgeons performed all the procedures. All 18 patients in whom glenohumeral chondrolysis developed received an IAPPC (DonJoy Pain Management PainBuster Catheter; DJO, Vista, CA) for postoperative analgesia. The IAPPCs were loaded with 0.5% bupivacaine with 1:200,000 epinephrine. There were 2 types of pain pumps: high flow and low flow. The high-flow IAPPCs had approximate fill volumes of 275 mL and flow rates of 5 mL/h, whereas the low-flow IAPPCs had approximate fill volumes of 100 mL and flow rates of 2 mL/h. Intra-articular placement of the IAPPCs was confirmed with an arthroscope. In addition to the IAPPC, most patients received an intra-articular bolus injection (15 to 60 mL) of bupivacaine (either 0.25% or 0.5%) with epinephrine at the conclusion of the case.

The arthroscopic stabilization procedure was the first surgery in all shoulders; none of the procedures were revision procedures at the time of insertion of the initial pain pump. However, there were 14 patients who did undergo repeat arthroscopic procedures (after the onset of shoulder problems) and 3 who did have a second pain pump inserted at this time.

Furthermore, aggregate data were compiled from the 2 surgeons’ practices. Information regarding the number of patients who underwent primary arthroscopic labrum repair between May 31, 2004, and December 7, 2005—the surgical dates of the first and last patients in whom chondrolysis developed—was obtained, and the number of IAPPCs used during such procedures was recorded. There were 113 patients who underwent arthroscopy during this time period, with 45 patients receiving an IAPPC postoperatively. There were an additional 3 patients who did receive a pain pump catheter, but these were placed subacromially.

All data gathered was done so in compliance with institutional ethical requirements. All 18 patients with known chondrolysis were informed that data concerning their cases would be submitted for publication.

Case Reports

Case 1: A 17-year-old right hand–dominant boy presented with a history of recurrent left shoulder instability. His first episode occurred while wrestling when he sustained an abduction, external rotation force to his left shoulder. He described the shoulder being subluxated for approximately 10 seconds. Since then, he had multiple episodes of left shoulder instability during activities such as ice hockey, wakeboarding, and dirt biking. On 1 occasion, he had a shoulder dislocation (anterior) that required a closed reduction in the emergency department.

Physical examination of the left shoulder showed full range of motion, normal rotator cuff strength, and 2+ anterior load and shift. The patient had a positive apprehension test, and there were no signs of generalized ligamentous laxity. Radiographs showed a Hill-Sachs lesion (Figs 1A and 1B), and an MRI arthrogram showed a normal glenohumeral joint (Fig 1C).

The patient’s recurrent instability had persisted for 19 months despite a supervised rehabilitation program. With conservative management having failed, the patient elected to proceed with arthroscopic surgical stabilization of his shoulder.

The intraoperative findings showed a deficient anterior inferior labrum, or Bankart lesion. The gelenoid articular surface appeared normal. A Bankart repair was performed with 2 bioabsorbable Smith & Nephew SureTac fixation devices (Smith & Nephew Endoscopy, Mississauga, ON, Canada). No thermal energy was used during the operation. Upon completion of the procedure, a high-flow IAPPC was inserted into
FIGURE 1. Case 1. Preoperative (A) anteroposterior glenoid and (B) axillary lateral radiographs showing normal glenohumeral joint space. A depression in the posterolateral humeral head (Hill-Sachs lesion) is seen (arrow). (C) Preoperative MRI scan (axial T2 gradient echo) shows a Bankart lesion (arrow) and normal articular cartilage. (D) Anteroposterior glenoid and (E) axillary lateral radiographs obtained at 3 months postoperatively show joint space narrowing. (F) Anteroposterior glenoid and (G) axillary lateral radiographs obtained at 8 months postoperatively show significant joint space narrowing, subchondral sclerosis, and subchondral cysts. (H) Postoperative MRI scan (axial T2 gradient echo) shows degenerative changes: there is an irregular joint surface and a subchondral cyst is present (arrow). (I) Intraoperative image, 19 months after index procedure. The humeral head is seen on the left (H), the glenoid surface on right (G). A surgical probe is entering the joint from the anterior. There is extensive loss of articular cartilage, with underlying areas of bare bone (photo courtesy of Brian J. Cole, M.D., M.B.A., Rush University Medical Center, Chicago, IL.)
the glenohumeral joint under direct vision by use of an arthroscope. The IAPPC was filled with 280 mL of 0.5% bupivacaine with epinephrine (1:200,000) and provided a continuous intra-articular infusion of local anesthetic. This high-flow IAPPC had a flow rate of 5 mL/h and provided analgesia for 56 hours postoperatively. In addition, a 60-mL bolus of 0.25% bupivacaine with epinephrine (1:200,000) was injected into the glenohumeral joint through a spinal needle at the end of the case. The patient’s extremity was placed in a sling immediately postoperatively, and he was instructed to wear it at all times (until the next clinic visit); no shoulder range of motion was permitted. A follow-up appointment 2 weeks later showed that the incisions were well healed with no signs of infection. The remainder of the examination was unremarkable. The patient began a supervised physiotherapy program at 6 weeks.

