Infrapatellar Contracture Syndrome
Diagnosis, Treatment, and Long-Term Followup
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ABSTRACT

Infrapatellar contracture syndrome is an uncommon but recalcitrant cause of reduced range of motion after knee surgery or injury. The results and conclusions presented here are based on a retrospective clinical study evaluating the long-term outcome in 75 patients who developed infrapatellar contracture syndrome. These 75 patients (76 knees) were evaluated at an average followup of 53 months after the index (inciting) procedure or injury. Comparing subgroups within the study population, factors that correlated with poorer results or more severe infrapatellar contracture syndrome were found to be acute anterior cruciate ligament repair or reconstruction, the use of patellar tendon autograft for anterior cruciate ligament reconstruction, nonisometric graft placement, multiple surgical procedures, use of closed manipulation, and the development of patella infera. We concluded that appropriate procedures can substantially increase the range of motion in patients with infrapatellar contracture syndrome. However, residual functional morbidity persists in many patients, and the outcome, as determined by subjective knee function scores, is only fair. The natural history of an anterior cruciate ligament-deficient knee appears to be more benign than the natural history of a knee that develops infrapatellar contracture syndrome.

Our initial 1987 study25 of a recalcitrant cause of knee stiffness, infrapatellar contracture syndrome (IPCS), described the development of this problem in two ways: first, primarily as an "exaggerated pathologic fibrous hyperplasia" of the anterior soft tissues of the knee, beyond that associated with normal healing, and second, as a result of certain risk factors associated with knee surgery such as nonisometric ligament graft placement, immobilization, and muscle weakness. Since that time, the number of investigations devoted to knee arthrofibrosis have testified to the significance of the problem and its perplexity.1,12,15,26,27 Graf and Uhr13 cited limited range of motion as the most frequent postoperative problem after knee surgery, noting an incidence of 11% in their series of 103 patients; other investigators report incidences of 0% to 35%.7,14,16,18,20,30,34

Several studies on factors contributing to knee arthrofibrosis have implicated the timing of ACL reconstruction. Shelbourne et al.30 have reported a much higher incidence of arthrofibrosis in knees that underwent ACL reconstruction within 1 week of injury. Harner et al.14 corroborated these findings, reporting the highest incidence of arthrofibrosis in knees where reconstructions were performed within 4 weeks of injury. Other studies16,34 support these findings, while other factors such as patient age and sex,14 graft type,28 associated ligament injury and meniscal repair,12 and mechanical lesions,16 have also been cited.

Scrutiny of the postoperative rehabilitation program as a possible cause of arthrofibrosis has resulted in a trend toward early postoperative knee extension.20,28,30 Over the last decade, changes in postoperative care after an ACL reconstruction, from a norm of 6 weeks in an above-knee cast in flexion with nonweightbearing2~24 to a new norm of early range of motion with full extension and earlier weightbearing,19,20,30 is a direct result of such probing.

In our present study, we undertook a long-term, retrospective, clinical analysis of patients requiring surgery for IPCS to determine the following: 1) long-term clinical results after the development of IPCS, 2) those elements associated with or resulting in a "successful" surgical treatment, and 3) factors that predict and affect outcome after development of IPCS for a more rational approach to the prevention and treatment of knee stiffness in general.

MATERIALS AND METHODS

Diagnosis

Patients in whom IPCS was diagnosed demonstrated a loss of knee motion ≥10° of knee extension and ≥25° of knee flexion. For the condition to be diagnosed as IPCS, the loss

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of knee motion had to be associated with significantly reduced patellar mobility (patellar entrapment) secondary to contracture of the infrapatellar tissues as demonstrated by reduced superior patellar glide with the knee in maximum extension. Patients with IPCS in this study were refractory to conservative measures. For inclusion in this retrospective study, patients had to undergo corrective surgery with a follow-up of more than 24 months after the index (inciting) procedure and more than 12 months after the last secondary surgical procedure for correction of IPCS. Ultimately, 75 patients (76 knees) met these criteria. Fifty-two patients were examined directly by the authors, and an additional 17 of these patients underwent examination and had radiographs taken at sites distant from Salt Lake City via qualified knee specialists. Sixty-eight of the 69 patients who underwent a physical knee examination completed “knee-stiffness” questionnaires.

