Original Article

Acute Proximal Hamstring Tears Can be Defined Using an Imaged-Based Classification

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Purpose: To develop a clinically meaningful proximal hamstring tear classification system and to present outcome data for defined subtypes. **Methods:** Retrospective review was undertaken of patients diagnosed with proximal hamstring tears at a single institution from 2012 to 2019. Images were reviewed by an orthopedic surgeon and musculoskeletal radiologist. Tears were classified as Type 1: partial with subtypes (1A, 1 cm or mild complete tear; 1B, 1-2 cm or full tear with <2 cm retraction), Type 2: complete single-tendon tears with subtypes (2c conjoint tendon only; 2s semimembranosus tendon only); or Type 3: complete tears with >2 cm retraction. Demographics, patient-reported outcome measures including Hip Outcome Score, Activities of Daily Living Subscore (HOS-ADL) and patient satisfaction were evaluated. A poor outcome was defined as HOS-ADL < 80%, and the patient acceptable symptom state (PASS) was defined as HOS-ADL 89.7%. **Results:** At a mean follow-up of 38.6 (range: 12-94) months for 114 patients, distributions were as follows: 18.4% Type 1A, 19.2% Type 1B, 7.8% Type 2c, 3.5% Type 2s, and 50.9% Type 3. Intra-observer and inter-observer reliability had a mean Kappa of 0.985 (95% CI: .956, 1.01) and .905 (95% CI: .895 .915). 66 patients underwent surgery, with 68.97% of them being Type 3. The mean HOS-ADL and PASS rate were higher for operatively treated patients (95%, 93.4%) than for nonoperatively treated patients (81.86%, 44.7%). There were significantly more patients satisfied in the surgery group in both Type 1 and Type 3 tears ($P = .046$ and $P = .049$). Body mass index was a significant predictor of a poor outcome in Type 3 tears ($P = .039$). History of corticosteroid or PRP injection, smoking, and diabetes were not significant predictors of a poor outcome. **Conclusion:** We present an MRI-based classification system for proximal hamstring injuries with both excellent intra-observer and inter-observer reliability. Outcome measures were improved in patients who underwent surgery. **Level of Evidence:** IV, cohort study: diagnostic case series.

Introduction

Proximal hamstring tears are relatively uncommon orthopedic injuries that can cause substantial morbidity if unrecognized.[1,2] Sequelae of proximal hamstring tears include decreased push-off strength, decreased endurance, and sitting intolerance. Because of the rarity of the condition, difficulty in diagnosis, and symptom overlap with lumbar spine pathology, patients often visit multiple health care practitioners before being correctly treated for a proximal hamstring tear. In a prior report, patients who had repairs performed greater than 6 weeks following injury visited on average 2.6 practitioners prior to evaluation by the treating surgeon.[3] This referral pattern combined with delay in diagnosis may lead to patient frustration, as well as a clinical dilemma for the treating orthopaedist.

The proximal hamstring complex consists of multiple tendinous attachments. The biceps femoris and semitendinosus tendons coalesce to form the conjoint tendon, and the separate semimembranosus tendon has a distinct, more lateral insertion on the ischium.[4,5] Tears may occur in one or both tendons, and each may be partial or complete. Furthermore, tears may be acute, subacute, or chronic in nature. There are few reports that attempt to categorize these injuries in detail: avulsions have been classified simply as either partial or complete on the basis of magnetic resonance imaging (MRI). These definitions are inconsistent, as some have reported surgical management of chronic, “incomplete” tears as successful without defining level of retraction.[6] Piposar et al. described those tears,

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including "high-grade" partial tears as well as complete tears with <2 cm of retraction.[4] The authors demonstrated that patients treated with surgery for both high-grade partial and complete tears with limited retraction had significantly better subjective and objective outcomes.[4]

Given the lack of consistency describing proximal hamstring ruptures, we have developed an MRI-based classification system. The purposes of this study are to develop a clinically meaningful proximal hamstring tear classification system and present outcome data for defined subtypes. We hypothesize that the classification will adequately describe proximal hamstring injuries.