Three months after the procedure, the patient was seen again. He did not report any significant pain. However, physical examination showed limited range of motion of the shoulder, as well as crepitus in the joint. Radiographs showed evidence of joint space narrowing (Figs 1D and 1E).

The patient continued with physiotherapy, and by 8 months postoperatively, he had become progressively worse, complaining of pain and grinding in his shoulder. Radiographs showed decreased forward elevation (110° on the left v 160° on the right), decreased internal rotation (T12 on the left v T3 on the right), and decreased external rotation (0° on the left v 40° on the right). Circumduction of the shoulder produced crepitus. There were no clinical signs of infection. Radiographs showed joint space narrowing, subchondral sclerosis, and subchondral cysts (Figs 1F and 1G). A diagnosis of chondrolysis was made.

An MRI examination showed an irregular glenohumeral joint surface (Fig 1H). The preoperative MRI findings were normal, with appropriate joint spacing (Fig 1F and 1G). A workup performed to assess infection—which included a complete blood cell count, erythrocyte sedimentation rate, and high-sensitive C-reactive protein level; a gallium citrate 67 scan; and a technetium bone scan—yielded negative findings.

Arthroscopic lavage, debridement, and capsular release of the left shoulder were performed 19 months after the index procedure (Fig 1I). Intraoperative findings were consistent with the diagnosis of chondrolysis. No evidence of foreign material (suture, IAPPC tip) was present.

**Case 16:** A 25-year-old male electronics technician underwent arthroscopic shoulder surgery by surgeon B, for a 2- to 3-year history of ongoing shoulder pain and recurrent subluxations. Preoperative radiographs were unremarkable (Fig 2A). An MRI arthrogram showed a small SLAP tear but no other abnormalities (Fig 2B).

Operative findings included normal glenoid and humeral head articular surfaces, a bucket-handle tear of the superior labrum, and a positive drive-through sign. The type III SLAP tear was resected, and a transfer of the anterior inferior glenohumeral ligaments was performed with 2 Smith & Nephew Bioraptor Suture Anchors. At the conclusion of the case, a high-flow IAPPC filled with 275 mL of 0.5% bupivacaine with epinephrine (1:200,000) was inserted into the glenohumeral joint and provided analgesia for 55 hours postoperatively.

The patient was well until approximately 17 months after his arthroscopic surgery, at which time he began having pain in his shoulder, as well as difficulties with reaching and overhead positions. The patient returned to physiotherapy because of this lack of mobility. He made only mild gains during physiotherapy, which prompted a referral back to his treating surgeon. Clinical examination showed that the patient had tenderness over the anterior glenohumeral joint and had glenohumeral crepitus with movement. Range of motion was decreased: forward elevation to 120°, external rotation to 20°, and internal rotation to L1. Radiographs showed cystic changes in the humeral head with significant articular space narrowing (Fig 2C). A diagnosis of chondrolysis was made.