We developed an algorithm to aid in the treatment of arthrofibrosis (Fig. 1) and, in accordance with the individual patient’s presentation, determined the timing and type of surgical procedure necessary. The presence and type of patellar entrapment were crucial to our therapeutic plan. Diagnosis of patellar entrapment was made based on a decrease in patellar mobility as compared with the opposite knee. The type of patellar entrapment was determined by which passive patellar motions were restricted. A zero or negative passive patellar tilt and a <2 cm measurement of superior or inferior patellar glide confirmed entrapment.26

Postdiagnostic measures

Where patellar entrapment did not exist, we judged it safe to become more aggressive in physical therapy and, if necessary, perform a closed manipulation under anesthesia. On the other hand, if patellar entrapment did exist the region of entrapment was determined based on which patellar motions were restricted. When recalcitrant suprapatellar entrapment was present (as confirmed by decreased inferior glide) secondary to pouch scarring, arthroscopic debridement followed by manipulation usually sufficed. However, if infrapatellar entrapment (IPCS) was present, great care was exercised. More aggressive physical therapy, repeat manipulation, or arthroscopic procedures would only worsen the problem and lead to patella infera.

On diagnosis of IPCS, all of our patients were removed from “formal” physical therapy and placed on a “nonforceful,” range of motion program. This included active range of motion exercises and closed-chain strengthening exercises (especially the quadriceps). Oral antiinflammatories were prescribed as well. Many patients responded to this treatment alone and did not require surgery. Only patients requiring surgery were included in this study.

Surgical procedures

Patients in our study group who did not achieve the desired range of motion but who demonstrated less swelling and pain with increased muscle strength, i.e., no quadriceps lag, were operated on according to the author’s preferred protocol. This protocol included open arthrotomy to achieve lateral or medial retinacular release and debridement of all of the adhesions, including medial and suprapatellar plicae and scarified fat pad. All fibrotic tissue between the distal pole of the patella and the anterior tibial plateau was resected. The retropatellar tendon bursa was released, and the patellar tendon was freed from the anterior tibial cortex down to, but not including, its normal tubercle attachment. Ligament repairs or grafts were resected or fractionally lengthened depending on their location and tension. For patients who had previously had ACL surgery, a notchplasty was performed as needed.

If patella infera of 8 mm or more was present, a tubercle osteotomy was performed (Fig. 2). This technique involves shifting the tubercle superiorly and anteriorly and attaching it with a bone screw. The distal defect is bone grafted. No forced manipulation of the knee should occur after this step so as not to risk fracturing the tibia at the osteotomy site.

A posterior capsular release is not necessary unless there has been trauma to the posterior joint or a prolonged flexion contracture (>5 years). No patients in this series required a posterior capsule release.

Postoperative treatment

After surgery, our patients were maintained in a continuous passive motion device and drains were left in place for 48 hours. Continuous cold modalities (Polar Care, Breg Inc., Vista, CA) and neuromuscular simulators were used during this early postoperative period. Full active range of motion was achieved as soon as possible, with emphasis on extension. Oral steroids (Medrol Dose Pack, UpJohn Co., Kalamazoo, MI) were used starting 2 to 3 weeks after surgery and continued for 1 to 2 weeks in 60 (80%) of the patients. Also, night splints for extension were used in 69 (92%) of the patients.

Once acceptable extension was achieved and the knee entered its progressive stages of healing with decreased swelling and increased strength (a period of 3 to 4 months), the patient was taken back to surgery, if necessary, for

Figure 1. Algorithm to show failure to progress.
Figure 2. DeLee osteotomy. Note that the osteotomy moves the affected attachment of the patellar tendon superiorly on the tibia as well as anteriorly. Not only does this osteotomy reduce the patella infera, but it also increases the distance between the patellar tendon and the anterior tibial cortex, thus reducing the tendency for these structures to fibrose.

Methods of clinical analysis

Methods of clinical analysis included a retrospective chart and record review. A "stiff-knee" patient questionnaire was used to determine Lysholm and Tegner activity scores and patient satisfaction. We chose the Lysholm scoring system because of the predominance of ligament cases and the patient population. A clinical follow-up examination and radiographs were also obtained. Radiographs included a 45° flexion weightbearing view of both knees and bilateral 45° nonweightbearing lateral and Merchant's views. Patellar height was measured using the technique of Blackburne and Peel.