Methods

This study was approved by the local Institutional Review Board (IRB) (approval no. 1546621-1). From January 2012 to December 2019, all consecutive patients who presented with a proximal hamstring injury to a single sports medicine fellowship-trained orthopedic surgeon (senior author: S.L.M.) were identified. Inclusion criteria consisted of patients presenting with proximal hamstring injury with adequate imaging and follow-up data. Patients were excluded from the radiographic portion of the study if they did not have an MRI available for review or if they sustained a bony avulsion, as seen on plain radiographs. Retrospective review of demographic data for all subjects including age, sex, body mass index (BMI), mechanism of injury, laterality, injection (corticosteroid or platelet-rich plasma, PRP), and time from injury to surgery for the operative cohort. Patient-reported outcomes, including the Hip Outcome Score-Activities of Daily Living Subscore (HOS-ADL) and patient level of satisfaction, were collected prospectively. The senior author's preferred operative technique consists of an open approach using three or four double-loaded suture-based anchors in the ischial tuberosity. All patients underwent the same rehabilitation program postoperatively.

Clinical Outcomes Data

A minimum of three attempts were made by telephone, e-mail, or both to contact each patient. Subjects were excluded if they were unable to be reached, did not complete the questionnaire, or had less than 1 year clinical follow-up. Patients completed the HOS-ADL questionnaire and answered a question of whether they were satisfied with the treatment chosen by providing a simple yes or no answer. No values have been validated for HOS-ADL or patient acceptable symptomatic state (PASS) for proximal hamstring injuries. Therefore, PASS and HOS-ADL values from hip arthroscopy were used as surrogates, with <80% defined as a poor outcome for HOS-ADL, and a PASS of 89.7%.[7,8]

MRI Analysis and Classification System

On the basis of the injury patterns, an MRI classification was developed to describe proximal hamstring tears. Figure 1 demonstrates the systematic MRI interpretation. Figure 2 describes the entire classification system. In our proposed classification, Type 1 tears are defined as partial tears or "peel-off" lesions. Type 1 tears are subdivided into 1A, a low-grade partial tear (<1 cm) and 1B, a high-grade partial tear with 1-2 cm of retraction (Fig 3). Type 2 tears are single-tendon retracted tears (>2 cm) involving either the conjoint tendon (2c, Fig 4) or the semimembranosus tendon (2s, Fig 5). Type 3 tears are complete tears involving both tendons (conjoint and semimembranosus) with retraction greater than 2 cm (Fig 6). The senior author's treatment algorithm is detailed in Fig 7.

Statistical Calculations

To validate this classification system, a separate reliability analysis of 30 MRIs was performed by four observers at the same time points. This group consisted of two sports medicine fellowship-trained orthopedic surgeons (S.S.S. and S.L.M.) and two musculoskeletal radiologists. All MRIs were blinded. Any discrepancies were settled by the senior author. Interobserver and intraobserver reliability were evaluated using Kappa's coefficient. The significance level for all tests was set at $P < .05$. Descriptive statistics (means and SD) were used to describe the patient characteristics and outcome variables, which included age, sex, BMI, tear type, time from injury to presentation, time from injury to surgery, injection status, patient satisfaction, outcome score, and complications. Fischer's exact test and Chi-squared tests were used to analyze categorical variables, while the Mann-Whitney *U*-test was used to analyze continuous variables, as appropriate. Fisher's exact test was used when the sample size was small. Binary logistic regression was used to analyze several variables in predicting HOS above or below an 80% poor outcome threshold and PASS at HOS-ADL of 89.7%. Tear types were analyzed together in groups 1,

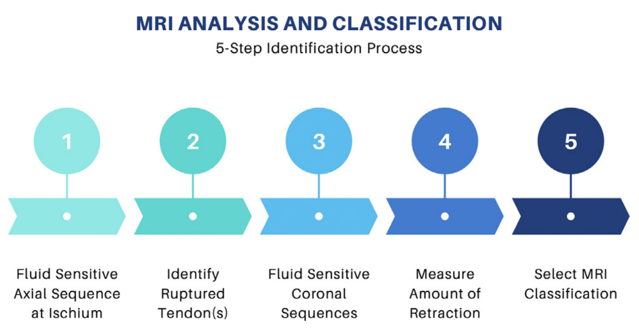

Fig 1. Magnetic resonance imaging review steps by which to identify a proximal hamstring rupture and begin to classify the type of injury.

