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Outpatient Physical Therapy Management of a Young Male following Anterior Cruciate Ligament Reconstruction

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OUTPATIENT PHYSICAL THERAPY MANAGEMENT OF A YOUNG MALE FOLLOWING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

by

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This Scholarly Project, submitted by Leslie Harris in partial fulfillment of the requirements for the Degree of Doctor of Physical Therapy from the University of North Dakota, has been read by the Advisor and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.

(Graduate School Advisor)

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Signature(s) Jessica Harris

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ABSTRACT

Background and Purpose. This paper describes the physical therapy management of a 17-year-old male high school student, from two weeks post-operative to week 10 outpatient , after left anterior cruciate ligament (ACL) reconstruction. An intra-articular patella bone-tendon-bone graft as well as a medial meniscus repair and notchplasty were completed using video arthroscopy. The patient presented with decreased range of motion and strength in the left knee and slightly decreased strength in the left hip. **Purpose**. The purpose of this article is to describe the interventions used for this patient, the results from these interventions and to discuss current ACL treatment alternatives and their outcomes. **Description.** The treatment of this patient involved range of motion, strengthening, stretching, joint mobilization, proprioceptive/balance training, patient education on the condition and prognosis. **Outcomes.** Following PT intervention, the patient achieved full active range of motion, good to normal strength and an absence of edema and pain. The patient also returned to high school football at the end of the 10 week period with the permission of his attending physician. **Discussion.** A physician based rehabilitation protocol was utilized to quickly advance the client through the rehabilitation process. The accelerated treatment protocol resulted in early return to sports with good knee stability and limited complications.

Key words: Anterior Cruciate Ligament (ACL), Bone-Patellar Tendon-Bone Graft (BPTB), Range of Motion (ROM), meniscal repair, notchplasty, Full weight Bearing (FWB), open kinetic chain (OKC), closed kinetic chain (CKC).

CHAPTER I

INTRODUCTION

The anterior cruciate ligament (ACL) is one of the most commonly injured ligamentous structures in the knee.[1] An article by Noyes and Barber-Westin [2] estimates that approximately 102,000 patients have their ACL replaced on a yearly basis due to sports related injuries. The primary motions of the knee are flexion and extension while secondary motions such as rotation, rolling and gliding also occur at the tibio-femoral joint interface.[3] Considered a primary stabilizer of the knee the ACL has many functions considered critical to normal function of the knee.[4] For example, the ACL prohibits anterior or forward movement of the tibia on the femur. Thus, according to Prentice [3], the ACL also controls posterior movement of the femur if the tibia is fixed. The ACL has also been purported to serve as a secondary stabilizer to prevent rotation and limit varus and valgus stress.

For athletes, ACL reconstruction is the recommended course following an ACL injury. [4] Surgery combined with a comprehensive rehabilitation program allows the opportunity for the patient to return to a previous level of activity. In athletes who require a higher level of function and stability, such as those playing in competitive sports, the emphasis is on a return to sports at the same or even higher level than prior to injury. The current demands of the athlete and the sport itself now emphasize an ever faster return to sports.[5] Historically, ACL rehabilitation programs that once sought up to a year to achieve success now attempt to complete the rehabilitation process in four to six months or less.[6] Constant changes in sports and lifestyles and the increasing demands made on the body by these changes are more often the driving force behind today's treatment of joint injuries.

CHAPTER II

CASE DESCRIPTION

The subject of this case study was a 17-year-old Native American male who sustained an ACL rupture during a high school basketball game in February of 2005. The patient was jumping up to block a shot and heard a popping sound and recalled intense pain in his left knee. The patient immediately iced the knee and did not seek medical help until he re-injured it approximately three days later in practice. He reported, and it was noted in the chart, that he had minimal swelling and denied a previous injury to the knee.

