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Fate of the ACL-injured Patient

A Prospective Outcome Study*

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ABSTRACT

We followed 292 patients who had sustained an acute traumatic hemarthrosis for a mean of 64 months. The KT-1000 arthrometer measurements within 90 days of injury revealed the injured knee was stable in 56 patients and unstable in 236. Forty-five unstable patients had an ACL reconstruction within 90 days of injury. Surgical procedures performed >90 days after injury included ligament reconstruction in 46 patients. Factors that correlated with patients who had late surgery for a meniscal tear or an ACL reconstruction ($P < 0.05$) were preinjury hours of sports participation, arthrometer measurements, and patient age.

Follow-up data are presented for the patients divided into four groups: I, early stable, no reconstruction; II, early unstable, no reconstruction; III, early reconstruction; and IV, late reconstruction. No patient changed occupation because of the knee injury. Hours per year of sports participation and levels of sports participation decreased in all groups. Joint arthrosis was documented by radiograph and bone scan. Joint surface injury abnormalities observed at surgery and meniscal surgery showed greater abnormalities by radiograph and bone scan scores ($P < 0.05$). Reconstructed patients had a higher level of arthrosis by radiograph and bone scan.

Anterior cruciate ligament injuries are common. The greatest number of these injuries occurs in sports activities, principally those that involve deceleration, twisting, cutting, and jumping movements. In a study of ski injuries, Feagin et al.[34] reported 72 ACL injuries per 100,000 skier-days and estimated over 100,000 ACL ski injuries in the U.S. per year. In a football injury study, Hewson et al.[46] reported 2.4 injuries per year on an American college football team. Many patients are left disabled for sports after an ACL injury; others appear to have minimal impairment. Some patients develop secondary meniscal tears and degenerative arthritis of the knee; others show little joint deterioration. Few studies have documented the incidence of late meniscal tears after an ACL injury.[5,44,70] Because of the variability of patient impairment after an ACL injury and the lack of documentation that ACL surgery prevents degenerative arthritis, there is controversy over the indications for ligament surgery.

The purpose of this prospective study was to document the outcome of the ACL-injured patient and search for factors identifiable early after injury that correlate with a greater risk of functional impairment, secondary meniscal tears, and joint arthrosis.

MATERIALS AND METHODS

Patient population

Between August 1981 and June 1986 all members of the San Diego Kaiser Health Plan who were evaluated in the San Diego Kaiser emergency department with a swollen knee after an injury were referred to a knee injury clinic in the orthopaedic department. During the study period, the health plan averaged 256,000 members. Approximately 800 patients a year were evaluated with knee injuries. History of the knee injury and any prior knee problems as well as the clinical examination were recorded on a protocol knee injury form. Joint effusions were aspirated to identify patients with a hemarthrosis. An AP and lateral radiograph was performed on all injured knees. Additional views were performed in some patients to identify fractures and patellofemoral abnormalities. The clinical laxity examination included varus-valgus stress tests in 30° of flexion to diagnose collateral ligament injuries[16] and the quadriceps active test in 70° to 90° of flexion to diagnose a posterior cruciate ligament disruption.[22] There were 389 patients

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with an acute traumatic knee hemarthrosis documented by joint aspiration who met the study admission criteria as listed in Table 1.

Between 1988 and 1990 a final follow-up evaluation was performed. Four patients had died and 87 could not be located. Thus, 298 patients were available for evaluation. These patients were offered transportation cost reimbursement and compensation for lost wages to encourage them to come in for an evaluation. There are 292 patients included in the follow-up study; 285 patients were interviewed and examined and 7 were interviewed by phone and not examined. Five patients refused to come in for an evaluation or be interviewed by phone. One patient classified as stable on the initial examination had posterior instability on the follow-up examination and was dropped from the study. There were 204 men and 88 women in the study group. There was no significant difference between the follow-up group of 292 patients and the 389 patients entered into the study with respect to age, sex, injury activity, treatment during the first 3 months after injury, or joint displacement measurements. The index injury occurred in a sports activity in 217 (74%) of patients. The incidence in the general population that met the criteria of admission to this study was 0.36 per 1000 health plan members per year. Two hundred sixty-six (91%) of the injured patients were aged 15 to 44; the injury incidence for patients in this age group was 0.8 per 1000 health plan members per year. The remainder of this report is confined to the 292 patients with a mean follow-up evaluation performed 64 months after injury (range, 46 to 113 months).

Sports participation

The patients were asked to name the two sports they participated in most frequently before injury. They were then asked to tell the number of weeks per year and the number of hours per week they played each sport. The number of hours per year of participation in the two sports was then calculated. There were no professional or major four-year college athletes in this study.

Motion measurements

A knee arthrometer was used to measure anterior-posterior joint displacement. Between August 1981 and June 1982, arthrometer measurements were performed with the KT-2000 arthrometer (MEDmetric, San Diego, CA), which records the displacement measurements on an x-y plotter.[18] Thereafter, testing was performed with the KT-1000 arthrometer (MEDmetric), a more portable instrument that displays the output on a dial.[22] Most clinical measurements were performed by author MLS. Between August 1981 and October 1982, arthrometer measurements (N = 62) were limited to the 89-N (20-pound) displacement test[18] and the quadriceps active test.[22] After October 1982 the manual maximum test was added to the testing protocol because it proved a more sensitive test of an ACL disruption (Fig. 1).[21,25] Injured minus normal knee displacement difference of less than 3 mm on all tests within 90 days of injury classified the knee as being found stable early by KT-1000 arthrometer examination (early KT stable). If any test within 90 days of injury revealed an injured minus normal difference of 3 mm or more, the knee was classified as being found unstable early by KT-1000 arthrometer examination (early KT unstable).

Many patients were examined more than one time within 90 days of injury. Examinations were performed in the clinic within 14 days of injury and before surgery on 286 patients. If the patient had a tense effusion, the joint was aspirated before the arthrometer measurement to allow satisfactory stabilization of the patella during testing. A second examination was performed in the clinic on 119 patients within 14 to 90 days after injury. Beginning in October 1982 an arthrometer examination was performed under anesthesia by the surgeon before arthroscopy; 122 patients had an examination under anesthesia within 90 days of injury. Arthrometer measurements were performed at the time of all follow-up evaluations. The final evaluations were performed with the KT-1000 arthrometer and included the manual maximum test, the quadriceps

TABLE 1
Study admission criteria

Inclusion criteria
Acute traumatic hemarthrosis
Examination within 14 days of index injury
Lower limb injuries limited to the index knee
Exclusion criteria
History of injury or ailment in either knee before index injury
Diagnosis of an acute patellar dislocation
Soft end point to varus/valgus stress indicating a grade III collateral ligament injury
Positive quadriceps active test indicating a PCL injury
Standard knee radiographs reveal abnormal bone structures