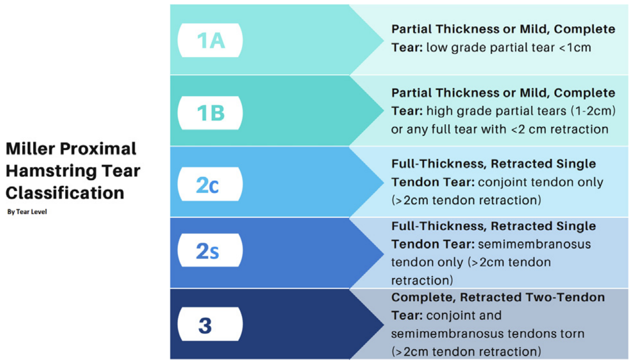

Fig 2. Definition of each type of proximal hamstring tear. Type 1 tears are partial thickness or mild, complete tears. Type 2 are full-thickness, single-tendon tears with minimal tendon stump retraction (i.e., <2 cm). Type 3 tears are complete tears of both tendons with more than 2 cm of retraction.

2, and 3 to maintain larger sample sizes. The statistical analyses were performed using SPSS V.23 and STATA 15 for Mac. A separate power analysis was not performed prior to the study.

Results

A total of 158 patients presenting with hamstring injury were identified. Of these, 44 were excluded, leaving 114 patients to include in the analysis. This cohort comprised 49 males and 65 females with an average age of 52.4 years (SD 11). There were 59 left-sided tears and 53 right-sided tears. The mean time from injury to presentation was 12 weeks, and mean follow-up was 38.6 months (range 12-94, SD 16). Classification types were as follows: Type 1: 42 patients (1A $n = 21$, 18.4%; 1B $n = 22$, 19.2%); Type 2: 13 patients (Type 2c, $n = 9$, 7.8%; Type 2s $n = 4$, 3.5%); Type 3: 58, 50.8% (Table 1). Both intraobserver and interobserver reliability demonstrated excellent agreement. Intraobserver reliability had a mean Kappa of .985 (95% CI: .956,1.01). Interobserver reliability had a mean Kappa of .905 (95% CI: .895 .915). Injection rate overall was 14.0% (16 patients), with 56% of injections administered being corticosteroid (9 patients), 18.7% PRP (3 patients), and 18.7% (3 patients) received both PRP and corticosteroid.

For those patients managed operatively, time from injury to surgery was a mean 11.6 weeks. The mean age of patients undergoing surgical intervention was 51.4 years. Of the 66 patients who underwent surgical intervention, 9 were Type 1A (42.8% of all Type 1A patients), 12 1B (54.5%), 3 Type 2c (33%), 2 Type 2s (50%), and 40 Type 3 (68.9%). 2.6% patients experienced deep vein thrombosis.

The patient-reported outcome measure survey response rate was 72%. The mean HOS-ADL for all patients was 89.5%, with means of the nonoperative cohort at 81.8% and operative cohort at 95%. In the nonoperative group, the mean HOS-ADL scores by types were as follows: Types 1A-86.1, 1B-84.4, 2c-76.5, 2s-100, and 3-77.4. The operative group had mean HOS-ADL scores of 1A-92.5, 1B-97.3, 2c-97.5, 2s-99.3, and 3- 94.5. When performing a Mann-Whitney *U*-test to compare outcome scores between nonoperative and operative groups, Type 1 tear and Type 3 tear cohorts did differ significantly in outcome score between operative and nonoperative groups (Type 1: $P = .012$, $Z = -2.524$, Type 3: $P = .001$, $Z = -3.293$), with Type 3 having the greater effect size. Type 2 tears did not differ in outcomes between operative and nonoperative ($P = .191$).

Overall, 17.5% of patients experienced a poor outcome, defined as a HOS-ADL below 80. When controlling for patient age, BMI >35 ($P = .039$) and nonoperative status ($P = .023$) were significant predictors of a poor outcome in Type 3 tears. This effect of BMI was not seen in Type 1 or 2 tears. In a logistic binary regression, age ($P = .058$) and injection status ($P = .211$) were not significant predictors of outcome.