The study population was divided into subgroups to determine the effects of various factors on clinical outcome. The parameters examined included patient age and sex, initial diagnosis, acute versus chronic condition at index (inciting) procedure, primary versus secondary IPCS, associated procedures at index surgery (injury), the graft type used for ACL reconstruction index procedures, the interval from index to the first secondary IPCS corrective procedure, type of secondary procedures, range of motion before IPCS surgery, final range of motion, number of other procedures for IPCS (techniques chosen by previous surgeons) or number of procedures as described in this paper (techniques of the author's choice), and length of followup. The types of secondary procedures were noted and these included arthroscopic debridement, open debridement, manipulation under anesthesia, and proximal tibial osteotomy (DeLee) for correction of patella infera.

Comparison of outcome based on different clinical factors

When compared with pretreatment status, "good" outcomes were arbitrarily defined as 1) a Lysholm score ≥80, 2) a Tegner score ≥4, and 3) a decrease in Tegner score from preinjury to final followup of ≥2. "Poor" outcomes were defined as 1) a decrease in a Tegner score of 4 or more and 2) persistent loss of extension ≥10° or flexion loss of ≥25°.

We assessed the statistical significance of the data using the chi-square test and Student's t-test; P < 0.05 was deemed significant.

RESULTS

Patient data

After reviewing the records of the initial group of 81 patients, 75 (76 knees) qualified for the study group (Table 1). The average age for these 75 patients (39 men and 36 women) was 28.8 years (range, 12 to 63) at the time of the index (inciting) procedure. A diagnosis of ACL deficiency requiring repair or reconstruction was made in 63 of 76 knees, 61 of which were intraarticular reconstructions done predominantly with patellar tendon autografts (Table 2). Five patients had undergone multiple ligament repairs and reconstruction for knee dislocation, 1 patient had a PCL reconstruction, 2 patients had meniscal repairs, and 4 others had "miscellaneous" procedures. One patient had no index procedure but had an acquired IPCS after blunt trauma to the knee. The average age of those requiring ACL reconstructive surgery was 29 years, whereas patients in other categories averaged 32 years.

The majority of patients were referred to us for IPCS treatment after their index (inciting) procedure and other types of secondary procedures had been performed elsewhere. Infrapatellar contracture syndrome was classified as primary (no identifiable cause) in 20 cases and secondary (iatrogenic) in 55 patients. The most common causes of the secondary IPCS were nonisometric ACL graft placement and graft impingement. Followup from the index procedure to the final clinical visit averaged 53.2 months (range, 24 to 86).
TABLE 1
Comparison of specific outcomes for IPCS based on a variety of clinical factors

<table>
<thead>
<tr>
<th>Factors affecting outcome</th>
<th>Total</th>
<th>Good</th>
<th>Poor</th>
<th>P</th>
<th>Good</th>
<th>Patella Infrac</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>76</td>
<td>13</td>
<td>12</td>
<td></td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>28.8</td>
<td>26.5</td>
<td>28.1</td>
<td>NS</td>
<td>13</td>
<td>19</td>
</tr>
<tr>
<td>Sex</td>
<td>53.0</td>
<td>38.0</td>
<td>58.0</td>
<td>NS</td>
<td>38.0</td>
<td>19</td>
</tr>
<tr>
<td>(%) men</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>25</td>
</tr>
<tr>
<td>Secondary</td>
<td>73.0</td>
<td>15.0</td>
<td>75.0</td>
<td>0.04</td>
<td>15.0</td>
<td>89.0</td>
</tr>
<tr>
<td>2 IPCS (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8.0</td>
</tr>
<tr>
<td>Acute (%) Incidence</td>
<td>51.0</td>
<td>54.0</td>
<td>83.0</td>
<td>0.04</td>
<td>54.0</td>
<td>79.0</td>
</tr>
<tr>
<td>PT auto at (%)</td>
<td>42.9</td>
<td>15.0</td>
<td>58.0</td>
<td>0.04</td>
<td>15.0</td>
<td>89.0</td>
</tr>
<tr>
<td>Incidence of tibial index</td>
<td>20</td>
<td>0</td>
<td>8.0</td>
<td>NS</td>
<td>0</td>
<td>21.0</td>
</tr>
<tr>
<td>tuberosity osteotomies (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>16.0</td>
</tr>
<tr>
<td>Time from index to secondary procedure (months)</td>
<td>4.3</td>
<td>3.75</td>
<td>5.17</td>
<td>NS</td>
<td>3.75</td>
<td>5.2</td>
</tr>
<tr>
<td>ROM at last F/U</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5.6</td>
</tr>
<tr>
<td>Flexion</td>
<td>-2.0</td>
<td>-2.1</td>
<td>-4.7</td>
<td>NS</td>
<td>-2.1</td>
<td>-3.9</td>
</tr>
<tr>
<td>Extension</td>
<td>128</td>
<td>134</td>
<td>130</td>
<td>NS</td>
<td>134</td>
<td>122.7</td>
</tr>
<tr>
<td>Lysholm score</td>
<td>72.2</td>
<td>89</td>
<td>48.6</td>
<td>0.04</td>
<td>89</td>
<td>69.2</td>
</tr>
</tbody>
</table>
| a P-values, significance level of comparisons. NS, Not significantly different.

