Risk Factors for Chondrolysis of the Glenohumeral Joint

A Study of Three Hundred and Seventy-five Shoulder Arthroscopic Procedures in the Practice of an Individual Community Surgeon

By Brett P. Wiater, MD, Moni Blazej Neradilek, MS, Nayak L. Polissar, PhD, and Frederick A. Matsen III, MD

Investigation performed at the University of Washington, Seattle, Washington

Background: Glenohumeral chondrolysis is a complication of arthroscopic shoulder surgery characterized by the dissolution of the articular cartilage of the glenoid and the humeral head. An analysis of 375 intra-articular shoulder arthroscopic surgical procedures by an individual community orthopaedic surgeon was performed to explore which factors or combinations of factors might be associated with glenohumeral chondrolysis.

Methods: The occurrence of chondrolysis was correlated with several demographic and surgical variables with use of hazard ratios from Cox proportional hazards models and Kaplan-Meier survivorship curves. Sensitivity analysis was used to examine the effect of two different definitions of the date of the onset of chondrolysis.

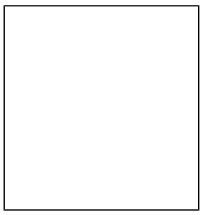
Results: In this cohort, each case of documented chondrolysis was associated with the intra-articular post-arthroscopic infusion of a local anesthetic, either Marcaine (bupivacaine) or lidocaine. In an analysis of the group that received an intra-articular postoperative infusion of a local anesthetic, the risk of chondrolysis was found to be greater for those with one or more suture anchors placed in the glenoid, for younger patients, and for those who had the surgery near the end of the ten-year study period.

Conclusions: To our knowledge, this is the first Level-II retrospective cohort study of the factors associated with the development of post-arthroscopic glenohumeral chondrolysis. In this cohort of intra-articular shoulder arthroscopic procedures, chondrolysis was observed only in cases in which either Marcaine or lidocaine had been infused into the joint during the postoperative period. Avoiding such a postoperative infusion may reduce the risk of chondrolysis.

Level of Evidence: Prognostic Level II. See Instructions to Authors for a complete description of levels of evidence.

Glenohumeral chondrolysis is a complication of arthroscopic shoulder surgery characterized by the dissolution of the articular cartilage of the glenoid and the humeral head[1-4]. The onset of chondrolysis is characteristically marked by unexpected progressive pain and loss of joint motion weeks to months following arthroscopic shoulder surgery[4]. Changes seen on radiographic and magnetic resonance imaging (MRI) include joint-space narrowing, periarticular bone edema, subchondral cysts, and a lack of osteophyte formation[4,5]. Glenohumeral chondrolysis has been reported in association with intra-articular thermal energy, intra-articular injection of radiopaque contrast medium, and postoperative infusion of a local anesthetic[2,6-23]. Shoulder arthroscopy is the second most common procedure performed by those taking Part II of the American Board of Orthopaedic Surgery certification examination[24]. The purpose of this investigation was to analyze the shoulder arthroscopic surgery practice of one community orthopaedic surgeon to identify factors or combinations of factors that might be associated with glenohumeral chondrolysis.

Disclosure: In support of their research for or preparation of this work, one or more of the authors received, in any one year, outside funding or grants of less than $10,000 from the DePuy/Douglas T. Harryman II Endowed Chair for Shoulder Research. In addition, one or more of the authors or a member of his or her immediate family received, in any one year, payments or other benefits in excess of $10,000 or a commitment or agreement to provide such benefits from a commercial entity (Jeff Wihtol Law Offices).



A commentary by William N. Levine, MD, is available at www.jbjs.org/commentary and is linked to the online version of this article.

Materials and Methods

The medical records and radiographs of patients treated with intra-articular arthroscopic shoulder surgery by one community orthopaedic surgeon from 1999 through 2008 were reviewed. These records were originally produced as a response to a court order for redacted copies of the records and radiographs for all patients on whom the surgeon had performed intra-articular arthroscopic shoulder surgery from 1999 through 2008. To ensure that we had access to unselected, complete, and unaltered copies of all of the primary source documents, we requested and received sworn affidavits from the surgeon and the lawyers transmitting the records to this effect. The surgeon and the surgeon's office personnel did not participate in any aspect of this study other than to provide the medical records. The inclusion criterion was an arthroscopic procedure in which the arthroscope had been inserted into the glenohumeral joint as a part of the procedure. The initial number of intra-articular shoulder arthroscopic procedures was 404. This number included two procedures performed prior to 1999 because the same shoulder had a second arthroscopic procedure during the decade of the study. Fifteen cases were excluded from the analysis because of described preoperative degeneration of the glenohumeral articular cartilage. Three surgical procedures were excluded because they had been performed by another surgeon and had been erroneously included in the initial cohort. Five cases were excluded because the operative report could not be located. Two cases were excluded because the patient died soon after the procedure. Four surgical procedures were excluded because they were not arthroscopic. This left 375 surgical procedures for analysis. Thirty-one repeat arthroscopic procedures were performed, with the most common revision procedures being debridement, capsulorrhaphy, cuff repair, and revision SLAP (superior labrum anterior-posterior) repair. When a shoulder had had repeat arthroscopic surgery, each procedure was considered individually and the follow-up for the prior procedure ended at the date of the subsequent surgery. Twenty-two patients had bilateral arthroscopic surgery.