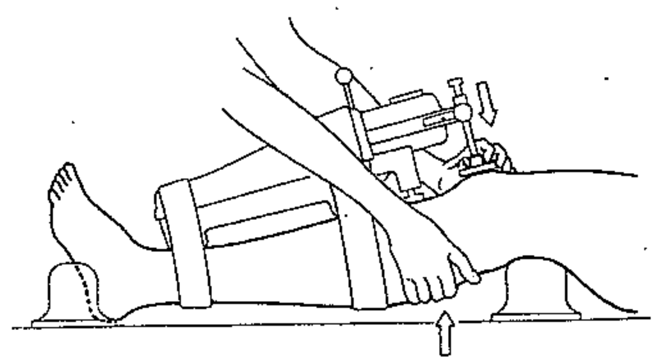

Figure 1. The KT-1000 arthrometer manual maximum test. The relaxed limbs are supported in about 30° of flexion. The patellar sensor pad is stabilized and the testing reference position is established by pushing with an 89-N load posteriorly and then releasing the force. While the patellar sensor is stabilized with one hand, the other hand applies a strong anterior displacement force directly to the proximal calf to produce the maximum anterior displacement. Care must be taken that the knee is not extended. The proximal load application allows forces of 30 to 50 pounds (134 to 222 N) while not extending the knee. Tibial displacement is read off the dial.

active test, and testing with an 89-N (20-pound) and a 134-N (30-pound) displacement force.

The pivot shift test was performed with the tibia in neutral rotation and the hip in slight abduction. It was graded as 0 (absent), 1+ (slight slip), 2+ (moderate slip), and 3+ (momentary locking).[16] Knee extension was measured as injured minus normal prone heel-height difference,[19,65] and knee flexion was measured as degrees of prone active flexion.

Patient management

Management decisions were made by the patients and their treating orthopaedic surgeons. Patients were encouraged to have a diagnostic arthroscopic examination; this was especially encouraged in those patients with joint instability. It was recommended that patients with a repairable meniscal tear and an ACL disruption have an early meniscal repair and ACL reconstruction. Other patients were generally encouraged to rehabilitate their knees and then test them in their desired sports activities before choosing to have ligament surgery. Young patients involved in vigorous sports activities with joint instabilities were told they may need to have their ACLs reconstructed. Many in this group elected to have early ACL reconstruction. Those patients who did not have early ligament surgery were directed in a home exercise program that emphasized bicycling, swimming, and hamstring isotonic exercises.[19] Joint immobilization or crutch ambulation or both were used during the first 2 weeks for comfort only. The patients were advised not to participate in running sports for a minimum of 3 months after injury and until the knee range of motion was full and there was no effusion. They were advised to not participate in Level I or II sports for 6 months (Table 2). If the knee was unstable by arthrometer measurements, a functional knee brace was advised for those participating in Levels I and II sports. After a 6-month period of rehabilitation, if the patient with anterior instability could not participate in his or her favorite sport or was having repeated giving-way episodes, ACL reconstructive surgery was recommended.

The early phase of patient care was directed by three orthopaedic surgeons. In this report the patient care is divided into the early phase (0 to 90 days after injury) and the late phase (more than 90 days after injury). During the course of the study, 298 diagnostic arthroscopies or surgeries were performed in 231 patients. There were 208 procedures performed during the early phase; 187 (90%) of these were performed within 21 days of injury.

With the exception of 1 procedure during the early phase and 12 procedures during the late phase, all surgical procedures were performed at the Kaiser Hospital. Operative reports of all procedures were reviewed by author DMD without reference to the patient history or outcome. Joint surface abnormalities were graded as follows: Grade 0, normal; Grade 1, fibrillation/fissuring of less than 1.3 cm; Grade 2, fibrillation/fissuring of 1.3 cm or more or cartilage erosion to bone of less than 1.3 cm; and Grade 3, cartilage erosion to bone of 1.3 cm or more or diffuse fibrillation/fissuring.[23] The segment of excised meniscus was recorded and the percentage of excised meniscus was estimated. Arthroscopy was performed with a 5-mm 30° and 70° arthroscope under general or spinal anesthesia.

Treatment after ligament surgery at the San Diego Kaiser Hospital consisted of a postoperative period of immobilization followed by a structured exercise and activity modification program that continued for 12 months after surgery.[19] Immobilization after surgery depended on the date of the operation. From August 1981 to February 1986, patients were immobilized in 30° of flexion for 3 weeks, followed by a range of motion brace with a 30° extension stop for an additional 3 to 5 weeks ($N = 67$). Between March 1986 and October 1989, the patients were immobilized in complete extension for 2 weeks ($N = 26$). The patient then used a brace to keep the knee in full extension while asleep and during the day used a brace that allowed motion from 30° to 120° for 4 weeks.[19]

Follow-up evaluation

At the follow-up examinations, clinical evaluations were performed by authors MLS, BED, and DMD. The evaluation included the following studies: impairment and symptom inventory,[23] documentation of sports participation and occupation, Cybex strength testing at 60 deg/sec, one-legged hop for distance,[23,24,65] physical examination[16] including prone heel-height difference,[65] and KT-1000 arthrometer measurements. The number of hours per year that the patient was participating in preinjury sports as well as new sports was recorded. If the patient had changed sports activity this was recorded, as well as the reason the preinjury sport was discontinued. Sports and occupations were classified into functional levels as noted in Tables 2 and 3.[23]

Radiographs of both knees of 231 patients were taken at the final evaluation. These included 30° standing AP, 30° lateral, and tunnel views of both knees. A grade of 0 (normal) to 3 (severe) was assigned to each of six radiographic factors: osteophyte formation, subchondral sclerosis, femoral condyle flattening, subchondral cysts, ligament calcification, and joint space narrowing. Osteophytes were

TABLE 2
Sports levels description

Level	Activity
I	Jumping, pivoting, hard cutting (basketball, football, soccer)
II	Lateral motion. Less jumping or hard cutting than Level I (baseball, racket sports, skiing)
III	Other sports (jogging, running, swimming)

TABLE 3
Occupation levels description

Level	Activity
I	Activity comparable with Level I sports
II	Heavy manual work, climbing, working on an uneven surface
III	Light manual work
IV	Activities of daily living

graded according to size: 0, no osteophyte; 1, small (1 to 3 mm); 2, moderate (4 to 6 mm); 3, large (more than 6 mm). They were measured at eight sites: medial femoral condyle, medial tibial condyle, femoral notch, tibial spine, lateral femoral condyle, lateral tibial condyle, femoral aspect of the patellofemoral joint, and patella. Subchondral sclerosis was graded 0, no sclerosis; 1, mild; 2, moderate; and 3, severe. Sclerosis was measured at six sites: medial femoral condyle, medial tibial condyle, lateral femoral condyle, lateral tibial condyle, femoral aspect of the patellofemoral joint, and patella. Femoral condyle flattening was graded on medial and lateral sides from 0 to 4. Subchondral cysts were evaluated as 0, absent; 1, one to two small cysts; 2, multiple small or single large cysts; and 3, several large cysts. The sites were the same as described for subchondral sclerosis. Ligament calcification was rated 0 to 3. Joint space narrowing was graded 0 to 3 for the medial, lateral, and patella femoral compartments. The maximum possible radiographic score was 83. All films were evaluated by author DCF, who was blinded to the patient's diagnosis and as to which knee was injured.