Before treatment by the authors’ protocol, a total of 180 unsuccessful procedures for correction of IPCS had been performed (average, 2.8 per patient; range, 1 to 16). This contrasts with a total of 129 procedures performed by the authors for correction of IPCS (average, 1.7 per patient; range, 1 to 4).

Knee motion

The protocol procedures resulted in significant gains of range of motion. All but two patients (three knees) were considered a good outcome (<8° knee extension to >125° knee flexion) judged on motion criteria alone. Excluding the three failures (discussed below), extension gains from the time of entrapment to the last followup ranged from 5° to 36°, an average gain of 14.2°. Flexion gains averaged 32.5° (range, 0° to 90°). The final range of motion averaged −2° of extension to 128° of flexion (range, 0° to −8° of extension, 125° to 150° of flexion) (Table 1). Examination of the patellar range of motion revealed a gain in passive patellar tilt of 6° (range, 0° to 15°), gains of superior and inferior glide of 9 mm (range, 5 to 15), and medial and lateral glide of one quadrant (range, 0.5 to 2.5).

TABLE 2
Index procedures \((N = 76)\)

<table>
<thead>
<tr>
<th>Procedure</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACL intraarticular reconstruction(^a)</td>
<td>61</td>
</tr>
<tr>
<td>ACL extraarticular reconstruction</td>
<td>2</td>
</tr>
<tr>
<td>Multiple ligament repair/reconstruction (dislocation)</td>
<td>5</td>
</tr>
<tr>
<td>Meniscal repair (MMR, MMR + LMR)(^b)</td>
<td>2</td>
</tr>
<tr>
<td>Isolated PCL reconstruction</td>
<td>1</td>
</tr>
<tr>
<td>Lateral release</td>
<td>1</td>
</tr>
<tr>
<td>Femur ORIF</td>
<td>1</td>
</tr>
<tr>
<td>Patellar pole excision (fracture)</td>
<td>1</td>
</tr>
<tr>
<td>Diagnostic arthroscopy</td>
<td>1</td>
</tr>
<tr>
<td>Anterior knee contusion</td>
<td>1</td>
</tr>
</tbody>
</table>

\(^a\) PT autograft (28), allograft (10), synthetic (6), hamstring autograft (8), repair and semitendinosus augmentation (7), and ACL repair with bone avulsion (tibia) (2).

\(^b\) MMR, medial meniscal repair; MMR + LMR, medial meniscal repair plus lateral meniscal repair.

Lysholm and Tegner activity level scores

At final evaluation, Lysholm scores averaged 72.2 of a possible 100. Scores for pain, limping, and squatting were particularly low (Table 3). Accessory scores not included in the Lysholm system rated crepitus and subjective weakness. These averaged 1.9 of 5 for crepitus and 3.9 of 5 for

TABLE 3
Average Lysholm scores

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain</td>
<td>14.7 of 25</td>
</tr>
<tr>
<td>Limp</td>
<td>3.3 of 5</td>
</tr>
<tr>
<td>Squat</td>
<td>3.1 of 5</td>
</tr>
<tr>
<td>Swelling</td>
<td>7.4 of 10</td>
</tr>
<tr>
<td>Stairs</td>
<td>7.3 of 10</td>
</tr>
<tr>
<td>Lock/catch</td>
<td>11.4 of 15</td>
</tr>
<tr>
<td>Instability</td>
<td>20.5 of 25</td>
</tr>
<tr>
<td>Support</td>
<td>5 of 5</td>
</tr>
<tr>
<td>Total</td>
<td>72.2 of 100</td>
</tr>
</tbody>
</table>

(range, 18–100)
weakness. The average instability score was relatively high at 20.5 of 25, and no patient required support for ambulation (5 of 5).