Our human subjects division determined that collection of deidentified data for this study does not constitute human subjects research. Therefore, no institutional review board approval was required for this data collection. From the medical records, we documented the patient's age at the time of surgery, side of surgery, date of surgery, preoperative diagnosis, type of anesthesia, procedure performed, use and type of suture anchors, use of radiofrequency, and use and location of a postoperative local anesthetic infusion catheter with an infusion pump. We also documented the type and concentration of local anesthetic used for postoperative analgesia and whether epinephrine had been included in the infusate. We analyzed the records for the earliest evidence of unexpected shoulder pain and stiffness and for definite evidence of chondrolysis.

We defined chondrolysis as the generalized loss of glenohumeral articular cartilage documented radiographically or at subsequent surgery in a shoulder without preexisting glenohumeral degenerative changes (Figs. 1-A through 1-D). It is the generalized loss of cartilage in chondrolysis that distinguishes it from the localized loss of cartilage that may result from mechanical damage at surgery or the damage that may result from a prominent suture anchor. Chondrolysis was distinguished from osteonecrosis by the absence of the bone infarcts and collapse characteristic of osteonecrosis. Chondrolysis was distinguished from rheumatoid or septic arthritis by the absence of evidence of systemic disease, local inflammatory findings, or positive cultures.

With use of these criteria, it was established that chondrolysis had occurred after forty-nine of the surgical procedures. Two different methods were used to identify the date of onset of this condition: (1) the date of the first symptoms suggesting chondrolysis and (2) the date of the definite diagnosis of chondrolysis based on radiographic or surgical findings.

Statistical Analysis

Descriptive statistics are presented as the mean and standard deviation for continuous variables and as the number and percent of surgical procedures for categorical variables. Survival analysis was conducted to assess associations between risk factors and the risk of chondrolysis. The strength of these associations was expressed by hazard ratios estimated from Cox proportional hazards models. The 95% confidence intervals and p values for hazard ratios were based on robust (jackknife) estimates of the variances of the Cox model

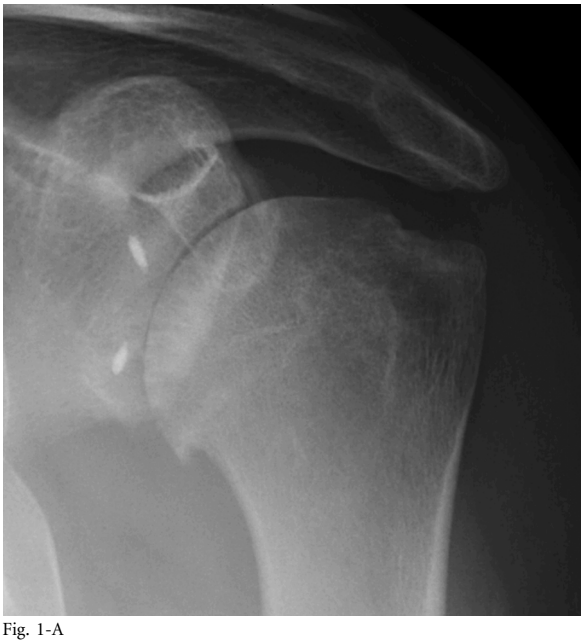


Fig. 1-A

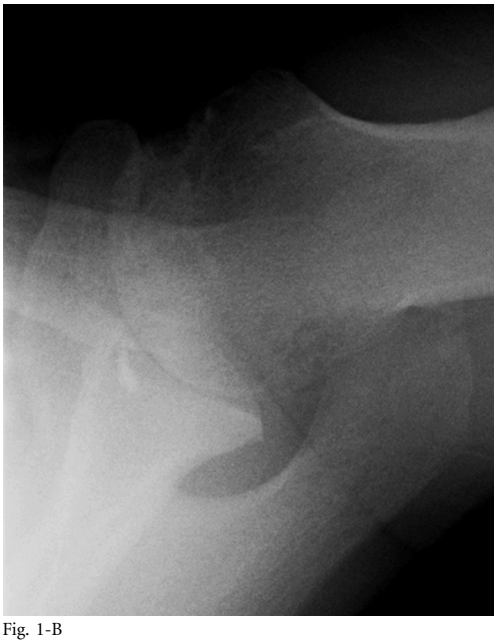


Fig. 1-B

Figs. 1-A through 1-D A forty-five-year-old physician was treated with arthroscopic Bankart repair followed by use of a pain pump for postoperative infusion of a local anesthetic. **Figs. 1-A and 1-B** Anteroposterior and axillary radiographs made four years after the procedure showing extensive loss of the joint space normally occupied by glenoid and humeral articular cartilage. The metallic suture anchors are well recessed in the glenoid bone.