There were 165 patients who had bone scans of both knees at final evaluation. Each patient received an intravenous injection of 15 to 20 mCi ^{99m}technetium methylene diphosphonate. Two hours later, scans in the anterior, posterior, and both lateral projections were performed. A GE Starcam gamma camera (General Electric Systems, Milwaukee, WI) was used. The film uptake was graded from 0 (minimal) to 4 (dense). Uptake was scored at each of six sites: medial femoral condyle, medial tibial plateau, lateral femoral condyle, lateral tibial plateau, patella, and femoral trochlea. Scores were then calculated for each compartment and summed for the total score in each knee. A maximum score of 24 was possible for any given knee. All scans were evaluated by author DJR, who was blinded as to the diagnosis and as to which knee was injured.

Data recording, processing, and statistical analysis

Study forms were used for all evaluations. The data were entered into a desk-top computer using the Ashton Tate DBase III Plus software program (Ashton Tate Corp., Torrance, CA). At the end of the study, the patients were divided into four groups based on the early-phase arthrometer measurements, the performance of ligament reconstruction surgery, and the interval between the index injury and the time of ligament surgery (Fig. 2). Group I, early stable, are patients who were early-phase KT stable and have not had a ligament reconstruction. Group II, "copers," are patients who were early phase KT unstable and have coped with their injuries without ligament surgery. Group III, early ACL reconstruction, are patients who had an ACL reconstruction within 90 days of injury. Group IV, late ACL reconstruction, are patients who had an ACL reconstruction more than 90 days after injury.

Unless otherwise indicated, for continuous variables (e.g., arthrometer measurements, Cybex test, one-legged hop test, age, hours of sports participation), one-way analysis of variance (ANOVA) was used to compare the groups. In cases where ANOVA proved significant, Tukey's studentized range test was used for post hoc analysis. The significance level was chosen as 0.05, and statistical power exceeded 60% for all parameters and 80% for most parameters. For categorical variables (e.g., rating scales used for pivot shift test, functional level, symptoms, and impairments), chi-square analysis was used to compare the groups. Again, significance level was chosen as 0.05. Stepwise discriminant analysis was performed to identify the combined factors that were most predictive of which KT unstable patient who had not been reconstructed during the early phase would require late meniscal surgery. The analysis was then performed to predict late ligament surgery. Significance level for entry into the model was 0.25.

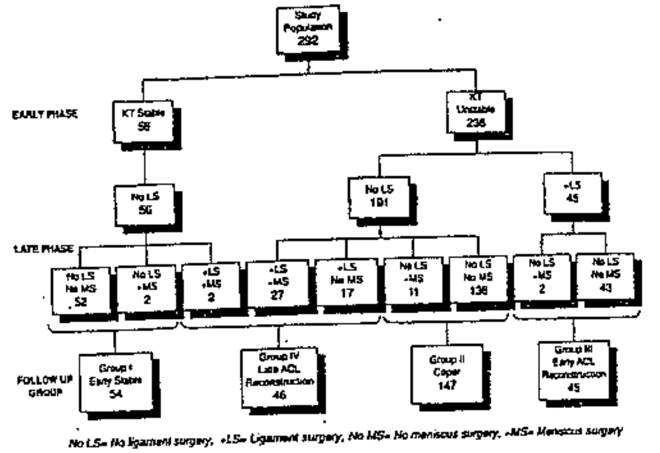

Figure 2. The study population divided into four groups. No LS, no ligament surgery; +LS, ligament surgery; No MS, no meniscal surgery; +MS, meniscal surgery.

Both imaging scores were not distributed normally, and could not be normalized using any of the standard transformations. Therefore, Kruskal-Wallis nonparametric ANOVA was used to analyze scores with respect to the four patient cohorts (Groups I to IV) and other categorical variables (pivot shift grade, "stable" versus "unstable," and the effects of meniscal injury and surgery). Post hoc comparisons employed Dunn's method. Frequencies of positive bone imaging scores were tested with respect to patient groups using chi-square analysis. Correlation of imaging scores with other continuous variables such as hours of sports participation and KT-1000 arthrometer displacement measurements employed least-squares linear regression.

RESULTS

Initial findings and surgical care

The mean time between injury and the first evaluation was 4 days. Fifty-six of the patients were KT stable and 236 were KT unstable (Fig. 2). Arthrometer classification for the patients who had undergone arthroscopy in the early phase is presented in Table 4. There were 144 patients with an arthroscopic diagnosis of a complete ACL disruption who had 89-N and manual maximum arthrometer tests on the first clinical visit; 96% were KT unstable (89-N test =

68%, manual maximum = 96%). A bar chart of the manual maximum measurements is presented in Figure 3. Under anesthesia, 95 patients with a complete ACL disruption were tested; 91 (96%) of these patients were KT unstable (89-N test = 76%, manual maximum test = 96%). Under anesthesia, 96% had a positive pivot shift. Early-phase arthrometer measurements are presented in Table 5 for patients who had both an 89-N and manual maximum measurement.

Early-phase arthroscopy in the 208 knees revealed 51 medial meniscal tears and 71 lateral meniscal tears in a total of 101 patients. Ten meniscal repairs and 55 partial meniscectomies were performed. No patient had more than 60% of a meniscus removed, and the average meniscectomy resected 35% of the meniscus. Forty-seven patients had hyaline cartilage lesion confirmed by arthroscopic examination. A summary of the findings in the patients in the early phase group is presented in Table 4.

Seventy-five patients had a total of 90 late-phase surgical procedures on the index knee (Table 6). Ten patients had surgery on their nonindex knees; one patient had had an ACL reconstruction. Ninety-one of the 292 patients (31%) had ACL reconstructive surgery, 45 patients in the early phase and 46 patients in the late phase. Only one of the 34 patients with an arthroscopically documented partial ACL tear had ligament surgery. Two of the patients treated with a late ACL reconstruction were KT stable in the early phase. Early arthroscopy revealed one patient had a complete ACL tear and the other patient had a normal ACL. The patient with the complete ACL tear became unstable over time; the patient with the normal ACL sustained an ACL tear in a second injury 18 months after the index injury. Before late ligament surgery 31 of the patients had sustained a second knee injury. Twenty-nine patients had meniscal surgery at the time of their late ligament surgery. In 19 of the patients, a medial meniscal repair was performed. Ligament surgery procedures are listed in Table 7.