The patient underwent a workup performed to assess infection, including MRI and a bone scan, which did not show any evidence of an infectious process occurring. However, the MRI study did show the findings of chondrolysis (Fig 2D). The patient received a series of Synvisc injections (Genzyme, Cambridge, MA) in an attempt to provide symptomatic relief. However, he continued to have pain and discomfort in the shoulder, and he thus elected to undergo a humeral head–resurfacing arthroplasty.

During the patient’s resurfacing procedure, 2 small fragments of what appeared to be the tip of an IAPPC were shown at the time of arthrotomy. However, these fragments were attached to the tissues and did not appear to be causing any mechanical irritation. Furthermore, the damage to both the glenoid and humeral head articular surfaces was very extensive, making it unlikely that the tip fragments caused the chondrolysis (Fig 2E). There were no complications in the postoperative period, and at 10 weeks after his resurfacing, the patient reported he was doing much better and no
longer had the chronic aching discomfort and nagging pain he had preoperatively. A follow-up appointment at 5 months showed that he was progressing quite well (Fig 2F).

**RESULTS**

Eighteen patients were diagnosed with glenohumeral chondrolysis after arthroscopic labral stabilization surgery. Cases 1 and 16 represent typical presentations of chondrolysis in our case series. The pertinent details of the 18 cases are provided in Table 1. The patients in our series had a mean age at index surgery of 23.83 years. There were 15 male patients and 3 female patients. All patients except 1 (case 12) reported a traumatic shoulder subluxation or dislocation before the development of symptomatic glenohumeral instability. Two surgeons, denoted by either A or B in Table 1, performed the index surgeries, which consisted of 15 anterior Bankart repairs, 1 posterior Bankart repair, 1 combined anterior and posterior Bankart repair, and 1 combined posterior Bankart and SLAP repair. Surgeon A exclusively used tacks for the procedures, whereas surgeon B used suture anchors in all
but 1 case. None of the arthroscopies involved the use of thermal energy. All 18 patients in whom glenohumeral chondrolysis developed received an IAPPC for postoperative analgesia. The mean time to diagnosis was approximately 9.5 months (range, 2 to 27.5 months). This statistic may be affected by bias, because the diagnosis in patients who presented early on was delayed; the 2 surgeons had not yet realized chondrolysis was occurring. In contrast, in the final few patients in the series, the diagnosis was made early, quite soon after the onset of symptoms.

There were no postoperative shoulder infections or wound complications documented. Furthermore, there was no clinical suspicion of infection in any of the cases. Several patients underwent a workup performed to assess infection, which included a complete blood cell count, erythrocyte sedimentation rate, and high-sensitive C-reactive protein level; a white blood cell scan; and a technetium bone scan, all of which yielded negative findings. Two patients (cases 7 and 16) had a retained IAPPC tip. The IAPPC fragment in case 7 was discovered 2.5 months later during a second shoulder arthroscopy and was removed at this time. The IAPPC tip was tethered to the inferior recess of the shoulder capsule. Although the IAPPC tip was not causing mechanical irritation to the articular surfaces, extensive grade 3 to 4 chondral damage of the anterior glenoid and anterior humeral head was observed during the IAPPC tip removal procedure. The IAPPC tip fragments in case 16 were discovered approximately 3 years later at the time of a humeral head–resurfacing procedure and were subsequently removed (as described previously).

Of the 18 patients, 14 underwent a second shoulder arthroscopy once a diagnosis of chondrolysis was suspected or established based on shoulder radiographs and clinical examinations. In all 14 cases, arthroscopic evaluation confirmed chondral changes consistent with chondrolysis. None of the 14 cases had evidence of suture anchor failure or mechanical irritation from the suture anchors. In addition, 5 patients received a humeral head–resurfacing procedure, 4 of whom had undergone the aforementioned second arthroscopy, as well as 1 patient who had not.

Several patients had physically demanding occupations, whereas many others were high-level athletes competing at the collegiate or university level. The pain and disability caused by the chondrolysis made it difficult or impossible for patients to return to their preoperative functional status.