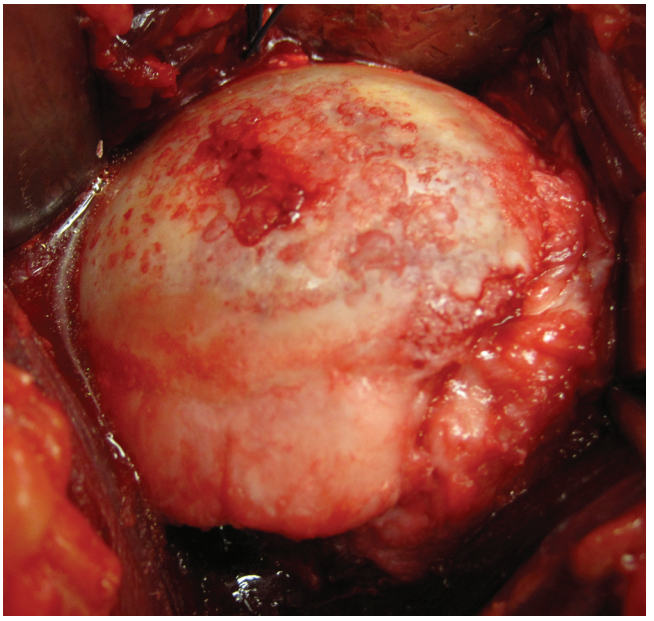


Fig. 1-C

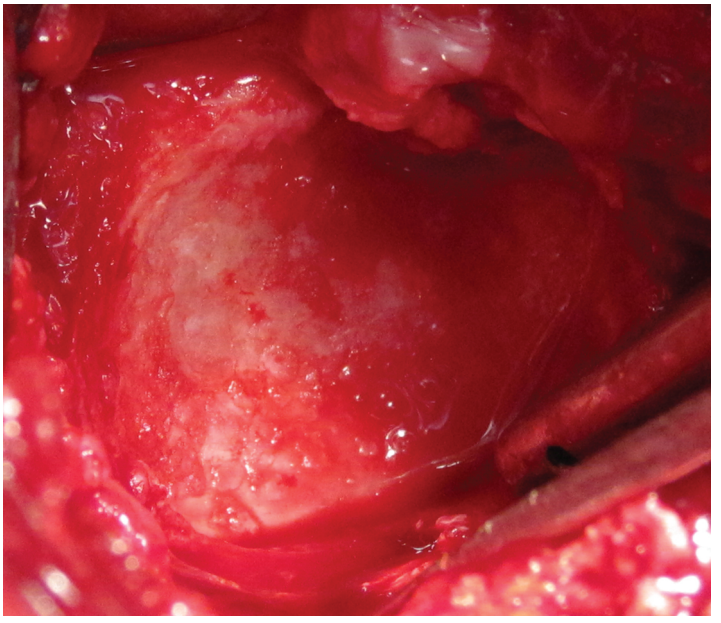


Fig. 1-D

Figs. 1-C and 1-D Surgical photographs of the humeral head and the glenoid at the time of the shoulder arthroplasty. Note the total loss of articular cartilage.

parameters, allowing for statistical dependence of multiple surgical procedures in the same patient[25]. Tests for proportionality of hazards were carried out for each Cox model to detect departures from the proportionality assumption of the model[26]. Kaplan-Meier curves were created to visually describe the proportion of chondrolysis-free shoulders in relation to the time from the surgery. This approach for data analysis was preferred over a case-control study because it enabled the inclusion of all of the data available, rather than being limited by an arbitrarily established requirement for the duration of follow-up.

Both univariate (unadjusted) and multivariate (adjusted) Cox proportional hazards models were used. Because our initial review of the data suggested that the age at, and the date of, the surgery might be important control variables, multivariate models adjusted for age and the date of surgery were fitted. Pearson correlation was used to quantify the associations between pairs of risk factors.

Sensitivity analysis was performed for both the unadjusted and the adjusted models to address the uncertainty about the date of the onset of the chondrolysis. The time of the onset of the first symptoms may underestimate the time to the onset of chondrolysis, while the date of the definitive diagnosis may occur considerably after the date of the actual clinical onset. The timing of the onset has an impact on the calculation of event rates and can potentially influence the hazard ratios. The two fits, one using the time of the onset of the first symptoms and one using the time of documentation of chondrolysis, were

TABLE I Surgical Procedure Details (N = 375 Procedures)

	No. (%)*
Arthroscopic SLAP repair	59 (16%)
Arthroscopic suture capsular plication	84 (22%)
Arthroscopic Bankart repair	40 (11%)
Arthroscopic debridement	137 (37%)
Arthroscopic cuff repair	163 (43%)
Arthroscopic decompression/acromioplasty	122 (33%)
Arthroscopic capsular release	11 (3%)
Arthroscopic biceps tenodesis	18 (5%)
Arthroscopic distal clavicular excision	126 (34%)
One or more sutures anchor in glenoid	92 (25%)
One or more suture anchors in humerus	8 (2%)
Metal anchors	216 (58%)
Bioabsorbable anchors	126 (34%)
Anesthesia	
General without scalene block	247 (66%)
General with scalene block	122 (33%)
Scalene block alone	5 (1%)
Unknown	1 (0%)
Radiofrequency inside joint	77 (21%)
Radiofrequency outside joint	140 (37%)
Pain pump	204 (55%)
Pain pump inside joint	109 (29%)
Pain pump outside joint	137 (37%)
Marcaine (0.5%)	48 (14%)
Marcaine (0.25%)	10 (3%)
Lidocaine	122 (35%)
Epinephrine	125 (36%)
Pump make	
DonJoy (Vista, California)	10 (3%)
I-Flow (Lake Forest, California)	46 (12%)
Stryker (Mahwah, New Jersey)	22 (6%)
Zimmer (Warsaw, Indiana)	8 (2%)
Not applicable or available	289 (77%)
Biceps tenotomy	134 (36%)
Thermal capsulorrhaphy	18 (5%)
Open surgery	127 (34%)
With biceps tenodesis	97 (26%)
Without biceps tenodesis	30 (8%)
Surgery not open	248 (66%)
Pump volume† *(mL)*	268 ± 96
Surgery duration *(min)*	131 ± 53