In general, Tegner activity level scores decreased throughout the entire group as a result of the IPCS (Fig. 3). The most common preinjury Tegner score was 6 (average, 6.7). At final followup, the average was 4.3, a decrease of 2.4. Only one patient's activity level increased (3 to 5), while seven patients noted no change. Fifty-eight of the 68 IPCS patients (85%) had decreased activity levels. Fifty-six of the 75 patients (75%) were able to return to work. Two thirds of these patients were able to work without limitations. Only three patients who were not able to return to work reported being fully disabled by their knees. Although Lysholm scores (Table 3) indicated that pain was prominent, 55 of the 69 patients (80%) never used analgesics. Patients who chose to use medication used antiinflammatory drugs only.

Forty-eight of the 69 patients (70%) were athletically active at followup. As previously noted, most patients had decreased activity levels, and only 16 reported exceptionally high Tegner scores: one score of 10 for a nationally competitive athlete and seven scores of 8. Despite the fact that Lysholm scores were only in the “fair” range and Tegner scores showed a significant decline, 44 of the 68 patients (85%) stated they would repeat their original decision in favor of the index (inciting) surgery.

Radiographic evaluation

Radiographic evaluation revealed that 48 patients (70%) had patellar osteopenia and patellofemoral degenerative changes at late followup. Radiographic findings were compared with preoperative radiographs in 47 patients. Only 15% (7 patients) of the preoperative radiographs reviewed demonstrated patellofemoral joint spurring, and this was very mild in all but 2 cases, which were considered moderate. Tibiofemoral joint space narrowing was present in 4 cases (9%) and ranged from 2 to 4 mm. There were no patients with constitutional patella infera noted.

Patients with patella infera had a patellar height index averaging 0.95 for the uninvolved knee, as contrasted with an index of 0.53 (range, 0.75 to 0.10) in the IPCS knees at the time of presentation. After tubercle osteotomy, however, the index was corrected to 0.84. Although this is not a full correction, the average proximal advancement was 21.4 mm. The height index showed a tendency to diminish with time, showing reduction to 0.80 at average 8-month followups and decreasing further to 0.75 at 24 months. Although not a significant difference, this measurement was interpreted as a consistent “trend.”

Analysis of “good” versus “poor” results

When comparing the “good” outcome patient group and the “poor” outcome patient group, several significant factors were noted. The incidence of patellar tendon autograft index procedures for ACL reconstruction was 58% (7 of 12) in the poor group, compared with 15% (2 of 13) in the good group ($P < 0.05$). Also, the incidence of secondary IPCS was 75% (9 of 12) in the poor group, in contrast to only 15% (2 of 13) in the good group ($P < 0.05$). The number of secondary procedures averaged only 1.5 in the good group versus 3.8 for those outcomes that were judged poor ($P < 0.05$). In addition, the majority of those achieving the desired range of motion within 12 months scored high in all categories (Fig. 4). Those cases judged poor had index ACL procedures done acutely at a frequency of 84%, versus 56.5% for good outcomes. Also, arthroscopy with manipulation alone had been performed more often in the poor group, 40.7%, versus 28.6% in the good group.

There were significant differences between patients with good outcomes and those who had developed patellar infera. In the infera group, 17 of 19 (89%) had received ACL patellar tendon autografts versus only 2 of 13 (15%) in the good outcome group ($P < 0.05$). Secondary IPCS was noted in only 2 (15%) of the good group versus 11 (58%) of the infera group. The number of secondary procedures in the infera group averaged 4.5 versus 1.75 in the good group ($P < 0.05$).

DISCUSSION

Although the type of patients in this study comprises only a small percentage of all types of patients who develop arthrofibrosis, the malignant outcome of IPCS demanded thorough analysis. Our analysis showed that, regardless of

Figure 3. Pre- and postoperative Tegner activity scores.