The patient was examined by a pediatrician on 2/17/05 and was given a knee brace with instruction to ice the knee for 48 hours and rest the knee for one week. According to the medical record, the physician performed both the Lachman and anterior drawer tests, which were negative. The patient was not referred to an orthopedic physician until May 5, 2005 following a positive magnetic resonance image for ACL rupture on 4/13/2005. An intra-articular patellar bone-tendon-bone graft as well as a medial meniscus repair and notchplasty were completed using video arthroscopy under general anesthesia. Harvest of the patellar bone-tendon-bone graft was taken from the anterior joint.

The patient was not referred to physical therapy until 2 weeks after surgery. While in physical therapy he was seen 2-3 days per week for ten weeks. His goal was an early return to sports without re-injury. The patients' past medical history was unremarkable.

Examination, Evaluation, and Diagnosis

Evaluation and treatment of the patient was based on the requirements of the physician protocol and textbook management techniques.[7, 6] Using the hospital wide pain inventory scale (a 0-10 scale, with 0="no pain" and 10 ="worst pain imaginable") the patient reported an initial pain level of 4 of 10, reducing to a pain level of 0 of 10 or no pain throughout the remainder of the treatment sessions. The surgical site was closed with no apparent signs or symptoms of infection and minimal or no edema. The patient presented with a post surgical immobilizer (Bledsoe Lever Lock Brace, Grand Prairie, TX), with the locking mechanism set at 10 degrees of flexion. The patient was instructed to wear the brace at night and with daily activities such as walking. The patient was allowed to remove the immobilizer for bathing and recommended exercise.

The patient's initial weight bearing was limited to twenty-five percent of body weight using bilateral axillary crutches. Given the protocol parameters, he was progressed to 50% weight bearing (WB) and then full weight bearing (FWB) at the end of week four or end of phase II. The patient displayed a modified independent gait using bilateral axillary crutches with normal balance in a three point pattern. The patient displayed independent bed mobility and activities of daily living. By the initiation of physical therapy sessions, the patient had weaned off of all medications for pain management.

Range of motion (ROM) was reduced but ahead of the protocol ranges (See Table 1). All ROM measurements were obtained using a universal 16" goniometer according to established guidelines by Norkin and White.[8] The patient was supine and

the stationary arm of the goniometer was aligned with the femur while the movable arm was aligned with the leg. According to Gogia et al [9] intertester reliability and validity using a universal goniometer is high with average correlation coefficients of 0.98 (r) and 0.99 (ICC). The correlation coefficients for validity, range from 0.97 to 0.98 (r) and 0.98 to 0.99 (ICC). All subsequent measurements were completed in the exact same manner, using the same goniometer, same position, and same therapist

Manual Muscle Testing (MMT) was performed according to protocols set by Hislop and Montgomery. [10] Initial left knee strength (See Table 2) was 2 (poor strength) on a scale of 0-5 (0=no activity and 5=normal strength). All other lower extremity muscles tested normal for strength except for left hip flexion at 4+ (good plus).

Table 1. Knee range of motion summary

	Uninvolved		Involved	
	Flexion	Extension	Flexion	Extension
Initial	135	0	95	10
Discharge	135	0	135	0

Table 2. Knee strength summary

	Uninvolved		Involved	
	Flexion	Extension	Flexion	Extension
Initial	5	5	2	2
Discharge	5	5	4+	4+

Prognosis and Plan of Care

According to the *Guide to PT Practice*, the diagnosis of anterior cruciate ligament reconstruction allows for a course of treatment from 1 to 8 months and that the range of visits is 6-70 per episode of care.[11] This diagnosis falls under practice pattern IV-I, which is impaired joint mobility, motor function, muscle performance and range of

motion associated with soft tissue or bony tissue. The frequency of visits and duration of care is determined by the physical therapist to maximize effectiveness and service delivery. The identified ICD-9 Code for this preferred practice pattern is ICD-9-717, internal derangement of the knee.