*With the exception of the last two values, which are given as the mean and standard deviation. The percentages in the column are based on the data available for the specific variable (i.e., N can be <375).
†Applies only to patients treated with a pump.

checked for consistency by comparing their hazard ratios and the corresponding 95% confidence intervals. For the models presented in the Results section, the date of diagnosis (not the date of symptom onset) was used as the date of chondrolysis onset.

Finally, a forward selection procedure was used to build a multivariate model predictive of chondrolysis risk[27]. The patient's age at, and the date of, the surgery were forced into the model. Other risk factors had to have a p value of <0.2 in both the age-adjusted and surgery-date-adjusted models in the sensitivity analysis to be considered for addition into the model. A p value of <0.05 was used as the criterion for entry into the model. In the variable selection, the date of diagnosis was used as the date of chondrolysis onset.

A p value of <0.05 was used to define significance.

Source of Funding

The DePuy/Douglas T. Harryman II Endowed Chair for Shoulder Research funded this study.

Results

A total of 375 surgical procedures in 322 patients were included in the study. One hundred and thirty-five (36%) of these operations were performed in women. The mean age at surgery (and standard deviation) was 50 ± 14 years (range, sixteen to eighty-seven years). A total of 238 surgical procedures (63%) were done on the right shoulder. The surgical procedures are listed in Table I.

Forty-nine surgical procedures were complicated by chondrolysis, with over half of the cases diagnosed within the first eighteen months after surgery (Fig. 2). Each of the forty-nine cases of chondrolysis was associated with postoperative intra-articular infusion of a local anesthetic, either Marcaine (bupivacaine) or lidocaine ($p < 0.001$, Cox regression). There

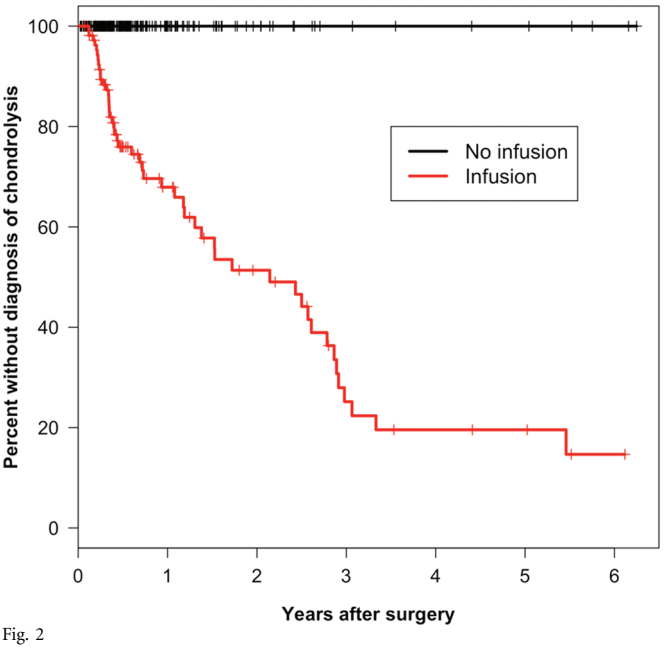


Fig. 2

Kaplan-Meier curves showing the estimated percentages of shoulders with no post-arthroscopic infusion (upper line) and with post-arthroscopic infusion of a local anesthetic (lower line) that did not have a diagnosis of chondrolysis.

were differences with regard to several patient and surgery characteristics between the procedures that were and those that were not followed by an intra-articular infusion (see Appendix). As no cases of chondrolysis were diagnosed following procedures without post-arthroscopic infusion of a local anesthetic, the remainder of the statistical analysis focused on cofactors for chondrolysis among the patients with intra-articular post-arthroscopic infusion of a local anesthetic.

Figure 3, *a*, illustrates the significant association between the date of surgery and the rate of chondrolysis per person-year. The rate of chondrolysis increased between 2000 and 2004 and remained high in 2005 and 2006. This significant trend suggested that the date of surgery was an important control variable to be included along with age in the adjusted model.

The results of the unadjusted and adjusted Cox regression models for chondrolysis are displayed in Table II. In the adjusted models, the following risk factors were found to be associated with an increased likelihood of chondrolysis developing after surgical procedures associated with the use of postoperative intra-articular infusion of a local anesthetic: arthroscopic Bankart repair, arthroscopic debridement, one or more suture anchors in the glenoid, and surgery duration. None of the six shoulders that had had infusion of 0.25% Marcaine was diagnosed as having chondrolysis; therefore, the use of 0.25% Marcaine (as opposed to 0.5% Marcaine or lidocaine) was associated with a significantly *decreased* likelihood of chondrolysis in the adjusted models.