TABLE 4
Early-phase arthroscopic findings

Anatomic site	Finding	KT unstable *N*	KT unstable %	KT stable *N*	KT stable %
Number		190		18	
ACL	Normal	2	1	9	50
	Partial tear	27	14	7	39
	Complete tear	161	85	2	11
Medial meniscus	Normal	143	75	14	78
	Tear, no surgery	21	11	2	11
	Tear, repair	9	5	0	0
	Tear, excised	17	9	2	11
Lateral meniscus	Normal	124	65	13	72
	Tear, no surgery	32	17	2	11
	Tear, repair	1	1	0	0
	Tear, excised	33	17	3	17
Meniscal surgery	Yes	54	28	5	28
Chondral lesions	Total number of knees with chondral lesions	44	23	3	17
	Medial compartment	24	13	3	17
	Lateral compartment	16	8	1	6
	Patellofemoral	25	13	2	11

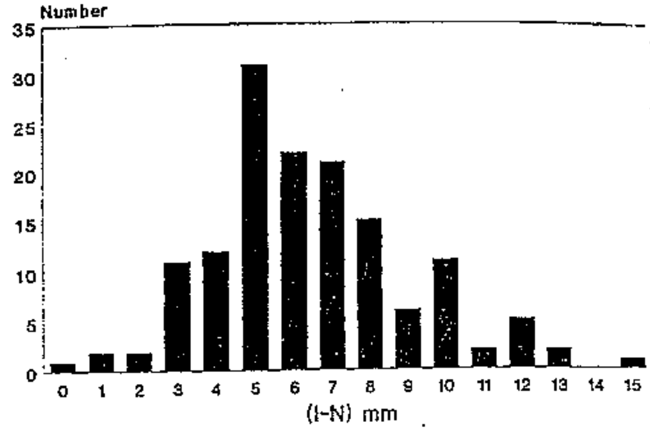

Figure 3. Manual maximum displacement on the first clinical examination frequency distribution of the injured minus normal (I-N) displacement difference in 144 patients with a complete ACL disruption examined in the clinic within 14 days of injury. The examination was performed before surgery.

Arthrometer measurements under anesthesia after reconstruction in 73 patients revealed a mean 89-N injured minus normal displacement of −1.5 mm. Sixty-nine of the patients had an 89-N reconstructed minus normal displacement of less than 3 mm (94%). Seven of the patients had a postsurgical manipulation under anesthesia to restore motion; 5 of these patients had been reconstructed early and 2 were reconstructed late.

A total of 16 surgical procedures were performed after ligament surgery. These procedures were treatment of infection (2), metal removal (4), arthroscopy (8), and a second ACL reconstruction (2). Six of the patients sustained meniscal tears after an ACL reconstruction. One meniscal tear was repaired and five were excised.

A total of 30 medial and 1 lateral meniscal repairs were performed in 27 patients. Ten were performed early and 21 were performed late. All patients needing meniscal repair had ACL disruptions. Six of the repairs were performed without reconstructing the ACL. In 3 of these patients there was no further surgery and in 3 the meniscus was repaired a second time when an ACL reconstruction was performed. Twenty-one patients had a meniscal repair with an ACL reconstruction. There was no further surgery in 18 patients. One patient had a second meniscal repair with a second reconstruction, and 2 had the meniscus subsequently excised.

Follow-up evaluation

Subsequent to the index injury, 11 patients had sustained a knee injury in their contralateral knees. Eleven patients had index knee ACL reconstructive surgery within 2 years

TABLE 5
Arthrometer measurements: millimeters of injured minus normal difference (I − N)

	Group							
	I		II		III		IV[a]	
	89-N	MM[b]	89-N	MM	89-N	MM	89-N	MM
Acute injury								
Clinic[c]	$N = 27$		$N = 115$		$N = 36$		$N = 37$	
I − N	−0.0	0.2	3.4	6.0	4.1	6.5	3.7	6.1
Anesthesia[d]	$N = 5$		$N = 58$		$N = 31$		$N = 28$	
I − N	−1.1	0.2	3.9	6.6	4.8	7.2	3.6	5.7
Postinjury (12 months)								
Clinic	$N = 20$		$N = 105$		$N = 33$		$N = 34$	
I − N	0.6	0.7	3.6	5.2	2.2	3.0	5.3	7.5

[a] Measurements taken before ligament surgery.
[b] Manual maximum displacement force.
[c] Within 14 days of injury.
[d] Within 90 days of injury.

TABLE 6
Surgery review of early-phase group

Months after injury	KT grade stable ($N = 56$)			KT grade unstable ($N = 236$)		
	Surgical exam	ACL reconstruction	Meniscal surgery	Surgical exam	ACL reconstruction	Meniscal surgery
0–3	18	0	5	190	45	54
9–12	2	0	0	25	15	13
13–24	1	1[a]	1	26	17	14
25–36	0	0	0	12	5	9
37–48	2	0	2	9	3	5
49–60	1	1[b]	1	4	2	2
61–72	1	0	0	6	3	5
73–84	0	0	0	1	1	1

[a] ACL disruption with second injury.
[b] ACL disruption with index injury.

TABLE 7
Ligament reconstruction surgery

Surgery	Early	Late
ACL repair and semitendenosus autograft	19	0
Bone block iliotibial band transfer	5	3
Patellar tendon autograft, over-the-top placement	19	22
Semitendinosus autograft, arthroscopic-assisted implantation	2	7
Patellar tendon autograft, double-tunnel placement	0	11
Other procedures	0	5
Total	45	48

of the follow-up evaluation. These 22 patients where excluded from the follow-up evaluation data. Evaluation data by groups are presented in the remaining 270 patients for sports participation, symptoms, and impairments.

Occupation and sports. No patient changed occupation because of the knee injury. Before injury, 38 patients worked at a functional level higher than Level IV, and at followup 60 patients worked at a functional level higher than Level IV. Before injury, more than 85% of all patient groups participated in a Level I or II sport 50 or more hours a year; at followup the percentage participating was reduced in all groups (Group I, 47%; Group II, 44%; Group III, 44%; and Group IV, 55%). The hours per year of participation in preinjury sports were also reduced in all groups (Table 8). Table 9 lists participation in the most frequently played Levels I and II sports preinjury and at followup.