A factor that may have influenced the duration and frequency of this patient's visit was the patient's young age and excellent overall health. He had no previous history of injury to the knee, was physically active in a variety of sports as well as daily exercise by running several miles a day. He was a non-smoker and had excellent family support for the procedure and the rehabilitation process. The patient received information and instruction prior to and following surgery in regard to the surgical and rehabilitation process.

The initial long term goal for this patient was as follows: Following PT intervention patient will return to previous level of activity without pain and with AROM and strength within normal limits in 16 weeks. The initial short term goals were as follows: 1) Following PT intervention the patient will increase AROM by 5-10 degrees within 1 week for eventual full athletic participation. 2) Following treatment the patient will increase strength by ½ grade or greater within 1 week for eventual full athletic participation. 3) Following PT intervention patient will be able to perform single leg standing with forward and lateral reaching for up to 60 seconds each, 5 consecutive times by 4-6 weeks for eventual full athletic participation.

Intervention

The patient was seen three to four days a week for forty-five minute sessions over a total of ten weeks. Treatment began with a review of precautions, a focus on a

transition to full weight bearing, weaning from the immobilizer and the establishment of a home exercise program. The home exercise program was completed independently three to four times per day and progressed based on patient report and demonstration of correct and safe technique.

The overall program consisted of exercise, proprioceptive/balance activities using a BAPS board, range of motion and gait. The ROM and strength were re-evaluated weekly. Cryotherapy was given at the end of each session to control edema and pain. The patient was given instruction with a review of precautions on the use of an ice bag/cold pack for home use and educated on the use of ice to control inflammation and pain following exercise. Exercises such as bilateral squats with ball squeeze were added in an effort to elicit quadriceps contraction.

Goals defined by the physician protocol included full active range of motion, good to normal strength, minimal or no pain, increased balance and proprioceptive sense with the end goal of return to sports without re-injury.[7] The physician also stated that obtaining 80% of functional strength in comparison to the non-involved extremity would allow a return to sports. This would include completion of a functional hop test and testing of joint laxity using the KT-1000 at the patient's next physician visit. The patient's stated goal was an early return to sports.

To prohibit shear forces on the ACL during strengthening, the physician protocol limited active range of motion (AROM) of the knee during open and closed kinetic chain exercise. Other precautions included monitoring development of patellofemoral irritation and avoidance of closed kinetic chain terminal extension for 8-10 weeks with limitations

in strengthening from 90-20 degrees. Open chain quadriceps activities were limited from 40 degrees to terminal extension until 10-12 weeks.

During Phase II (1-4 weeks postoperative) closed chain activities such as bilateral mini-squats were initially limited to 30 degrees of knee flexion. The terrific ten exercises were continued up to 30 repetitions 3-4 times per day as well as continuation of extension stretching activities such as prone hangs and heel props. The terrific ten exercises were as follows, straight leg raise, heel slides, passive knee flexion and extension, isometric hamstring, quadriceps and gluteus exercises, abduction slides, ankle pumps, and prone hangs for extension. To also assist in range of motion, biking was implemented at the beginning of each session starting at 5 minutes and was increased to 10 minutes. All strengthening exercises were begun at 2 sets of 15 repetitions each and progressed to 30 repetitions. Bilateral calf raises as well as bilateral leg press within range of motion limitations of 70-10 degrees were added to the patient's regimen; beginning at 50 lbs and progressing by 10-20 pounds as repetitions were increased to 30 repetitions. Forward step-ups starting at 2" and progressing to 6" were begun as was treadmill ambulation on level surfaces. Multi-hip strengthening with heavy resistive elastic band was added with the band placed above the knee. To address proprioception and balance, single leg standing with eyes open was added and progressed to eyes closed at 1minute to eventually 3 minutes.