Several important differences were noted between the unadjusted and adjusted models. When we controlled for the patient's age and the surgery date, the significant unadjusted hazard ratios for suture capsular plication, decompression/acromioplasty, arthroscopic distal clavicular excision, radiofrequency outside the joint, infusion outside the joint, and lidocaine use changed substantially—i.e., became closer to the null hazard ratio of 1.0 and were no longer significant. On the other hand, the non-significant unadjusted hazard ratios for arthroscopic debridement, one or more suture anchors in the glenoid, and surgery duration moved further away from the null hazard ratio of 1.0 and became significant. This change toward or away from the null hypothesis points to the close relationship of age and/or date of surgery with the type of diagnosis in this data set. Older age was correlated with a higher probability of arthroscopic decompression/acromioplasty ($r = 0.40$), arthroscopic debridement ($r = 0.19$), arthroscopic distal clavicular excision ($r = 0.26$), anesthesia with a scalene block

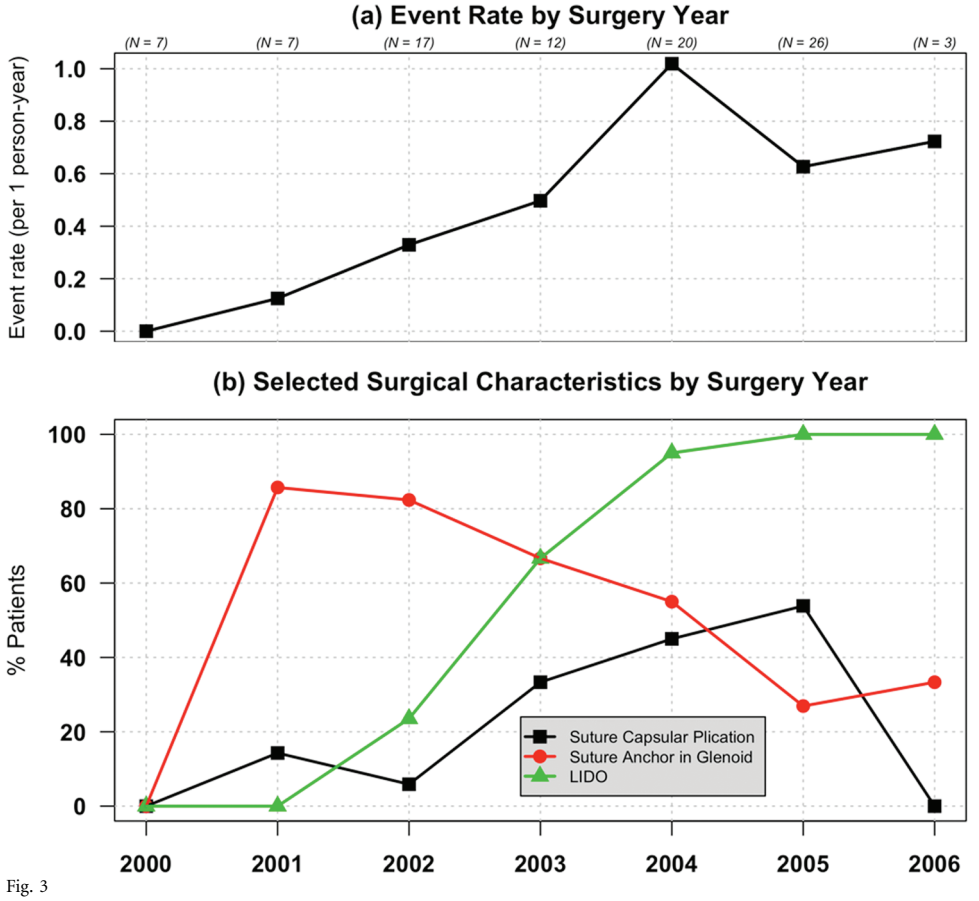


Fig. 3

Chondrolysis event rate (a) and prevalence of selected risk factors (b) by calendar year for patients who had had post-arthroscopic infusion of a local anesthetic. N = 92 surgical procedures. The analysis was limited to patients for whom data for all risk factors were available. LIDO = lidocaine.