Much of the change in sports activity over the 5-year period was because of changes in life-style not related to the knee injury. Before injury, 251 patients were participating in a Level I or II sport 50 or more hours a year. At followup, 127 patients had discontinued participating at this level. Thirty-three patients stated they discontinued a total of 54 Level I or II sports activities because of their knee injuries. Knee-related discontinuation of Level I or II divided by the number of Level I or II sports played before injury are

TABLE 8
Participation in Levels I, II, and III sports (hours/year/patient)[a]

	Group			
	I	II	III	IV
Age	25	29	24	22
N	53	139	45	33
Preinjury sports				
Preinjury	306	322	459	523
Followup	129	107	110	122
Followup (total sports)	217	223	268	281

[a] Significant difference ($P < 0.05$). Preinjury: Group I vs. IV, Group II vs. III, Group II vs. IV.

TABLE 9
Patients participating 50 hours per year or more in most frequently played Levels I and II sports[a]

Sports level	Group I (N = 53) PI	Group I (N = 53) FU	Group II (N = 139) PI	Group II (N = 139) FU	Group III (N = 45) PI	Group III (N = 45) FU	Group IV (N = 33) PI	Group IV (N = 33) FU
I								
Basketball	7	5	18	8	8	5	4	3
Football	8	3	17	0	4	0	2	0
Soccer	9	1	12	3	12	1	7	0
II								
Baseball	9	5	24	13	10	4	9	2
Racquet sports	6	3	26	16	7	6	6	6
Snow ski	1	1	12	1	1	1	0	2

[a] PI, preinjury; FU, follow-up evaluation.

Group I, 3/52 (6%); Group II, 33/143 (23%); Group III, 9/49 (18%); and Group IV 9/51 (18%). Before injury, 121 patients were participating in Level III sports 50 or more hours a year. At followup, participation had been discontinued in 37 Level III sports. In only two cases was the discontinuation in a Level III attributed to the knee injury. Brace use for sports by group was Group I, 2%; Group II, 14%; Group III, 11%; and Group IV, 18%.

Symptoms and impairments. Group I patients had fewer symptoms and impairments than those in Groups II, III, and IV (Table 10). Although 20% of the patients had symptoms of swelling, in only 3% was the swelling classified as greater than mild and infrequent. Swelling and difficulty with kneeling were more common in patients who had undergone reconstruction ($P < 0.05$). Eighty-three percent of the patients who had late ligament surgery said they were better after the ligament surgery; none said they were worse.

Functional tests. Functional tests were performed when the patient had not had ligament surgery in the preceding 24 months and had no lower limb problem other than the index knee. Equipment was not available to test some patients evaluated outside our clinic. Functional tests were performed in 245 patients. Group I patients had better performance on the one-legged hop for distance and quadriceps strength testing than those in Groups II, III, and IV ($P < 0.05$). The mean performance ratio involved/noninvolved is presented in Table 11 by group.

Motion measurements. Follow-up motion measurements were performed in patients who came in for a follow-up evaluation if the patient had not had ligament surgery in the preceding 24 months and had no problems in the contralateral knee ($N = 263$) (Table 12). There was no significant difference between groups in the contralateral normal knee on all tests: 89-N test ($P = 0.57$), 134-N test ($P = 0.46$), quadriceps active test ($P = 0.79$), or manual maximum test ($P = 0.41$). A significant injured minus normal difference was noted between Group I and the other groups ($P < 0.001$) on all tests. There was no difference between Groups II, III, and IV on the 89-N, 134-N, quadriceps active, or manual maximum tests. Anterior displacement measurements for both the early and late reconstructed population increased over time after ligament surgery ($P < 0.0001$), but at followup this was less than the prereconstructed condition ($P < 0.0001$). Because of guarding, a

TABLE 10
Symptoms and impairments—final evaluation

	Group I	Group II	Group III	Group IV
N	53	139	45	33
Symptoms (%)				
Pain (more than mild and infrequent)	11	21	27	24
Swelling	6	18	36	33
Giving way with sports	4	18	20	3
Giving way with ADL[a]	0	9	16	3
Impairments (%)				
Walk	8	6	11	11
Climb	10	24	36	24
Stairs	13	22	24	24
Kneel	21	37	64	64
Squat	19	40	40	55
Run	15	37	33	39
Jump	13	34	33	36
Cut	13	56	42	52
Impairments more than mild (%)				
Walk	0	0	0	0
Climb	0	0	4	0
Stairs	0	1	0	3
Kneel	2	2	16	12
Squat	4	4	13	9
Run	8	12	8	18
Jump	8	11	8	9
Cut	9	31	13	30

[a] Activities of daily living.

TABLE 11
Functional tests: Final evaluation—patient mean ratio involved/noninvolved

Ratio	Group I (N = 49)	Group II (N = 123)	Group III (N = 41)	Group IV (N = 32)
Hop				
Mean	1.00	0.95	0.94	0.91
≥0.90	48 (98%)	95 (77%)	34 (83%)	19 (59%)
Quadriceps				
Mean	1.05	0.97	0.90	0.90
≥0.80	49 (100%)	113 (92%)	37 (90%)	27 (84%)
Hamstring				
Mean	1.00	0.98	0.93	0.90
≥0.80	46 (94%)	113 (92%)	36 (88%)	30 (94%)

TABLE 12
KT-1000 arthrometer displacement measurements: millimeters of injured minus normal difference (I – N) follow-up evaluation

Displacement	Group I ($N = 53$)	II ($N = 134$)	III ($N = 43$)	IV ($N = 33$)
Quadriceps active				
Mean	0.4	3.0	2.4	2.4
<3 mm	89%	44%	49%	55%
89-Newton				
Mean	0.5	2.3	1.7	2.5
<3 mm	93%	55%	63%	61%
134-Newton				
Mean	0.6	3.1	2.3	2.8
<3 mm	92%	39%	49%	45%
Manual maximum				
Mean	0.7	5.0	3.7	4.3
<3 mm	91%	16%	33%	30%
Pivot shift % = 0	92%	16%	64%	48%

pivot shift test could not be performed on 11% of the patients at the follow-up evaluation. Results of those who could be tested are presented in Table 12. The mean heel-height difference was 1.7 cm (2°) in early reconstructed patients (Group III), which was greater than the heel-height difference in Groups I, II, and IV ($P < 0.05$). There was no difference detected in degrees of prone active knee flexion between the groups (Group I, 135; Group II, 134; Group III, 132; Group IV, 132) ($P = 0.15$).

Who had late surgery? Three factors known at the time of the first examination correlated with patients who had late surgery for a meniscal tear or an ACL reconstruction ($P < 0.05$): patient age, preinjury hours of sports participation, and the acute arthrometer examination measurements. Factors of interest that did not correlate with who had late surgery ($P > 0.1$) were sex, injury activity, hyperextension of the contralateral normal knee, AP displacement of the contralateral normal knee, pivot shift tests under anesthesia during the early-phase examination, and associated collateral ligament injuries. Based on the discriminant analysis, the most important single variable for predicting meniscal surgery or ligament surgery was total hours per year of Levels I and II sports participation before injury. Because of the correlation between age and sports participation, once sports participation was placed into the formula, age added no additional predictive value.