A chart review of the 2 surgeons’ practices showed that there were 113 primary arthroscopic labral stabi-
Table 2. Summary of Use of IAPPcs and Development of Chondrolysis

<table>
<thead>
<tr>
<th>Surgeon</th>
<th>Chondrolysis</th>
<th>No Chondrolysis</th>
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<td>Surgeon A</td>
<td>Surgeon B</td>
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<td>9</td>
</tr>
<tr>
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</tr>
<tr>
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<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>8</td>
<td>10</td>
</tr>
</tbody>
</table>

NOTE. Surgeon B had 1 patient exposed to a low-flow IAPPC at index surgery and then a high-flow IAPPC at repeat arthroscopy. This patient has been included in the high-flow group. Surgeon B also had 2 patients exposed to a high-flow IAPPC at index surgery and then another high-flow IAPPC at repeat arthroscopy. These patients are included in the high-flow group. There were 3 patients (2 from surgeon A and 1 from surgeon B) who did have pain pumps inserted, but they were placed subacromially. These patients are not included in the data table.

DISCUSSION

Chondrolysis has been described in many different joints including the hip, knee, ankle, and shoulder. The cause of chondrolysis has not been well defined, but it is likely due to the introduction of a noxious stimulus. This stimulus may present in many different forms including heat, pressure, mechanical irritation, or a toxic substance. Exposure of articular surfaces to any of the aforementioned harmful substances or states may induce rapid death of chondrocytes and subsequently result in dissolution of the cartilage matrix.

The hip joint historically has been most commonly associated with chondrolysis especially in the pediatric literature. There have been several reports after slipped capital femoral epiphysis, with some authors attributing intra-articular pin penetration as the cause. Chondrolysis of the hip was reported in a 49-year-old after intra-articular leakage of methylmethacrylate bone cement. The exothermic reaction of methylmethacrylate, suggested as the cause by the authors, highlights the potential for thermal energy to be chondrotoxic. Chlorhexidine-induced chondrolysis of the knee joint has been documented after irrigation during arthroscopic surgery. Chondrolysis of the glenohumeral joint has been reported with increasing frequency. There have been case reports of glenohumeral chondrolysis after the use of gentian violet in rotator cuff tear surgery. Moreover, several case reports of glenohumeral chondrolysis after arthroscopic shoulder surgery have recently been published. The majority of these cases involve the use of thermal energy. Good et al. have shown that the use of a thermal probe can heat glenohumeral joint fluid to temperatures high enough to cause significant chondrocyte death. Other causes of chondrolysis include infection, trauma, prolonged immobilization, and burns.

There has been increasing concern that a continuous infusion of bupivacaine through an IAPPC may be another cause of chondrolysis. Intra-articular bupivacaine and the use of IAPPcs have been established as useful adjuncts in providing analgesia after arthroscopic shoulder surgery. Although the effectiveness of these modalities has been well documented, literature regarding their safety is scant. Recent reports have detailed the chondrotoxic effects of bupivacaine and bupivacaine with epinephrine. Dogan et al. documented histopathologic changes in rabbit knee articular cartilage after exposure to 0.5% bupivacaine. These changes included inflammatory infiltration of articular cartilage and synovium, as well as (mild) synovial membrane cell hyperplasia and hypertrophy. A study by Chu et al. showed that exposure of bovine articular chondrocytes (in vitro as well as within intact articular cartilage) to 0.5% bupivacaine solution for 15 to 30 minutes was toxic to the chondrocytes and resulted in significant chondrocyte death.
Using a rabbit shoulder model, Gomoll et al.\textsuperscript{29} showed decreased cell viability as well as significant histopathologic and metabolic changes in articular cartilage chondrocytes subjected to continuous intra-articular infusion of 0.25% bupivacaine (both with and without epinephrine).