Use of the local hotel pool was obtained for the patient and was incorporated into his routine. Exercises that were deemed appropriate were modified for the patient's pool routine. Resistance was provided by an inflatable tube that was wrapped around the patient's lower extremity to cause a drag in the water when the patient moved the

limb during activity. Precautions remained in effect and the tube was initially placed above the knee; later in the regimen it was lowered to a proximal placement on the calf; this was done to reduce the shear forces on the graft during strengthening. Precautions obtained in the physician protocol were continued, limiting active range of motion (AROM) of the knee during open and closed kinetic chain exercises. Hospital regulations directly prohibited the physical therapist from observing the pool exercises. The pool instructions were given with a demonstration while in the treatment facility. The patient reported diligence in adhering to the pool exercise precautions.

At the end of phase II, the patient demonstrated an AROM of 120 degrees of knee flexion and zero degrees of knee extension. Knee strength was a 3 + (fair plus) for flexion and extension which was also obtained by the end of Phase II.

Phase III (4-6 weeks postoperative) found the patient with full range of motion and fully weight bearing. Some of phase II exercises were continued and the patient was progressed to a single leg press between 70-10 degrees of flexion and up to 30 repetitions at 50 pounds initially, increasing by 10-20 pounds as tolerated. Lateral step-downs of 4-6" were added to tolerance. Patient initiated single leg mini squats to 45 degrees. Aquatic exercises continued with modification of land exercises during this phase.

During Phase IV (6-10 weeks postoperative) Phase III exercises were continued and progressed. The patient implemented open chain leg extension from 90-40 degrees with proximal placement of the resistance pad. The treadmill incline was increased to 20% for both forward and backward ambulation. Step ups in all directions were added and progressed to 8" as tolerated. During this phase the patient began to

implement phase V (10-16 weeks postoperative) exercises. He demonstrated good control during performance of 25 single leg squats to 45 degrees as well as controlled landing on bilateral leg jumps up to 6" progressing to single leg jumps with good control.

The patient had also implemented goals from Phase VI (16-20 weeks postoperative) during this phase. Bilateral to single leg rotational jumps and controlled landings from a 12" box were completed without problems. Running at half speed for 3-5 minutes was started and progressed to 10 or more minutes in forward and backward movement. Backward running was begun at an incline of 20-30%. Cutting movements, such as a wide figure eight, were also added to mimic return to sport activity such as football and basketball.

The patient was extremely motivated and worked, often with family assistance, approximately 4 times per day on his home program. The patient frequently exceeded his goals for the established phase and was at times cautioned to slow down. The addition of the meniscal repair at the time of ACL reconstruction placed initial delays on ROM and weight bearing progression. However, given his early achievements in both AROM and strength the patient was allowed to proceed with a progressive ACL protocol one week into the treatment program. Stability was determined to be excellent including Lachman sign, lateral collateral ligament straining and radiographic images showing good position of tunnels and no abnormalities. After an initial extensor lag of 10 degrees that resolved three weeks post operatively (one week into therapy), and the establishment of normal, full weight bearing gait, the immobilizer was discontinued at four weeks.

Outcomes at Discharge

At the end of Phase IV (6 to 10 weeks post-operative) the patient achieved full knee flexion and extension (see Table 1). Knee strength also improved demonstrating a manual muscle test score of good to good plus strength (see Table 2). At ten weeks post operatively, the patient had met the goals not only for phase V but for post operative phase VI (16 -20 weeks post operative). He returned to his orthopedic physician ten weeks post operatively where it was determined that he had met the physicians pre-set goal of achieving 80% functional strength in the involved knee in comparison to the non-involved and he was allowed to return to sports in the fall. This was ascertained on the last physician visit by the physical therapist using a KT-1000 arthrometer and completion of a functional hop test with good control and no report of pain.