Figure 4. Outcome versus length of time to achieve the desired range of motion. Note that the longer the knee was without acceptable motion, the more likely a poor result.
the time elapsed from the index surgery or injury to entering our protocol (range, 3 months to 5 years), we were able to achieve the desired range of motion in the majority of patients and had only two failed outcomes (three knees) in the group. The outcome in terms of function, however, was fair at best. Average Lysholm scores were below what is considered good-to-excellent results and below what has been recorded for uncomplicated ACL reconstruction.9,22,29,30 Tegner activity levels were also significantly reduced. These reduced functional indices were recorded despite documentation of stability in the high-stability components of the Lysholm score. It is thus apparent that although salvage of the IPCS-involved knee is possible and confirmed by the significant gains in range of motion after secondary procedures, residual morbidity persists. Nevertheless, gains in range of motion achieved by the authors' protocol are consistent with values observed by others when treating less malignant forms of arthrofibrosis.5,8,14,18,23,33

Effect of ACL graft choice on outcome

The effects of graft choice and donor morbidity have been increasingly scrutinized. Although some studies have shown no correlation between limited knee motion after ACL reconstruction and the type of graft used,18 others have reported a greater risk of arthrofibrosis with the use of patellar tendon autograft.4,6,7,14,17,32 Attention, therefore, has centered on other graft sources such as allograft and synthetics, both of which were represented in this series.

Our comparison of patients with IPCS who had an index ACL reconstruction with patellar tendon autografts and those who had intraarticular grafts, including semitendinosus-gracilis autografts, synthetics, and allografts, revealed significant differences. There were fewer patients with acute reconstructions in the group who did not have patellar tendon autograft (10 of 32, 31%) than in the patellar tendon autograft series (20 of 28, 71%). The patellar tendon autograft recipients averaged a higher number of secondary procedures for IPCS correction, and the proportion of osteotomies in this group was significantly higher (P < 0.05), 21% versus 3% in the group without patellar tendon autograft.

When comparing patellar tendon autografts with other graft types, both tested reasonably well, approximating the average Lysholm score (74.8 and 70.2, respectively). However, patellar tendon autograft recipients had a greater reduction in Tegner scores compared with those who had other ACL intraarticular procedures (−2.27 versus −1.73). Also, the patellar tendon autograft group showed a higher incidence of patella infera. The patellar tendon autograft group had a higher incidence of secondary IPCS as well, although this typically resulted from nonisometric graft placement and graft impingement caused by improper technique by the surgeon.

There are a number of related factors that could bias retrospective results against patellar tendon grafts. Given the fact that many of these related factors are under the surgeon’s control, it would seem prudent to correct these factors rather than totally eliminate the patellar tendon as a graft source. Nevertheless, it is readily apparent from this study that the patellar tendon autograft may be a “riskier” choice, particularly in older patients with acute injuries.

Causes of IPCS

In our original study, we relegated the majority of IPCS cases to the primary group.26 However, with added experience and longer followup we became increasingly aware of subtle and not-so-subtle surgical causes of IPCS such as nonisometric graft placement, high initial graft tension, and excessively large grafts (or too little notchplasty). Although many of these errors may lead to pathologic laxity in the knee, IPCS can ensue if the errors occur in combination with patients having greater scarring potential, too little or too aggressive physical therapy, persistent quadriceps weakness, and knee immobility.

Timing and type of index procedure

The opinion that surgery in the acutely injured knee predisposes the patient to arthrofibrosis is nearly unanimous.13,15,22,30,32,34 In this series, acute was defined as the interval of 0 to 6 weeks between injury and index procedure. Among those patients undergoing ACL reconstructions who had good results, 7 of 13 (54%) were operated acutely. This contrasts with 10 of 12 (83%) acute operations for those with poor outcomes and 15 of 19 (79%) acute operations for those developing patella infera. However, for patients who needed only one or two secondary procedures for correction of IPCS, only 9 of 25 (36%) had ACL reconstructions in the acute phase. This contrasts sharply to a 72% incidence of acute operations among those 18 patients who necessitated three or more secondary procedures. Thus, in this series it is apparent that index surgery performed acutely may lead to a more refractory type of IPCS. From the data in this study and review of the literature, it seems most prudent to wait for inflammation to subside and for the patient’s range of motion to return to more normal levels before adding further insult to the knee. An arbitrary time designation is not appropriate. “Reading the soft tissues,” regardless of the time from surgery, would be more prudent.

The fact that ACL surgery predominates in an IPCS study but not in arthrofibrosis studies appears logical. Knee stiffness can occur from a variety of conditions, but IPCS is a result of severe fibrosis of the anterior knee tissues (e.g., fat pad, patellar tendon), which are potentially more at risk with ACL graft procurement, placement, and fixation.

Associated procedures

Although Graf and Uhr13 noted a correlation between limited motion and associated ligamentous injuries and meniscal repair,22 other investigators have failed to elucidate this relationship.14,32 This study found no significant relationship between arthrofibrosis and concurrent extraarticular reconstruction, associated ligament repair, or
meniscal repair performed with ACL reconstruction, unless it was performed nonanatomically.