TABLE II Unadjusted and Adjusted Cox Regression Models for Chondrolysis*

	Unadjusted Model			Model Adjusted for Age and Date of Surgery		
	No.	Hazard Ratio (95% Confidence Interval)	P Value	No.	Hazard Ratio (95% Confidence Interval)	P Value
Arthroscopic SLAP repair	109	0.86 (0.47-1.58)	0.6	108	1.33 (0.75-2.35)	0.3
Arthroscopic suture capsular plication	109	2.17 (1.25-3.77)	0.006	108	0.98 (0.48-2.03)	1
Arthroscopic Bankart repair	109	2.60 (1.32-5.13)	0.006	108	2.76 (1.47-5.17)	0.002
Arthroscopic debridement	109	1.29 (0.74-2.26)	0.4	108	1.77 (1.04-3.00)	0.03
Arthroscopic cuff repair	109	0.81 (0.43-1.53)	0.5	108	0.92 (0.38-2.23)	0.9
Arthroscopic decompression/ acromioplasty	109	0.52 (0.27-0.98)	0.04	108	0.67 (0.34-1.31)	0.2
Arthroscopic capsular release	109	0.81 (0.23-2.83)	0.7	108	1.00 (0.38-2.65)	1
Arthroscopic biceps tenodesis	109	1.04 (0.22-4.86)	1	108	1.11 (0.26-4.79)	0.9
Arthroscopic distal clavicular excision	108	0.49 (0.24-0.98)	0.04	107	0.66 (0.31-1.39)	0.3
One or more suture anchors in glenoid	109	1.41 (0.82-2.44)	0.2	108	2.60 (1.54-4.39)	<0.001
Metal anchors	108	0.93 (0.54-1.61)	0.8	108	1.55 (0.87-2.77)	0.14
Bioabsorbable anchors	108	1.20 (0.54-2.71)	0.7	108	1.78 (0.89-3.54)	0.10
Anesthesia	108		0.6	107		0.4
General with scalene block		Ref. category			Ref. category	
General without scalene block		1.28 (0.54-3.07)	0.6		1.44 (0.63-3.28)	0.4
Scalene block alone		NA (NA)†	NA†		NA (NA)†	NA†
Radiofrequency inside joint	109	1.39 (0.83-2.32)	0.2	108	1.36 (0.80-2.31)	0.3
Radiofrequency outside joint	109	0.47 (0.26-0.82)	0.008	108	0.60 (0.32-1.12)	0.11
Pain pump outside joint	108	0.32 (0.18-0.59)	<0.001	107	0.52 (0.25-1.10)	0.09
Marcaine (0.5%)	96	0.59 (0.30-1.19)	0.14	95	1.25 (0.61-2.58)	0.5
Marcaine (0.25%)	97	0.00 (NA)‡	<0.001	96	0.00 (NA)‡	<0.001
Lidocaine	100	2.42 (1.15-5.10)	0.02	99	1.31 (0.45-3.78)	0.6
Epinephrine	96	2.10 (0.94-4.70)	0.07	96	2.36 (0.94-5.87)	0.07
Biceps tenotomy	109	1.15 (0.53-2.49)	0.7	108	1.88 (0.75-4.71)	0.2
Thermal capsulorrhaphy	109	1.09 (0.42-2.84)	0.9	108	1.67 (0.57-4.93)	0.4
Open surgery	109	0.89 (0.40-1.98)	0.8	108	1.82 (0.94-3.52)	0.08
Open surgery/biceps tenodesis	109		0.8	108		0.3
Open surgery without biceps tenodesis		Ref. category			Ref. category	
Open surgery with biceps tenodesis		9.07 (0.91-90.25)	0.06		2.03 (0.18-22.49)	0.6
Surgery not open		5.10 (0.56-46.42)	0.15		1.01 (0.09-10.86)	1
Female	109	1.51 (0.89-2.56)	0.12	108	0.99 (0.57-1.73)	1
Right side	109	1.10 (0.63-1.91)	0.7	108	0.94 (0.54-1.61)	0.8
Pump volume (per 100 mL)	95	1.10 (0.93-1.29)	0.3	95	1.24 (0.99-1.55)	0.06
Surgery duration (per 1 hour)	101	1.04 (0.72-1.49)	0.8	101	1.41 (1.07-1.86)	0.01
Age at surgery (per 10 years)	108	0.66 (0.52-0.82)	<0.001	—	—	—
Surgery date (per 1 year)	109	1.44 (1.19-1.74)	<0.001	—	—	—

*The analyses included only the procedures followed by use of an intra-articular pump. The date of diagnosis was used to define the onset of chondrolysis.
†The results are not shown because there were only two procedures with a scalene block alone. NA = not applicable. ‡The zero hazard ratio was due to no chondrolysis cases in the six patients who received 0.25% Marcaine. The 95% confidence interval was not estimated. NA = not applicable.

TABLE III Multivariate Model Selected by the Forward Selection Method (N = 85)*

	Hazard Ratio (95% Confidence Interval)	P Value
Age (per 10 years)	0.62 (0.49-0.79)	<0.001
Surgery date (per 1 year)	1.52 (1.22-1.89)	<0.001
Suture anchor in glenoid	2.77 (1.49-5.13)	0.001

*The analysis included only the procedures followed by use of an intra-articular pump.

alone (r = 0.14), radiofrequency outside the joint (r = 0.32), and a pain pump outside the joint (r = 0.35) and with a lower probability of arthroscopic suture capsular plication (r = −0.22) and one or more suture anchors in the glenoid (r = −0.14). More recent surgical procedures were associated with a higher probability of arthroscopic suture capsular plication (r = 0.40) (Fig. 3, *b*) and lidocaine use (r = 0.81) and with a lower probability of one or more suture anchors in the glenoid (r = −0.20) and a shorter surgery duration (r = −0.21).