The second variable added to the equation was the manual maximum displacement difference. No additional variables improved the ability to predict which patient would have late meniscal or ligament surgery. Using these two variables, the linear discriminant function was calculated. The sensitivity and specificity of the formula to predict late surgery were tested in 158 early-phase KT unstable patients who had a manual maximum displacement measurement in the clinic within 14 days of injury. Thirty-seven of the patients had late ligament surgery and 30 had late meniscal surgery. A total of 45 (28%) patients had late ligament or meniscal surgery or both. The percent sensitivity/specificity of the formula for meniscal surgery was 53/75, for ligament surgery it was 46/78, and for late meniscal or ligament surgery it was 47/76. Thus, the equation is better at predicting who did not rather than who did have late surgery. A guide to the patients' surgical risk factor is presented in Table 13. The incidence of late meniscal or ligament surgery in patients with a low risk factory was 3/33 (9%), moderate risk factor 15/58 (26%), and high risk factor 27/67 (40%).

Imaging evaluation. An analysis of the precision of interpreting imaging studies was performed by having two independent observers evaluate the studies of 80 patients. Correlation was high both for total bone scan score ($r = 0.89$) and for total radiographic score ($r = 0.75$). Mean differences by compartment and total scores tended to have the same sign, indicating that the differences in interpretation between two observers were consistent. More importantly, relative scoring among the four groups was independent of observer. These results suggest that a single observer should score all images of a given type, along with a number of normal knees to determine a baseline score for comparison.

Bone imaging scores by group are presented in Figure 4. Radiographs revealed mild joint arthrosis after acute knee hemarthrosis. The average score among all injured knees was 5.8 (range, 0 to 32). The highest arthrosis score possible on the radiographic scoring system is 83. Bone scans revealed a greater level of arthrosis among injured knees: the average score across all groups was 8.6 (range, 0 to 24). The maximum bone scan score possible is 24. Interestingly, the area of graft tunnel placement in the reconstructed knees did not show increased uptake on bone scan. The bone scan frequently revealed a much greater level of arthrosis than did the radiograph.

At each site, the mean scores of injured knees were significantly greater than the scores in the contralateral uninjured knees ($P < 0.01$). Radiograph and bone scan scores varied similarly among the four groups. Minor changes were common after acute knee hemarthrosis, even in stable knees. The highest degenerative scores on both imaging modalities were observed in the reconstructed patients (Groups III and IV). Scores in uninjured contralateral knees revealed no differences among the groups ($P > 0.5$).

Radiographs of the injured knees revealed the medial compartment was most frequently involved (64%), followed by notch changes (63%), patellofemoral joint changes (50%), and lateral compartment changes (35%). Differences in frequency of degenerative change among the groups were significant by total score ($P < 0.05$), medial

TABLE 13
Surgical risk factor[a]

KT-1000 arthrometer manual maximum I – N	Sports hours per year (Level I or II) <50	50–199	≥200
<5	Low	Low	Moderate
5–7	Low	Moderate	High
>7	Moderate	High	High

[a] The risk of meniscal or ligament surgery more than 90 days after index injury in the early KT unstable population. The KT-1000 measurements were performed in the clinic within 14 days of injury.

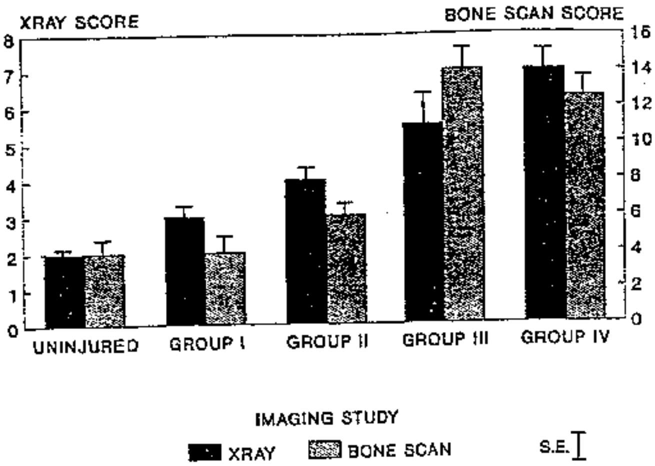

Figure 4. Imaging score by group. The index knees are listed by group. All contralateral uninjured knees are presented together.

compartment ($P < 0.05$), lateral compartment ($P < 0.05$), patellofemoral joint ($P < 0.05$), and notch ($P < 0.01$).

The most characteristic radiographic changes after acute knee hemarthrosis were osteophytes: 182 (79%) of 231 injured knees had osteophytes versus 106 (48%) in the 222 uninjured contralateral knees that underwent radiographic evaluation at followup. In all sites the frequency of osteophytes was significantly higher in the injured knee ($P < 0.05$). The reconstructed knees showed the greatest number of femoral notch and tibial spine osteophytes. The second most frequent difference between the noninjured and injured knee was femoral condyle flattening. There were 151 (65%) injured knees with femoral condylar flattening versus 90 (40%) of noninjured knees. The medial femoral condyle had a greater frequency of change than the lateral femoral condyle. Subchondral sclerosis was present in 100 (43%) injured and 56 (25%) noninjured knees. Joint space narrowing was observed in 90 (39%) of the injured knees and in 74 (33%) of the uninjured contralateral knees. The medial compartment was more often affected than the lateral or the patellofemoral compartment.

Radiographic scores correlated with bone scan scores both by total score ($P < 0.02$), medial compartment ($P < 0.01$), and patellofemoral compartment ($P < 0.01$). Lateral compartment radiographic scores did not correlate with lateral compartment bone scan scores. Joint surface injuries observed at surgery correlated with both radiograph and bone scan scores ($P < 0.05$). Patients who had meniscal surgery showed more abnormalities by radiography ($P = 0.0001$) and by bone scan ($P = 0.0002$).

Regression analysis revealed weak but significant linear relationship between total radiography scores and manual maximum displacement measurements ($P = 0.01$) and quadriceps active displacement measurements ($P = 0.01$) in patients who had not undergone reconstruction ($N = 155$). Total bone scan scores in the nonreconstructed patients ($N = 111$) revealed a linear relationship only with the manual maximum displacement measurement ($P = 0.03$). The pivot shift grade at followup did not correlate with imaging scores ($P > 0.1$). Current hours of sports participation per year did not correlate with imaging scores ($P > 0.5$).

Patients who had undergone reconstruction had a higher level of arthrosis by radiograph and bone scan evaluation, but they also had a higher incidence of meniscal surgery. A comparison of bone scan scores for patients who did not have meniscal surgery ($N = 115$) revealed a greater incidence of arthrosis in the reconstructed patients ($P < 0.05$). A comparison of radiographic scores for patients who did not have meniscal surgery ($N = 160$) revealed a similar trend, but this was not significant at the 5% level ($P = 0.07$).