PASS for hip arthroscopy has been defined at a value of 89.7 for the HOS-ADL. No value has been defined in operative management of hamstring injury. The

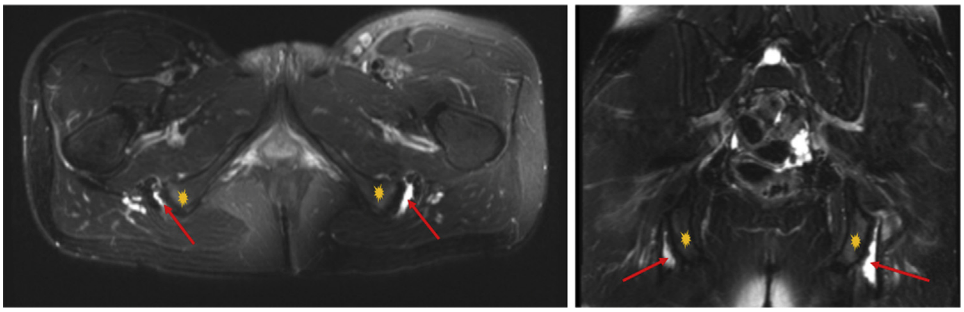

Fig 3. Axial and coronal T2 MRI with fat saturation in a patient with a right-sided Type IA injury and a left-sided Type IB injury. Type 1A injuries are classified as low-grade partial tearing with less than one centimeter of retraction. Type IB injuries are high-grade partial tears with 1-2 centimeters of retraction. If a tendon is fully torn but is less than 2 centimeters retracted, this qualifies as a Type IB tear. Orange stars indicate the ischial tuberosities, and the red arrows indicate partial tears.

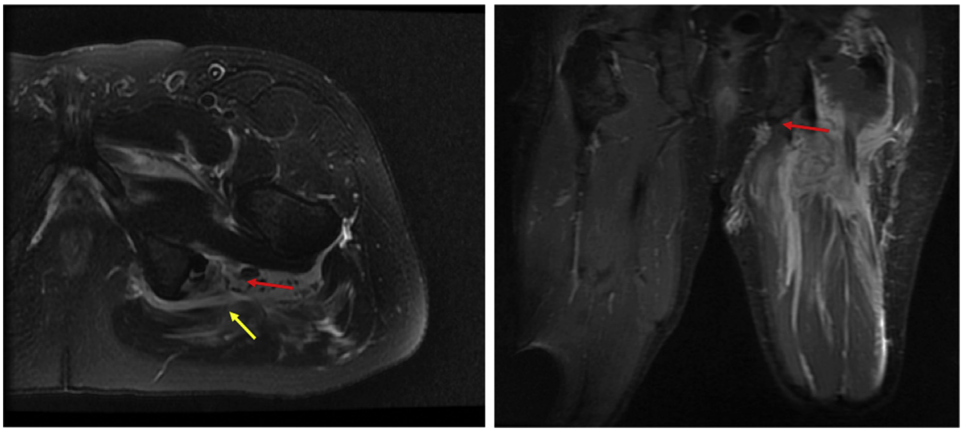

Fig 4. Axial and coronal T2 MRI sequences with fat saturation demonstrating a left-sided Type 2c injury. Type 2c constitutes a conjoint tendon tear with more than 2 centimeters of retraction. Yellow arrow on the axial cut indicates a bare footprint at the ischial tuberosity, and a red arrow indicates an intact semimembranosus origin.

number of patients who achieved this PASS score for hamstring ruptures was higher in the operative cohort (57, 93.4%) than in the nonoperative cohort (21, 44.7%). By type, the operative cohort had a PASS rate of 75% for Type 1A, 100% for Type 1B, Type 2c, and Type 2s, and 87.5% for Type 3. For the nonoperative group, pass rates by type were as follows: 50% for Type 1A and Type 1B, 43% for Type 2c, 100% for Type 2s, and 35% for Type 3. The odds of having a score greater than or equal to the 89.7 threshold in the operative group was greater than the nonoperative group ($P <$ .0001, OR 9.32, 95% CI 3.66,23.71).