Timing and type of corrective procedures

At first glance, it seems that there are conflicting data in this series with regard to the proper timing of corrective procedures for IPCS. This can be explained by the fact that a large number of corrective procedures were performed before the patients entered our treatment protocol. Pre-protocol procedures that failed to correct the IPCS were predominantly closed manipulation or arthroscopic debridement performed early while the knee was still "hot." On the other hand, protocol procedures were timed to allow the soft tissues to "cool down." Protocol procedures were predominantly open debridement followed by arthroscopic debridement at a later date if needed. Those with multiple procedures most frequently underwent a manipulation under anesthesia and, in fact, had a closed manipulation at the first attempt (76% of the time). Closed manipulations were also the most common secondary procedure (90%) performed in those patients with a "poor" outcome. For IPCS cases, open debridement (with or without a DeLee osteotomy) is the procedure of choice. A manipulation or arthroscopy for initial treatment is rarely, if ever, indicated for IPCS. However, early arthroscopic debridement followed by manipulation may well be one's first choice if treating arthrofibrosis other than IPCS. Christel et al. noted significant morbidity and complications associated with manipulation under anesthesia for arthrofibrosis. Results in their series were significantly less satisfactory than those treated with arthroscopic debridement. The damaging effects of manipulation have been documented in animal and human investigations. Other studies further substantiate the value of arthroscopic debridement for early intervention of the (non-IPCS) arthrofibrotic knee.

Postoperative care

Although it is typically thought to lead to arthrofibrosis, immobility was not a significant factor in this review. In fact, virtually all of the patients (69 of 75) were engaged in some type of formalized physical therapy before or during the development of IPCS. Also, only 21 (28%) of the patients were immobilized after their index surgery or injury. Their immobilization period averaged 3.6 weeks (range, 1 to 6).

Those patients who underwent physical therapy were for the most part involved in therapy that only worsened their plight. Unfortunately, painful forced manipulation appears to be the treatment of choice by the majority of physicians and physical therapists when confronted with a stiff knee. Those patients in the good categories had a significantly lower number of manipulations and entered the author's treatment protocol significantly sooner, thus ending or avoiding painful aggressive physical therapy.

Patella infera

Although patella infera has been the subject of other studies, its association with IPCS had not been elucidated until our publication in 1987. Since that time, we are more convinced that the development of patella infera is a combination of muscular, biomechanical, and biochemical factors. As shown in Figure 5, lack of extension and inflammation in association with the unique anatomy of the fat pad, patellar plicae, patellar tendon, and the retropatellar
tellar tendon bursa can be responsible for IPCS. The patellar tendon shortening that can develop is the result of several conditions occurring simultaneously. First, the patella becomes entrapped both superiorly and inferiorly with the knee in flexion. The quadriceps weaken and the patellar tendon relaxes. The retropatellar tendon bursa will become fibrotic, effectively moving the distal patellar tendon attachment superiorly and increasing the posterior-inferior forces on the patella (Fig. 6). The fat pad will have tethered the distal pole of the patella to the anterior tibial plateau, and the patellar tendon will undergo collagen reformation and cross-linking, a process well elucidated in studies by Wojtys (unpublished data, 1992).

Twenty percent of the patients developed significant patella infera and eventually required a tibial tubercle osteotomy. This was associated with a relatively poor outcome, with Lysholm and Tegner scores lower than the overall series' averages. Seventy-nine percent of these 19 patients had ACL reconstructions on an acute basis, and a statistically significant 89% of the patients had a patellar tendon autograft index procedure. Additionally, it was found to be significant that 89% of these 19 cases had secondary causes of IPCS. They required an average of 4.5 secondary procedures for correction of IPCS, and tubercle osteotomies represented 12% of the total number of these secondary procedures. At final followup, this subgroup had the least amount of knee flexion when compared with the entire study population. Burks et al. noted significant decreases in patellar tendon lengths (9% to 10%) in dogs after removal of the central one third of the tendon. Our data would seem to support the hypothesis that patellar tendon autograft patients may be predisposed to tendon shortening and to the potential development of patella infera. It is notable that some cases displayed resistance to correction by tubercle advancement with a tendency toward recurrence of the infera over time.