DISCUSSION

A high percentage of patients with an acute traumatic hemarthrosis have sustained an ACL injury. Some authors have advocated arthroscopic examination of the knee with an acute hemarthrosis.[15,27,40,61] However, not all patients wish to undergo arthroscopy, nor perhaps is arthroscopy indicated. To include all patients who met our study criteria, we did not exclude patients who did not wish to have arthroscopy.

Clinical evaluation of anterior displacement and anterior end point with the Lachman test has been used by the clinician to diagnose an ACL disruption with test sensitivity ranging from 73% to 99%.[26,42,52] The KT-1000 arthrometer has been used to measure anterior-posterior displacement and to diagnose an ACL disruption. Some investigators have reported it to be a useful measurement,[3,7,14,37,69,71,80] while others have not found it useful.[36,51] To avoid spurious measurements requires careful instrument placement, patella stabilization, and patient relaxation.[20,21] Measurements in our clinic of 338 normal subjects with the KT-2000 arthrometer revealed a right/left difference of no more than 2 mm with an 89-N test, while 96% of 89 patients with a unilateral chronic ACL disruption had an injured knee/normal knee difference of more than 2 mm.[16] The KT-1000 arthrometer measurement of 120 normal subjects revealed a right/left difference of less than 3 mm with the 89-N test, quadriceps active test, and the manual maximum displacement test in 98% of subjects.[21] An injured knee/normal knee difference of 3 mm or greater is classified KT unstable. If the quadriceps active test in 70° to 90° of flexion is negative,[22] a KT unstable knee is an ACL-disrupted knee.

In our study, 161 (99%) of the 163 patients with confirmed complete ACL disruptions were KT unstable, while only 2 KT unstable knees had a normal ACL. Therefore, in this study there was a 98% probability that a KT unstable knee had an ACL disruption. The manual maximum test revealed the greatest displacement difference between the injured and normal knees and proved to be the most sensitive test of an ACL disruption. During the early period, the physician performing the arthroscopy diagnosed 34 partial ACL disruptions; 7 were KT stable and 27 were KT unstable.

The early KT grade was predictive of the later KT grade: 53 of the patients classified KT stable in the early phase were evaluated at followup and 91% were KT stable. One-hundred thirty-four patients classified as KT unstable during the early phase did not have ligament surgery and had arthrometer measurements at followup; 84% were KT unstable (Table 12). The mean displacement measurements in the Group IV patients increased from the early measurements to the measurements taken before their late reconstructive procedure, while in the Group II patients, the joint displacement decreased slightly over time, perhaps secondary to healing of the ACL disruptions[45] or to secondary stabilizing structures[10,73] (Tables 4 and 12).

During a 5-year period a total of 305 acute knee hemarthrosis patients with KT unstable knees were evaluated in a population of 256,000 health care members. Assuming that these knees had an ACL disruption, the incidence of an ACL disruption that met the study criteria was 0.24 per 1000 health plan members per year. A prior report on the incidence of acute ligament injuries between 1985 and 1988 from the San Diego Kaiser Health Plan membership included all ACL injuries, isolated and combined. The ACL injury incidence was 0.34 per 1000 health plan members per year.[56] Nielsen and Yde[58] reported an ACL injury incidence of 0.3 per 1000 population in Denmark during a 1-year period. Their report included patients with associated collateral ligament disruptions.

The incidence of ACL disruption in a patient with an acute traumatic hemarthrosis has been previously reported to range from 62% to 77%.[11,26,42,61] In this study, 81% of patients with acute hemarthroses were KT unstable. As has been previously reported, more than 50% of patients with acute ACL disruptions have associated meniscal tears, although many of these tears do not require surgery.[11,26,42,61,79] The incidence of meniscal tears in the patient with an acute ACL injury is high, although the incidence of repairable meniscal injuries is low. There is a higher incidence of meniscal repairs in patients having chronic ACL reconstructions (Fig. 2).[48,78] Chondral lesions were observed in 23% of our KT unstable patients who underwent arthroscopy, compared with previous reports of 16% to 23%.[42,47,61]

Most of the literature pertaining to patients with an unoperated knee with an ACL injury and the natural history of the ACL-injured knee is retrospective and has analyzed patients with chronic ACL disruptions with knee symptoms,[39,62] mixed patient populations with acute or chronic injuries,[35] patients with failed ACL repairs,[33] and patient populations gleaned from surgical logs[6,54,63] or hospital records.[50,57,67] Three prospective studies have been reported with a 4-year or more followup. Clancy et al.[13] reported a 4-year followup of 22 patients, Hawkins et al.[44] reported on a 4-year followup of 40 patients, and Andersson and colleagues[4,5] reported on a 58-month followup of 59 patients.

All of the patients in the Clancy et al. and Andersson and colleague studies were surgically evaluated. Clancy et al. treated 92 patients with acute ACL disruptions. They reconstructed 70 patients (those with a "moderate or severe" pivot shift), and treated nonoperatively 22 patients (those with an "absent, trace or mild" pivot shift). Andersson and colleagues randomized 156 patients into three treatment groups: ACL repair, ACL repair plus augmentation, and associated injury repair without ACL repair, which is the ACL nonoperative population. Fifteen of their non-ACL surgery patients had acute medial collateral ligament repairs, 10 had posterior oblique ligament repairs, and 1 had an arcuate ligament complex repair. Hawkins et al. did not report on what basis it was decided to treat their 40 ACL-injured patients without ACL ligament surgery or what percentage of their ACL-injured patients the nonoperative group represented. Twenty-five of their patients were evaluated surgically. The remainder of their patients were not examined surgically as "examination without anesthesia was sufficient for diagnosis in 15 of the patients, all of whom had a positive Lachman test, anterior drawer and pivot shift maneuver."[44]

Thus, there are a number of differences between the patient populations in these three studies and the present study. The present study included all patients who met the study admission criteria over a 5-year period. It also includes patients who did not choose to have a surgical evaluation of the knee and patients with a wide range of joint instabilities. The results of the prior studies will be cited as the results of the present study are discussed.

The patients with a stable hemarthrosis are presumed to have a normal ACL or a partial tear of the ACL. This population has been included in this report because follow-up studies have not previously been reported on this population and they serve as a comparison group to those patients with an unstable ACL-injured knee. This report is not an unbiased comparison of operative versus nonoperative management of the ACL-injured knee. The patients were not randomized into treatment groups, but selected their own treatment program. The populations are undoubtedly different in a number of ways. We documented that the patients who elected to have surgery were younger and more athletically active before injury. The main focus of this report is the outcome of the ACL-injured patient who did not elect to have early ACL surgery. How many patients coped with their problems without ACL surgery and at what price? It is instructive to compare their results with the outcome of the population with stable hemarthrosis, the early ACL-reconstructed patients, and the patients who underwent late reconstruction. This report is not an evaluation of a surgical procedure as a number of different surgical procedures were performed (Table 7).