Overall, patient satisfaction was good in the nonoperative cohort and excellent in the operative cohort: 79.2% and 97% of patients, respectively, were satisfied with their treatment. Nonoperative satisfaction by type was as follows: Type 1A, 66.7% Type 1B, 80%, Type 2c, 83.3%, Type 2s, 100%, and Type 3, 83.3%. In the operative group, percent satisfaction for tear types 1A, 1B, 2c, 2s, and 3 was 88.9%, 100%, 100%, 100%, and 97.5%, respectively. There were significantly more patients satisfied in the surgery group in both Type 1 ($P = .046$) and Type 3 tears ($P = .049$).

Discussion

In this study, 82.5% of total patients were considered to have a good outcome by score alone, and 72% achieved patient-acceptable symptom state for a similar condition; these results were improved in operative patients. The results of this study demonstrate this classification system as clinically useful by describing the disrupted anatomy and guiding treatment decisions, as well as patient expectations. Furthermore, the classification demonstrated both high intraobserver and interobserver reliability/agreement among both sports medicine-trained orthopedic surgeons and musculoskeletal radiologists. Using the described algorithm to analyze fluid-sensitive MRI sequences make this a reproducible classification system and may help guide patients toward a treatment option that optimizes outcomes.

Proper classification of pathology may provide alternative treatment pathways to optimize outcomes. Multiple studies have investigated both complete and incomplete proximal hamstring tears;[2,4,6,9–11] however, a majority of these lack specific definitions of the tear type. Our detailed characterization allows for

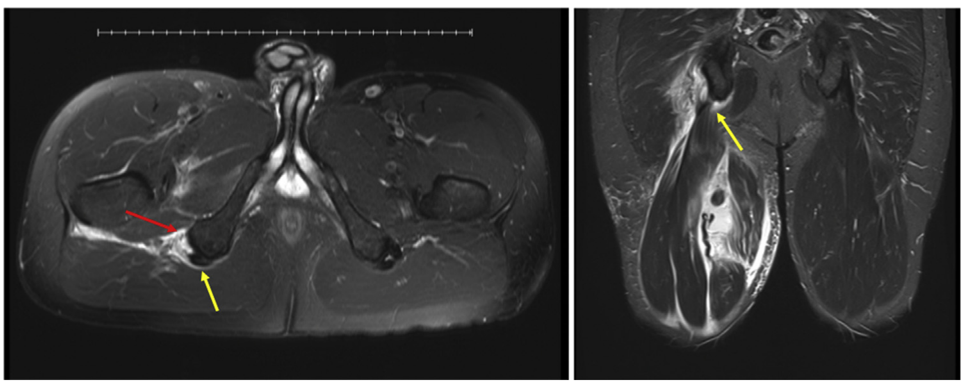

Fig 5. Axial and coronal T2 MRI sequences with fat saturation demonstrating a right-sided Type 2s injury, classified as a semimembranosus avulsion with greater than 2 centimeters of retraction. The red arrow indicates a bare semimembranosus footprint, and the yellow arrow indicates an intact conjoint tendon.

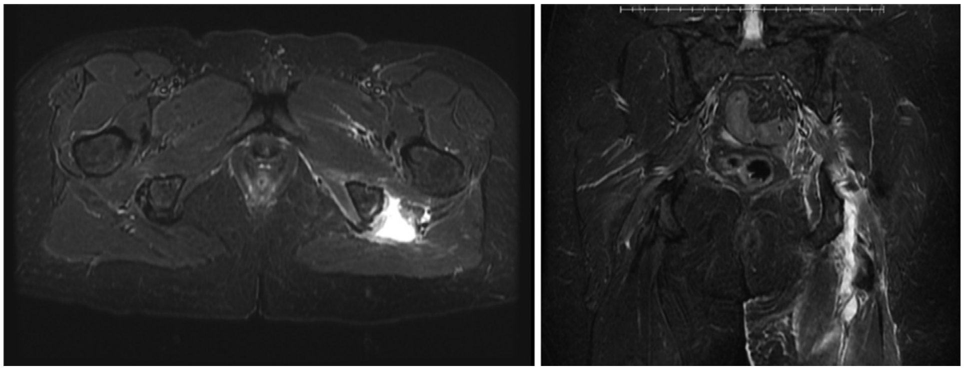

Fig 6. Axial and coronal T2 MRI sequences with fat saturation demonstrated a left-sided Type 3 injury with complete avulsion of both the conjoint and semimembranosus tendons with greater than 2 centimeters of retraction. Edema is evident at the ischial tuberosity with bare tendon footprints.