No clinometric scale was used at any time in the treatment of this patient. However, the Lysholm Knee Scale[12] could have been used to assess the patient initially and at discharge. The scale is a self evaluation format that measures outcomes in eight domains with a scoring range of 0-100. It is easy to use and originally designed for assessment of ligament injuries of the knee but has been used for a variety of knee conditions. Briggs et al [12] conducted a study to determine the psychometric properties (reliability, validity and responsiveness) of the Lysholm Knee Scale and the Tegner Activity Scale for patients with meniscal injury of the knee. The Lysholm test-retest reliability rating was deemed acceptable with an overall 0.927 ICC (95% confidence interval 0.90-0.95).

CHAPTER III

DISCUSSION

Considered one of the most commonly injured knee ligaments in sports, the ACL's function as a primary stabilizer makes it an important component in returning the athlete to a previous level of function by rehabilitation specialists and physicians.[1, 4] The type of graft, age or fitness of the patient, choice of surgical procedure and type of post-operative rehabilitation program all factor into the outcomes. The question of how to overcome complications, such as limitations in ROM, decreased strength and anterior knee pain, while still maintaining knee stability, is the overall focus of researchers and providers.

In the case of ACL reconstruction, numerous studies are carried out each year in an effort to assess the quality of the reconstruction process.[13] Yet, despite all the research there is still no definitive answer for an optimal surgical approach and rehabilitation program. Many disagree on the type of graft which should be utilized as the best alternative to the native ACL. In this case, an intra-articular bone-patellar tendon-bone graft was used to form the ACL. In the past, it has been the graft of choice over a variety of hamstring choices.[13] Some believe the patellar graft to have many of the same properties of the ACL and thus a stronger choice. Others contend that both hamstring and BPTB have individual qualities that appear to improve a patient's outcome.[1, 4]

Controversy remains over the right choice of graft. In regard to the patellar tendon graft, concerns remain about damage to the knee extensor mechanism, subsequent anterior knee pain, possible patellar fracture, ligament rupture and

infrapatellar contracture. On the other hand, there are also concerns over the harvest of the hamstring graft and its effect on the muscle function of the hamstring.[14] According to Foster and Foster, studies comparing BPTB and four-strand hamstring grafts (4SHS) have found similar results in both types of grafts. Some of these studies have concluded that the BPTB grafts were significantly better in achieving higher post-operative activity levels, static stability and lower graft failure but in these studies the hamstring group consisted of both two and four strand grafts. Not analyzing the four strand hamstring grafts independently may have led to bias towards the BPTB graft.[15] Nonetheless, there appears to be no difference between the grafts in terms of Lachman testing, the return to previous level of sport, clinical knee scores, graft failures, static knee stability or other complications.[15] Taking into consideration the advantages and disadvantages of each graft there are very few differences between them.

The type of exercise and level of activity is also of interest. Questions as to the benefits of using open vs. closed chain exercises and when to introduce the exercise in the rehabilitation program have been considered. In addition, the safety of the graft and joint stability in regard to accelerated vs. non-accelerated programs is also a concern. Mikkelsen and associates[16] found that patients introduced to OKC exercises as well as CKC exercises displayed an increase in quadriceps torque without a reduction in joint stability; leading to a higher number of athletes returning earlier to a previous level of activity. ACL reconstruction with BPTB graft followed by either accelerated or non-accelerated programs produces no difference in anterior knee joint laxity.[17] Others believe that the early mobilization as well as FWB activities is possible without

endangering the healing tissues.[18] Accelerated rehabilitation, it seems, does not compromise joint stability, nor does it predispose a patient to re-injury.[17, 19]

In this case, the patient was an extremely motivated young male with the goal of returning to high school football in the fall season. The initial protocol delays in WB and ROM secondary to meniscal repair were discontinued early with evidence of good knee stability. The protocol also limited ROM in relation to strengthening and exercise to limit shear forces on the healing graft.[6] Closed chain exercises such as squats or the leg press appeared to offer the safer choice in regards to limiting stress on the graft.[6] According to Bynum et al [20] including closed chain exercises in the post-ACL rehabilitation resulted in lower KT-1000 arthrometer side to side differences and less anterior knee pain. Patients, they concluded, were more satisfied with the end results and often returned to previous activity sooner than expected.