Failures and complications of the authors' protocol

Two patients (three knees) failed to achieve the desired range of knee motion using the authors' protocol. The first patient was a 53-year-old woman who developed IPCS after an insignificant trauma and routine arthroscopy. After the authors' protocol was instituted, the patient underwent other (nonprotocol) corrective procedures and failed to progress in follow-up physical therapy. The patient ultimately underwent total knee arthroplasty but still demonstrated severely reduced knee motion at last report.

The second patient was a 30-year-old woman who suffered bilateral ACL-MCL injuries during a ski accident. She underwent simultaneous acute ACL repair and reconstruction using the semitendinosus tendon as the graft source. Despite multiple procedures (bilateral), the patient failed to regain functional knee motion in either knee. The fact that both knees were involved severely hindered the treatment protocol, and at last followup, the patient was scheduled to undergo bilateral external skeletal fixation procedures.

There were no major complications in this series. However, the potential for skin loss, infection, and tibial

Figure 6. A, formula depicting the normal patellofemoral joint reaction force with active quadriceps extension. B, scarification of the posterior patellar tendon to the anterior tibial surface results in proximal migration of the "effective" attachment of the patellar tendon. This increases the $\theta$ and $\alpha$ angles, thus increasing the patellofemoral joint reaction force and the tendency for the patella to migrate inferiorly and posteriorly. C, radiograph depicting severe patellar infera secondary to infrapatellar contracture syndrome.
tubercle nonunion still exists. Early in the series, two patients developed superficial skin loss at the incision edges when subcuticular running sutures were used to close the incision. After converting to interrupted staple closure, no further wound complications were encountered.

One patient developed a tibial stress fracture at the osteotomy site 4 months after surgery. The fracture healed spontaneously after the patient remained nonweightbearing on crutches for 6 weeks. Another patient sustained a minimally displaced tibial fracture at the tibial osteotomy site during manual manipulation at the time of surgery. Obviously, the depth of the osteotomy cut should be minimized and any manual manipulation should be performed before osteotomy to avoid this complication.

The most common causes of failure with the authors' protocol were 1) failure to recognize the need for intra- or extraarticular releases, 2) failure to release the patellar tendon off the anterior tibial surface, 3) reinitiation of forced, painful physical therapy modalities, and 4) initiation of a surgical protocol before allowing the knee to progress from an indurated and weakened condition to a less irritated and less painful condition with adequate quadriceps strength.

PREVENTION

The morbidity associated with IPCS is profound, and it would be far better to prevent IPCS than treat it. Unfortunately, there is no screening method available to detect those patients who are susceptible to developing IPCS. However, by being aware of associated factors one may be able to reduce the chances of developing IPCS.

The following suggestions are based on statistically significant findings in this paper:

1. Perform surgery in the acute phase only if motion is near normal and there is minimal inflammation.
2. Perform extraarticular procedures on older or acutely injured patients only when absolutely necessary.
3. Anticipate risks associated with using patellar tendon autografts in older patients, acute injuries, and knees with physiologic patella infera.
4. Employ procedures that advocate near-isometric ligament placement or repair.
5. See the patient early and often and decrease painful, forceful physical therapy modalities if the patient is not progressing.

In addition to these suggestions, there are a number of "opinions" that we have developed based on our experiences and observations. The following suggestions were not evaluated in our paper and can only be offered as possibly helpful:

1. Avoid surgery if a quadriceps lag is present.
2. Resect redundant plicae and avoid fat pad trauma at the time of surgery.
3. Perform a lateral retinacular release if lateral patellar compression syndrome is present (negative passive patellar tilt).
4. Use immediate passive range of motion and include full extension.
5. Teach passive patellar glide (manual) techniques to the patient.

CONCLUSIONS

A retrospective review of the long-term outcome of IPCS with a series of 75 patients was completed. Although the desired range of motion was achieved in a majority of the patients, the residual symptoms, patellofemoral dysfunction, and activity-related pain and swelling were significant. A better result was achieved in those patients with primary IPCS who were younger and had fewer corrective procedures. The worst results were in those patients who were operated on acutely, had patellar tendon ACL grafts harvested, developed patella infera, and required a larger number of corrective procedures.

A selective approach to arthrofibrosis, which includes nonoperative and operative procedures, appears effective. Early detection of the more recalcitrant variant of arthrofibrosis, IPCS, is crucial. However, prevention is the only true way to avoid the morbidity associated with IPCS. Suggestions have been given to help avoid this devastating complication.

REFERENCES