standardized communication between health care providers, as well as the potential to improve future research in the area. It may also help guide treatment decisions. Wood et al. previously developed a hamstring tear classification with 5 types that included both proximal and musculotendinous injuries.[9] This classification did include incomplete and complete tears but was far less specific than our proposed classification. By differentiating semimembranosus-only tears (2s) from conjoint tendon tears (2c), the authors feel our classification may better address the patient's pathology and guide divergent treatment paths.[9]

Historically, surgical treatment of Type 1 proximal avulsions has been recommended for those patients who have failed initial nonoperative treatment, and this is consistent with our senior author's treatment algorithm. More recently, multiple studies have demonstrated excellent outcomes in surgical treatment of these tears.[2,4,10–13] Professional athletes have demonstrated excellent outcomes following repair of proximal semimembranosus injuries; however, these were non-avulsions.[14] A professional athlete population is not generalizable to a typical population with proximal hamstring tears. It is well established that surgical treatment of complete proximal avulsions (Type 3) has improved outcomes in respect to nonoperative treatment. Across all types, patients in our cohort who underwent surgical intervention had improved HOS-ADL outcome scores. Significantly more patients were satisfied in the surgery group for both Type 1 and Type 3 tears.

Lempainen et al. provided their outcomes on surgical treatment of partial tendon avulsions in 47 patients at mean follow-up of 36 months.[12] These included conjoint and semimembranosus tendon tears that were not analyzed separately. 69% of patients had an excellent outcome and 19% had a good outcome that included 11 professional and 13 competitive athletes. All 47 patients felt that they benefited from surgery.[12] In our study, we did not find a significant difference in HOS-ADL scores in those patients treated with surgery in Types <3. Independent predictors for a poor outcome were non-operative treatment and BMI > 35 in Type 3 tears. Prior injections were not predictive of a worse outcome, demonstrating that it may be

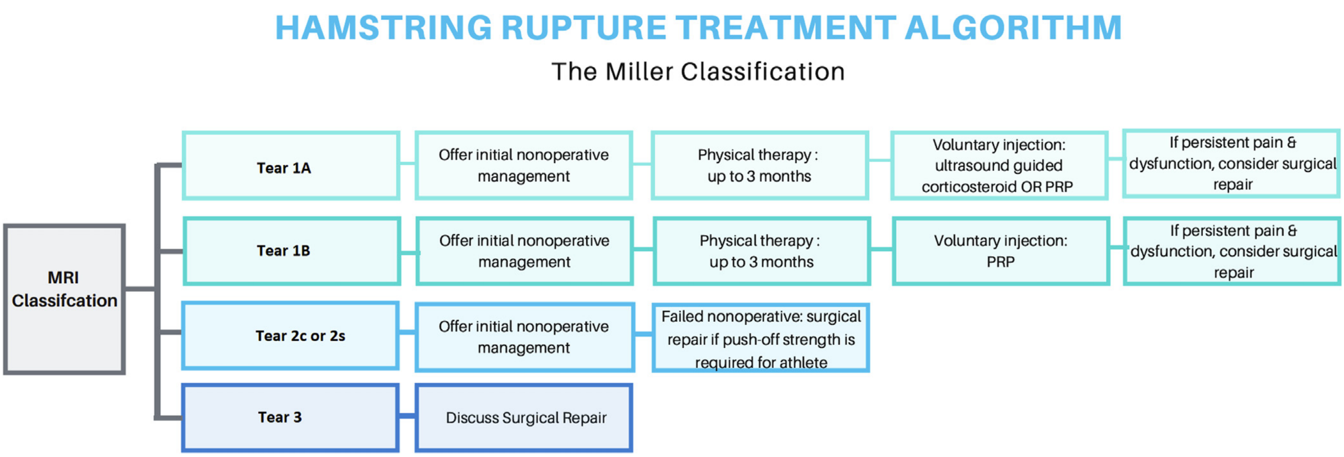

Fig 7. Visual representation of the treatment algorithm used to treat proximal hamstring ruptures. All discussions that are held with the patient include a thorough assessment of risks, benefits, and alternatives to types of treatment.