The patient in this case study frequently achieved goals ahead of his current phase. At ten weeks post operatively, the patient had met the goals not only for phase V but for post operative phase VI (16 -20 weeks post operative). Considered to have 80% functional strength he was given the go ahead by the physician to incorporate phase VII activities into his routine and return to sports. He was discontinued from therapy at approximately ten weeks but continued with his home program and aquatic exercise independently. His coach was made aware of the injury and rehabilitation intervention by the parents. The coach slowly reintroduced the individual into practices and games, ultimately obtaining normal playing time mid-season. The patient has also completed a full season of basketball without re-injury.

Reflective Practice

It is unusual for most patients to return to sports so early in recovery. In most cases, even the most gifted athlete does not see a return to sports in 10 to 12 weeks following ACL reconstruction. Given the variety of choices in types of grafts now being used, related surgical techniques and associated complications, an ideal ACL intervention for everyone remains elusive. An individual's level of fitness, their age and type of sport as well as their level of commitment and type of rehabilitation program are factors in recovery.

The results of this patient may not be considered typical given the shortened time frame. This author would however, utilize a combination of OKC and CKC exercises for future patients that have undergone ACL reconstruction. Whether or not to use an accelerated program will be based on the individual patient. This author would also incorporate a functional scale at the initial stages and end of the overall treatment process.

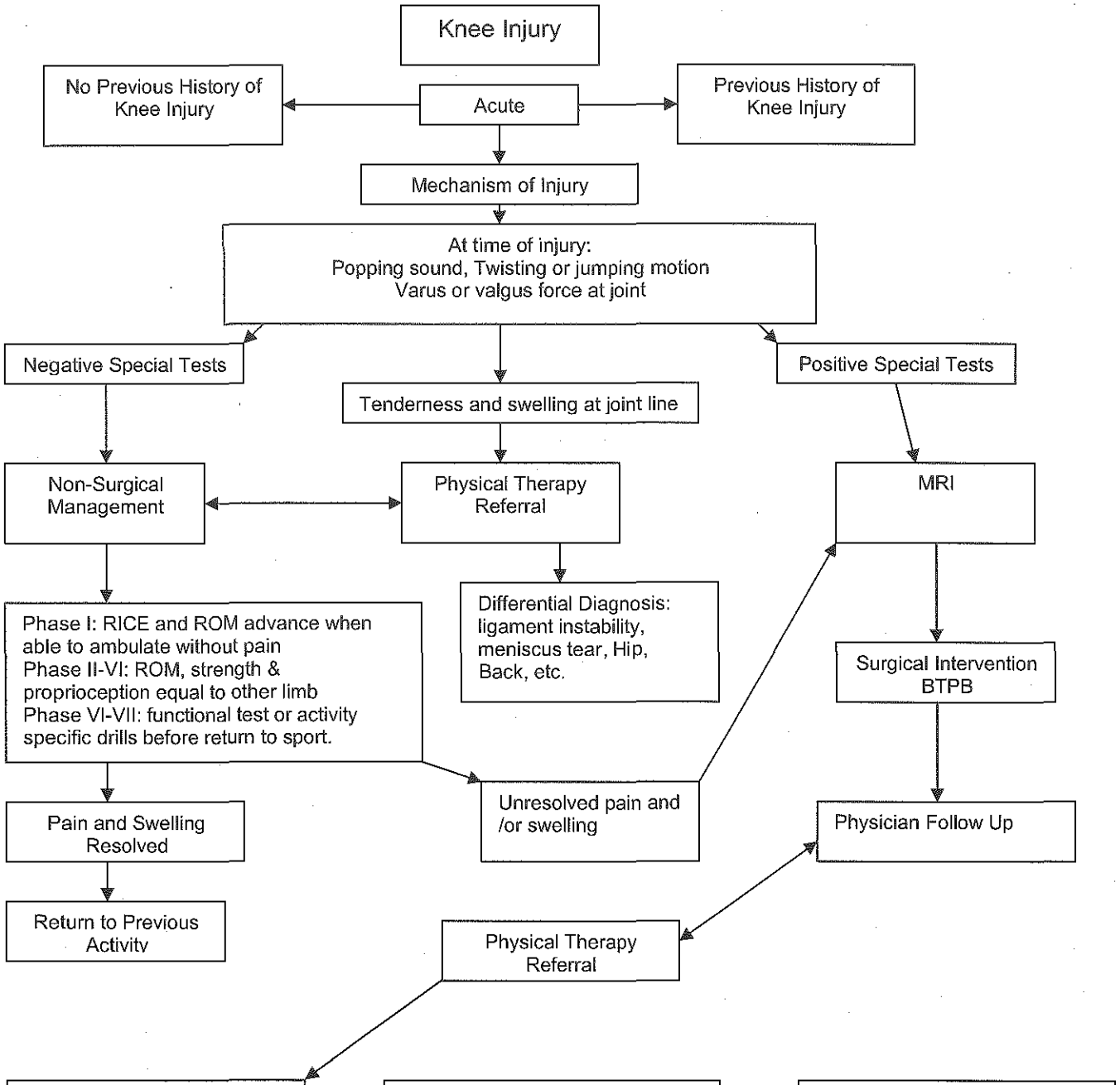
The patient and family both reported happiness with the patient's outcomes and expressed that their time and money were well spent. The patient was seen for approximately 21 sessions, 2-3 times per week for a period of 45 minutes per visit. It was estimated that the average cost per patient visit, paid by private insurance, was $133.93. The patients co-pay was $15.00 per visit but this was not billed by the facility. The total cost billed to insurance was $ 4,144.00, of which only $2843.98 was expected to be collected by the health facility. This is a reasonable fee for the limited time the patient spent in therapy and the patient's early return to sports. Consideration must be given to the patients' opportunity for scholarships and chance to play college sports.