Prior reports of ACL-injured patients have used a variety of reporting systems combining symptoms, impairments, range of motion, radiographic findings, and patient activity.[32,53,59,72,76,78,83] This requires assigning a relative importance to each item to allow a final score to be calculated. To permit the greatest opportunity to compare the outcome of the patients in this study with other studies, the results of each measurement parameter are presented and no total score or grade is assigned to the patient outcome.

Symptoms of pain and swelling were less in Group II than previously reported in patients with a chronic ACL injury.[44,55,62] Symptoms of giving way were also less than previously reported.[44,62,63] Disability for sports after ACL injury is the principle reason that patients request ligament surgery. Therefore, documenting pre- and postinjury sports activity is an important part of the patient evaluation. A number of systems have been used to document sports activity.[9,32,41,60,72,75,83] The essential elements are sport level, participation level, performance, symptoms during or after participation, and frequency of play or exposure. The International Knee Documentation Committee has divided sports into three levels based on the committee's perception of the risk of injury to the knee when participating in that sport (Table 3).

Reporting sports activity as hours per year of participation at a specific functional level provides a simple method of documenting sports activity that lends itself to comparison between groups. Persons involved in competitive athletics will usually participate a greater number of hours than those in recreational sports. The patient with greater symptoms while participating will participate less hours.[70] Therefore, hours per year of play reflects the participation intensity level and symptoms, as well as measures directly the patient's exposure. This system does not measure patient performance. If there is a change in activity, the patient is asked if the change is knee-related. There were a number of Group II patients who continued participation in Levels I and II sports.

Tests used to evaluate knee function have included strength testing[38,43,49] and the one-legged hop for distance.[43,49] Wyatt and Edwardo[81] reported 89% of normal subjects (N = 100) had a nondominant/dominant quadriceps strength ratio with isokinetic testing at 60 deg/sec of 0.8 or more and 90% had a hamstring strength ratio of 0.8 or more. The Group II patients in this study had a mean injured/noninvolved quadriceps ratio of 0.97 and a hamstring ratio of 0.98, greater than the quadriceps ratio of 0.86 and hamstring ratio of 0.90 reported by Kannus[49] in a study of 41 patients with ACL-deficient knees. The Groups III and IV reconstructed/noninvolved quadriceps ratio of 0.90 and hamstring ratio of 0.93 and 0.90 may be compared with the quadriceps ratio of 0.90 and hamstring ratio of 0.97 previously reported in 24 patients who had ACL reconstruction.[43] We reported a left/right one-legged hop for distance ratio of 0.9 or more in 95% of 100 normal subjects.[24] Barber et al.[8] reported 81% of 93 normal subjects had a hop ratio of 0.9 or more. Prior reports of the involved/noninvolved hop ratio in ACL-deficient patients of 0.9[76] and 0.82[8] are less than the mean hop ratio of 0.95 in Group II.

The ACL-injured patient is at risk of secondary meniscal tears. The previously reported incidence of late meniscectomy in the ACL-injured knee/years of followup are 16%/12 years,[70] 10%/4 years,[44] and 24%/5 years.[5] The incidence in the present study is 20%/5 years. An ACL reconstruction appears to protect the menisci; two of 45 patients who had an early ACL reconstruction had late meniscal surgery, an incidence of 4%.

Previous reports have documented that radiographic changes[12,41,44,55,62,67,70] and bone scan changes[29] occur in the patients with a chronic ACL-deficient knee. This is the first report that presents the prospectively studied results of imaging studies in a large ACL-injured population. Many patients had mild degenerative changes by radiographic evaluation and moderate changes detected by bone scan in the index knee. Some of the changes on radiograph and bone scan may be secondary to occult bone lesions sustained at the time of injury that are diagnosed by MRI in the majority of ACL-injured patients.[64] Meniscal surgery correlated with increased degenerative changes, which supports the findings of previous authors.[62,67,68,71] The relationship between osteoarthritis and meniscectomy has been previously documented.[31,48,74] This is the first report to correlate degenerative changes with displacement measurements.

The effect of ligament surgery on degenerative arthritis has not been reported. A disturbing finding in this study is an increased incidence of degenerative joint disease in patients with reconstructed knees, which can be explained in part by a higher incidence of meniscal surgery in the patients who have undergone knee reconstruction. However, a comparison of bone scan scores for patients who did not have meniscal surgery revealed a greater incidence of arthrosis in patients who had reconstructed knees. We propose five possible explanations for this occurrence: 1) greater injury in the reconstructed knees before surgery than in the patients who did not choose reconstruction, 2) joint injury occurring at the time of surgery, 3) the joint's response to stress deprivation after surgery,[1] 4) prolonged joint inflammation after surgery,[2,66] and 5) abnormal joint mechanics after surgery.[66] Hopefully, recent advances in ligament surgery technique[17] and earlier postoperative mobilization programs will decrease the incidence of degenerative changes after ligament surgery. We recommend that ligament surgery follow-up studies of 5 years or more include the evaluation of knee arthrosis.

The reported incidence of late ligament surgery in an ACL-injured population ranges from 25% to 38%.[5,30,44] Forty-four (23%) of the 191 KT unstable knees that were not reconstructed early were reconstructed late in this study. Most authors agree that there is a "high-risk" patient who should be treated with early surgery and a "low-risk" patient who should be treated nonsurgically.[27,61,77,82] There is general agreement that the patient's risk depends on age, sports activity, and degree of joint instability.[27,61,77,82] This study reports patient risk guidelines (Table 13).

CONCLUSIONS

1. Instrumented measurement of AP knee displacement is a sensitive test of a complete ACL disruption. Ninety-six percent (N = 144) of the patients with an ACL disruption documented by arthroscopy who were tested with the KT-1000 arthrometer manual maximum test on the first examination had an injured minus normal displacement difference of 3 mm or more.

2. There is a low probability (13%) that patients with an acute traumatic hemarthrosis that is found stable on instrumented examination will develop instability over a 5-year period.

3. A high percentage (49%) of patients with an acute ACL injury have a meniscal tear. Not all patients with a torn meniscus need meniscal surgery.

4. Total preinjury hours per year of participation in Levels I and II sports, and displacement measurements were predictive of who would not require late surgery.

5. Many ACL-injured patients who did not undergo knee reconstruction continued to participate in sports activities.

6. Patients who had meniscal surgery had a greater incidence of joint arthrosis than those who did not have this surgery.

7. Patients with an ACL injury who did not require meniscal surgery had a greater level of joint abnormalities by bone scan if they had ligament surgery than those who did not have ligament surgery.

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