Table 1. Total Number of Patients in Each Classification Group, Subdivided by Treatment Status

Tear Type	Nonoperative	Operative	Total
1A	12	9	21
1B	10	12	22
2c	6	3	9
2s	2	2	4
3	18	40	58
Total	48	66	114

reasonable to offer a trial of nonoperative treatment in Types 1 and 2 tears, including an injection (whether it be PRP or corticosteroid) and still achieve a satisfactory outcome after surgery.

In a large systematic review, 24 studies compromising 795 proximal avulsions were evaluated.[10] These included partial and complete tears in both the acute and chronic settings.[10] Notably, the definition of what was included as a partial avulsion varied among the included studies. In another study, a majority of the partial tears treated surgically (94%) were classified as chronic (>2 months).[13] Mean time from injury to surgery was 202.3 days compared to 81.1 days in our study. This may be due to a longer trial of nonoperative care but also highlights diagnostic difficulties in proximal hamstring tears, as these injuries often go unrecognized.[13] Overall, 90.81% of operative patients in the large systematic review were satisfied with their treatment in comparison to 97% in our study signifying that across all tear types, patients often do quite well postoperatively in both the acute and chronic settings.[10] These results are in spite of the risk of complications from surgery, most notably venous thromboembolism. Acutely operated patients experienced improvement in patient satisfaction and sitting tolerance. These data suggest that a shorter trial of nonoperative treatment in Type 1 and 2 injury may be recommended to optimize results. Our senior author considers a trial of 3 months rather than the 6 months often cited as sufficient conservative treatment trial time.

A strength of this study included the large number of patients who sustained a relatively rare injury. While muscular or myotendinous strains of hamstrings are common, proximal avulsions make up a small percentage of hamstring injuries, and a study of 114 patients, 82 of whom had full outcome scores for review, represents a relatively large, single-institution series on proximal hamstring avulsions, including both nonoperative and surgical patients. As a rare injury, the senior author's practice represents a tertiary referral center for proximal hamstring tears.

Limitations

As with all studies, our study had limitations. Despite our analysis lacking preoperative scores to calculate minimally clinically important difference (MCID) or substantial clinical benefit (SCB), we are able to report satisfactory results in this patient-reported outcome measure. However, a recently published study defined patient-acceptable symptom state (PASS) for hip arthroscopy and found this value for the HOS-ADL subscale to be 89.7%.[8] The percentage of patients who achieved this PASS was higher in the operative cohort (93.4%) than in the nonoperative cohort (44.7%). Furthermore, the odds ratio of having a HOS-ADL score above this threshold in the operative group was 9.32 times than in the nonoperative group. No value currently exists for hamstring injuries, and the historical PASS value may not apply to patients treated nonoperatively. The 1-year HOS-ADL historical PASS value for hip arthroscopy is not specific to this study population; however, to our knowledge, this is the most specific PASS score available in the literature related to proximal hamstring tears. For our study, we had a compliance of 72%, excluding 28% of patients initially enrolled in the study due to missing data. This relatively high rate of exclusion could lead the study to be more prone to selection bias, in which the attrition bias might be present if these lost patients had poorer outcomes that could influence the results. However, the distribution of injury types among patients lost to follow-up closely mirrored that of the study patients. Another limitation is the paucity of objective data such as strength testing postintervention to contribute to assessing treatment effectiveness. However, our main goal of this study was to present the validity of a straightforward classification system with a clinical application rather than to provide data about return of strength parameters.

Conclusions

We present an MRI-based classification system for proximal hamstring injuries with both excellent intraobserver and interobserver reliability. Outcome measures were improved in patients who underwent surgery.

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