In addition to the studies conducted on bovine and rabbit chondrocytes, recent studies have investigated the effects of local anesthetics on human chondrocytes in vitro.\textsuperscript{30,31} Dragoo et al.\textsuperscript{30} examined the effects of 1% lidocaine, 0.25% bupivacaine, and 0.5% bupivacaine, all with and without epinephrine, on human articular cartilage cells. Chondrocytes isolated from the peripheral cartilage of femoral condyles at the time of knee arthroplasty were perfused with the aforementioned local anesthetics for 24, 48, and 72 hours and were compared with controls. The authors discovered that there was no significant difference in chondrocyte viability in those cells exposed to 0.25% and 0.5% bupivacaine without epinephrine for 24 and 48 hours when compared with controls. However, 0.5% bupivacaine without epinephrine was toxic to articular chondrocytes when infused for 72 hours. Furthermore, all local anesthetics containing epinephrine produced significant chondrocyte death at all time periods. The authors did make an important observation that the pH of those anesthetics containing epinephrine was between 4.0 and 4.5, as compared with 5.0 to 6.5 for those anesthetics without epinephrine. The acidic environment created with the use of epinephrine may be chondrotoxic and serve as a contributing mechanism to the increase in cell death observed; however, further investigation is required in this regard.

Piper and Kim\textsuperscript{31} also showed the chondrotoxic effects of bupivacaine. Human articular cartilage was isolated from the femoral head and tibial plateau of 5 patients. Both full-thickness cartilage explants and cultured chondrocytes were treated with 0.9% normal saline solution, 0.5% ropivacaine, or 0.5% bupivacaine for 30 minutes; chondrocyte viability was assessed after 24 hours. The authors found a significant decrease in chondrocyte viability in the bupivacaine-treated group in both full-thickness cartilage explants (78% cell viability vs 95.8% viability for normal saline solution) and cultured chondrocytes (37.4% of the value in the normal saline solution–treated group). Ropivacaine was also found to be toxic to chondrocytes in culture; however, there was no difference in chondrocyte viability in the full-thickness cartilage explants between the ropivacaine-treated and normal saline solution–treated groups. The authors noted that the full-thickness cartilage explants mimic the actual clinical situation, where intra-articular injection is given in vivo, wherein chondrocytes are not directly exposed to local anesthetic because of the intact extracellular matrix. They thus suggest that ropivacaine may be a safer alternative to bupivacaine for intra-articular analgesia.

To date, there have been 5 published reports on the chondrotoxic effects of bupivacaine and IAPPCs in human subjects in vivo.\textsuperscript{13-15,32,33} Three of these involve the glenohumeral joint,\textsuperscript{13-15} and more recently, reports involving the knee joint have been published.\textsuperscript{32,33} Hansen et al.\textsuperscript{13} have described the development of chondrolysis in 12 shoulders (10 patients) undergoing shoulder arthroscopy. They conducted a review of these patients’ perioperative information and discovered that there were 4 common factors among these 12 cases of chondrolysis; only the use of an IAPPC was a new factor. Furthermore, they reviewed 152 patients with shoulder arthroscopies (during the same time period) and found that 121 patients received IAPPCs. Of these, 104 had their catheters placed extra-articularly, and none had chondrolysis develop. Chondrolysis developed in 12 shoulders among the 17 patients (19 shoulders) whose catheters were placed intra-articularly, for an incidence rate of 63%. Furthermore, 13 patients had the same procedure as those with IAPPCs placed intra-articularly but without the use of the catheter, and none had chondrolysis develop. The authors have concluded that a significant association between the use of IAPPCs and the development of chondrolysis exists and have thus recommended that the use of IAPPCs should be avoided.

Greis et al.\textsuperscript{14} have also described the development of glenohumeral chondrolysis in 2 patients undergoing arthroscopic shoulder surgery. Both patients had bilateral capsular plication procedures for pain and instability, and both had bilateral IAPPCs inserted, which infused 0.5% bupivacaine without epinephrine at a rate of 4 mL/h for 48 hours postoperatively. Chondrolysis subsequently developed in all 4 shoulders as confirmed by symptoms of pain and decreased range of motion, radiographs and MRI (showing joint space narrowing and degenerative changes), and repeat arthroscopic procedures (showing extensive loss of articular cartilage). Furthermore, 3 of the 4 shoulders were exposed to a second dose of bupivacaine postoperatively at the time of these repeat procedures. Ultimately, the severity of chondrolysis in these 3 shoulders progressed to the point that they required treatment with a hemiarthroplasty. Although the authors cannot specifically attribute the continuous infusion of bupivacaine postoperatively as the cause of the
extensive destruction of articular cartilage, they do conclude that the use of an IAPPC was a common factor in their patients, and they thus believe it was a probable causative factor in the development of glenohumeral chondrolysis. Their study also outlines the devastating effects of chondrolysis, because their patients had significant pain that interfered with their daily activities and ultimately required arthroplasty procedures at very young ages.