The sensitivity analysis addressed the two different definitions of chondrolysis onset (the date of the onset of symptoms versus the date of the definitive diagnosis) and showed consistent results with regard to the unadjusted and adjusted values for the two definitions. Details of this analysis can be found in the Appendix. Twelve risk factors had a p value of <0.2 in the age-adjusted and surgery-date-adjusted model (consistently for both definitions of chondrolysis onset) and were considered for inclusion in the multivariate predictive model. They included Bankart repair, arthroscopic debridement, one or more suture anchors in the glenoid, metal anchors, bioabsorbable anchors, radiofrequency outside the joint, a pain pump outside the joint, use of epinephrine, biceps tenotomy, open surgery, pump volume, and surgery duration. The variable 0.25% Marcaine, which was highly significant, was not considered in the predictive model building because 0.25% Marcaine was used after only six procedures, and none were followed by the development of chondrolysis. Among the eleven other risk factors considered for inclusion, the only one added by the forward selection procedure was one or more suture anchors in the glenoid. The final predictive model is presented in Table III. Younger age, later surgical procedure, and one or more suture anchors in the glenoid were independently and significantly associated with a higher risk of chondrolysis when the date of the definitive diagnosis was used as the date of the chondrolysis onset. When the date of the first postoperative symptoms defined the date of the chondrolysis onset, the final model included the same variables (age, date of surgery, and one or more suture anchors in the glenoid) and pump volume (hazard ratio = 1.33 per 100 mL; p = 0.04). When an interaction between one or more suture anchors in the glenoid and capsular plication was added to the multivariate model shown in Table III, we found a differential effect of one or more suture anchors in the glenoid depending on the presence of capsular plication (p = 0.01 for the interaction). On the basis of the model, one or more suture anchors in the glenoid was associated with a mildly elevated risk among those without capsular plication (hazard ratio = 1.58, 95% confidence interval = 0.64 to 3.90) while it was associated with a highly elevated risk among those with capsular plication (hazard ratio = 9.30, 95% confidence interval = 3.31 to 26.17).

Discussion

The purpose of this study was to investigate a cohort of surgical procedures performed by an individual community surgeon to determine the factors associated with the development of glenohumeral chondrolysis. Of the 375 shoulder arthroscopic procedures, forty-nine (13%) were followed by the development of chondrolysis, and a postoperative intra-articular infusion of a local anesthetic, either Marcaine or lidocaine, had been used in each case in which chondrolysis developed. Analysis of the procedures followed by the intra-articular infusion of a local anesthetic showed younger patient age (hazard ratio = 1.52 per ten-year decrease), suture capsular plication (hazard ratio = 2.17), Bankart repair (hazard ratio = 2.60), the use of lidocaine (hazard ratio = 2.42), and the date of surgery (hazard ratio = 1.44 per year) to be associated with an increased risk of identified chondrolysis. Distal clavicular excision (hazard ratio = 0.49), arthroscopic decompression/acromioplasty (hazard ratio = 0.52), extra-articular radiofrequency (hazard ratio = 0.47), extra-articular infusion (hazard ratio = 0.32), and the use of 0.25% Marcaine were all associated with a decreased risk of chondrolysis. After we had adjusted for age at, and the date of, surgery, we still observed a significant effect of Bankart repair (hazard ratio = 2.76) and 0.25% Marcaine. Use of epinephrine, which was a marginally significant factor in the unadjusted analysis, was also marginally significant after the age and date-of-surgery adjustment (hazard ratio = 2.36). Several risk factors became significant in the adjusted analysis: arthroscopic debridement (hazard ratio = 1.77), one or more suture anchors in the glenoid (hazard ratio = 2.60), and surgery duration (hazard ratio = 1.41 per one hour).

The differences between the adjusted and unadjusted models reflected association of some of the risk factors with age or the date of surgery, or both. The date of surgery was chosen as a control variable because it likely captures some as yet undetermined factors related to the risk of chondrolysis. The increase in chondrolysis rates over time (Fig. 3) could possibly be attributed to the increased awareness of and surveillance for chondrolysis cases in later years or to the use of more efficient pumps for the administration of the local anesthetics at higher volumes and flow rates. The observation that chondrolysis was not diagnosed in cases in which 0.25% Marcaine had been used but was observed in those with infusion of 0.5% Marcaine suggests the possibility of a dose effect in the pathogenesis of this condition. However, neither of these factors could be explored in this cohort because insufficient data were available.

While the adjusted hazard ratios often suggested a weaker effect of the risk factors than the unadjusted hazard ratios, the impact of these factors on the risk of chondrolysis cannot be excluded (as expressed by the typically wide 95% confidence intervals for the adjusted hazard ratios). An example of such a risk factor is the use of lidocaine. The age-adjusted and date-of-surgery-adjusted hazard ratio for lidocaine was 1.31, a much smaller value compared with the hazard ratio of 2.42 derived from the unadjusted analysis. However, the confidence interval for the adjusted hazard ratio for lidocaine was 0.45 to 3.78, indicating a rather wide range of plausible hazard ratios.

The dramatic drop in the hazard ratio for lidocaine between the unadjusted and adjusted analyses can be attributed to (1) a change in the use of lidocaine over time and (2) confounding by the date of surgery (and unmeasured variables that the surgery date likely captures). While lidocaine was not used for the intra-articular infusion of a local anesthetic after any of the surgical procedures done in 2000 and 2001, this practice rapidly changed, and since 2005 lidocaine was used whenever intra-articular infusion of a local anesthetic was employed following arthroscopic shoulder surgery (Fig. 3, *b*). As a result, the unadjusted hazard ratio of 2.42 for lidocaine reflects not only some possible true effect of lidocaine but also the effect of other factors that may be related to the date of surgery. The adjusted hazard ratio of 1.31 for lidocaine was similar to the hazard ratio of 1.34 estimated for procedures performed between 2002 and 2004—the only period when arthroscopic procedures were done both with and without lidocaine. This result supports the idea that lidocaine may not have as strong an effect as indicated by the unadjusted analysis. Again, the 95% confidence interval for the lidocaine hazard ratio in the period between 2002 and 2004 was 0.62 to 2.92, a range that includes both protective and deleterious effects. Thus, we cannot exclude the possibility of a lidocaine effect on chondrolysis risk.