Saltzman et al.\textsuperscript{15} reported on the case of a 37-year-old law enforcement officer in whom chondrolysis developed after bilateral arthroscopic shoulder procedures. Importantly, chondrolysis only developed on the side that had a functioning pain pump catheter inserted postoperatively. The 2 published reports involving the knee joint link the infusion of bupivacaine and bupivacaine with epinephrine infused postoperatively after arthroscopic anterior cruciate ligament reconstruction to the development of chondrolysis.\textsuperscript{32,33}

Our study examines 18 patients in whom chondrolysis has developed after arthroscopic glenohumeral labral stabilization surgery. All of the patients received postoperative infusion of bupivacaine with epinephrine through an IAPPC, and chondrolysis developed in all of them. The mean time to diagnosis was approximately 9.5 months (range, 2 to 27.5 months), although almost all patients began having symptoms well before this, usually within a few months of their index surgery. None of these patients had thermal energy, a known cause of chondrolysis, as part of their procedure. The 2 orthopaedic surgeons discontinued use of the IAPPCs in January 2006. There have not been any new cases of glenohumeral chondrolysis since the surgeons stopped using the IAPPCs. We suspect that the development of glenohumeral chondrolysis is associated with the use of an IAPPC.

The basic science studies showing the chondrotoxicity of bupivacaine, the recent case reports linking the postoperative infusion of bupivacaine and bupivacaine with epinephrine to the development of chondrolysis, and our own experiences with the 18 patients led us to perform a review of all patients who had arthroscopic shoulder surgery during the same time period as our chondrolysis patients, to determine the rate of use of IAPPCs and to ascertain the incidence of the development of chondrolysis in relation to the use of an IAPPC. We discovered that chondrolysis developed in 40% of patients who had an IAPPC eluting 0.5% bupivacaine with 1:200,000 epinephrine. Moreover, the relation between bupivacaine with epinephrine and the development of chondrolysis does appear to be dose dependent. Chondrolysis developed in half of all patients who received a high-flow IAPPC (with a total dose of approximately 275 mL), while this complication only developed in 17% of patients with a low-flow IAPPC (with a total dose of approximately 100 mL). The length of delivery may also play a role. Dragoo et al.\textsuperscript{30} have documented the chondrotoxic effects of bupivacaine administered for prolonged periods.

There does not appear to be a correlation between one-time injections of bupivacaine and the development of chondrolysis. The majority of our patients (>85%) received an intra-articular bolus of either 0.25% or 0.5% bupivacaine with 1:200,000 epinephrine (between 10 and 60 mL); however, chondrolysis only developed in those with a continuous infusion. In addition, 4 patients with chondrolysis did not receive a bolus injection. One-time injections had been used by the 2 surgeons before the institution of pain pumps in their surgical practice, and no cases of chondrolysis had occurred at that time. To our knowledge, there have not been any reports in the literature of chondrolysis developing from one-time intra-articular injections.

Hansen et al.\textsuperscript{13} determined the incidence of chondrolysis associated with the use of an IAPPC to be 63%. We calculated our overall incidence rate to be 40%. This figure includes patients with both high-flow and low-flow IAPPCs, as well as the 1 patient who had an IAPPC but whose flow rate was undetermined. It should be noted, however, that in the study by Hansen et al., the IAPPCs were of 1 type: they were filled with 250 mL of 0.25% bupivacaine with epinephrine and infused at a rate of 4.16 mL/h. These IAPPC specifications correlate with our high-flow IAPPCs, which had a fill volume of 275 mL and a flow rate of 5 mL/h. With this in mind, our incidence rates do appear comparable.