The predictive model building showed that, aside from age and surgery date, one or more suture anchors in the glenoid was the only other risk factor with an independent effect on chondrolysis risk. Specifically, when age and the date of surgery were forced into the multivariate model, one or more suture anchors in the glenoid (hazard ratio = 2.77) was the only variable to be selected for addition into the multivariate model by a forward procedure. This result confirms that one or more suture anchors in the glenoid is a very strong predictor of a higher chondrolysis risk among shoulders that receive a post-arthroscopic infusion of a local anesthetic. There may be other independent risk factors for the risk of chondrolysis, but our data do not provide sufficient evidence to support this. We found that the effect of one or more suture anchors in the glenoid was significantly modified by the presence or absence of capsular plication. The risk associated with one or more suture anchors was only mildly higher in the absence of capsular plication (hazard ratio = 1.58) but was highly elevated in the presence of capsular plication (hazard ratio = 9.30).

Multiple in vitro animal and human studies as well as in vivo animal studies have shown local anesthetics, including ropivacaine, lidocaine, and bupivacaine, to be cytotoxic to chondrocytes[28-35]. Recent in vitro data has shown that chondrotoxicity of lidocaine or bupivacaine is both time and dose-dependent[28,30,33,36]. Of the clinical cases of post-arthroscopic glenohumeral chondrolysis reported to date, approximately 60% have been associated with local anesthetic infusion and approximately 30% have been associated with intra-articular use of radiofrequency energy[1,3,6,7,9-12,15,16,18,19,21-23].

The results of this investigation need to be viewed in light of certain limitations. This was not a prospective study. However, we were able to examine all of the operative records and the records in the surgeon's office for the procedures over the time period of the study. Many of the risk factors were related to each other, and the effect of individual risk factors (particularly the use of lidocaine) was difficult to determine with certainty. The fact that the observed substantial increase in chondrolysis rates over time could not be attributed to variables in the data set suggests that this increase is related to variables that were not measured in this study. While long-term follow-up data were not available for many of these patients, the survival analysis appropriately handled the different follow-up times for the individual procedures. Our data did not provide an exact date of chondrolysis onset. Two surrogate dates were used instead: the date of the first postoperative symptoms and the date of the definitive diagnosis of chondrolysis. It seems reasonable that, for most patients, the true chondrolysis onset would be bounded by these two dates. A sensitivity analysis was performed to examine the effect of the uncertainty about the exact timing of the onset of chondrolysis by comparing the results derived with use of these two surrogate dates for chondrolysis onset. The conclusions of the study were robust under this sensitivity analysis. These data reflect the experience of only one community surgeon and therefore may not apply to other practices. While we thought that all of the procedures performed by this surgeon during the period of study had been included, it is possible that some were omitted. Finally, we recognize that the dose of local anesthetic and the time of exposure may be important determinants of the response of cartilage to the post-arthroscopic infusion of a local anesthetic and that these quantities may be affected by the rate of infusion, the volume of infusion, continuous versus bolus infusion, and the integrity of the capsule. We were not able to evaluate the effects of these variables on the risk of chondrolysis.

In spite of these limitations, this description of forty-nine new cases of chondrolysis represents one of the largest reports of this complication after arthroscopic surgery. This study also represents the first attempt to correlate the risk of chondrolysis not only with the postoperative infusion of local anesthetic and intra-articular radiofrequency, but also with combinations of factors, including patient demographics, diagnosis, surgical procedure, date of surgery, and type of local anesthetic used.

In conclusion, to our knowledge, this is the first retrospective cohort (Level-II) study of the factors associated with the development of post-arthroscopic glenohumeral chondrolysis. All of the documented cases of chondrolysis were associated with

the intra-articular post-arthroscopic infusion of a local anesthetic. In the analysis of the arthroscopic procedures that were followed by the infusion of a local anesthetic, the risk of chondrolysis was found to be greater for patients with one or more suture anchors in the glenoid, for younger patients, and for those who had the surgery near the end of the study period. In this cohort of shoulder arthroscopic procedures, chondrolysis was not observed in the absence of postoperative infusion of a local anesthetic. This result suggests that avoiding such a postoperative infusion may reduce the risk of chondrolysis.

Appendix

(eA) Tables showing patient and surgery characteristics according to the presence or absence of an intra-articular pain pump and the results of the sensitivity analysis of the effect of the definition of the date of the onset of chondrolysis are available with the electronic version of this article on our web site at jbjs.org (go to the article citation and click on "Supporting Data"). ■

Brett P. Wiater, MD
Frederick A. Matsen III, MD
Department of Orthopedics and Sports Medicine,
University of Washington Medical Center,
Box 356500, 1959 N.E. Pacific Street,
Seattle, WA 98195.
E-mail address for F.A. Matsen III: matsen@u.washington.edu

Moni Blazej Neradilek, MS
Nayak L. Polissar, PhD
The Mountain-Whisper-Light Statistics,
1827 23rd Avenue East, Seattle, WA 98112-2913

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