There have been reports of articular cartilage damage in the shoulder due to mechanical wear from an intra-articular suture anchor and tacks.\textsuperscript{8-12} The majority of these cases involve loosening of the implant and subsequent migration into the intra-articular space.\textsuperscript{8-10} The location and pattern of chondral wear in these patients corresponded to the areas of the articular surface in direct contact with the implant. Moreover, in those studies that mentioned the joint space specifically, the overall joint space was preserved.\textsuperscript{8} Improperly placed implants were also implicated. Kaar et al.\textsuperscript{9} reported that implants incorrectly placed in an extraosseous manner cause damage by 2 mechanisms, either direct protrusion into the intra-articular space or
improper placement resulting in implant failure, which thus results in loosening and migration into the intra-articular space. They also reported that when more than 3 anchors were used, at least 1 was incorrectly placed in an extraosseous manner. Rhee et al.\textsuperscript{11} also reported on 5 cases of improperly placed metallic suture anchors; prominence of the implant tips resulted in mechanical damage to the humeral articular cartilage surface. Freehill et al.\textsuperscript{12} found that in 10 of 52 patients with bioabsorbable poly-L-lactic acid tacks, the tacks degraded and fragmented, which may have led to erosion of articular cartilage. Synovitis and foreign body reactions to the implant fragments also developed in these patients.

There were 3 different type of implants used in our patients, including both metal and bioabsorbable (Table 1). We consider it unlikely that the suture anchors or tacks used in these patients contributed to the development of chondrolysis. Radiographic evaluation of our patients showed joint space narrowing, a phenomenon not seen in the case reports involving articular damage from implants. In addition, radiographs did not show any evidence of prominent or misplaced implants in the 8 cases with metallic anchors. Intra-articular findings at repeat arthroscopy (14 patients) or arthroscopy (5 patients) (at the time of a humeral head–resurfacing operation) showed that the chondral wear pattern was too extensive to be explained by local suture anchor or tack abrasion. There were no loose implants, and none appeared prominent. The implants all appeared to be appropriately placed. Furthermore, the surgeons in our series only used a maximum of 3 implants, lessening the likelihood of incorrect placement. Specifically with regard to the bioabsorbable implants, there were no implant fragments identified, and only a minority had synovitis present. Furthermore, the implants used in our patients with chondrolysis were also used in the patients in whom chondrolysis did not develop, both those who received IAPPCs and those who did not. These suture anchors have also been used by the same orthopaedic surgeon for over a year, whereas both surgeons have used the tacks for several years; many patients have received these anchors or tacks and have not had chondrolysis develop.

There are some limitations to this study. First, not all patients had a complete workup for infection. An infective process could very well cause significant joint destruction and symptoms similar to those seen in our patients. However, we believe that it is very unlikely that infection was the cause in any of our cases. Our patients did not fit the clinical (and radiographic) picture of patients with a septic joint, and any patients who did undergo a complete workup were found to have completely normal laboratory results. Furthermore, by the time the final few cases had presented with symptoms of chondrolysis, we were already highly suspicious of the IAPPCs eluting bupivacaine as the cause. These patients underwent repeat arthroscopic procedures within 2 to 3 months after their index surgery. Intraoperative findings and tissue cultures did not show any signs of an infective process occurring. Second, this is a retrospective case series, a descriptive type of study. Our case series shows that shoulder chondrolysis may be the result of postoperative infusion of bupivacaine with epinephrine through an IAPPC. We thus caution against the use of a continuous infusion of bupivacaine or bupivacaine with epinephrine (through an IAPPC) into a joint with intact articular cartilage.

**CONCLUSIONS**

We report on 18 patients in whom chondrolysis developed after arthroscopic labral repair surgery. All patients received an IAPPC postoperatively, and all had clinical and radiographic evidence of rapid articular cartilage destruction. Chondrolysis developed in 16 of 32 patients receiving high-flow IAPPCs and 2 of 12 patients receiving low-flow IAPPCs. Although we cannot establish a causal link, the development of glenohumeral chondrolysis may be related to the intra-articular infusion of bupivacaine with epinephrine postoperatively. We thus caution against the use of IAPPCs.

**REFERENCES**