The patient's parents considered this to be a real possibility and therefore an issue to consider.

Given his prior level of activity and future opportunities, it is best that this patient continued with his outpatient therapy to not only guide his treatment but to control the patient's tendency to overdo. For this type of patient it would be irresponsible at this point and time to further limit patient visits following ACL reconstruction without causing possible harm to the patient. However, for those patients that are less active and not seeking a return to competitive sports, it would be appropriate to establish a treatment plan that combined a home program with a decreased frequency of visits to guide the patient. The frequency and duration of visits would be determined by the therapist and based on an individual's condition or circumstances. In these instances, costs could be controlled through a limitation on the number of visits based on patient condition and expected outcomes or goals. With so many advances in the area of ACL reconstruction and given the rise in limitations placed on services it would be beneficial to seek additional information and training aimed at attaining outcomes at a faster rate.

A weakness of the study is that the case study is of one subject and cannot be generalized to other groups or individuals. Whether to use an accelerated program is dependent on the above factors. Noting the vast amount of research on the subject of ACL reconstruction and rehabilitation, much has been learned and questioned. With so many looking for the ultimate technique or program more detailed studies are needed.

APPENDIX


Knee Injury
No Previous History of Knee Injury
Acute
Previous History of Knee Injury
Mechanism of Injury
At time of injury:
Popping sound, Twisting or jumping motion
Varus or valgus force at joint
Negative Special Tests
Tenderness and swelling at joint line
Positive Special Tests
Non-Surgical Management
Physical Therapy Referral
MRI
Phase I: RICE and ROM advance when able to ambulate without pain
Phase II-VI: ROM, strength & proprioception equal to other limb
Phase VI-VII: functional test or activity specific drills before return to sport.
Differential Diagnosis: ligament instability, meniscus tear, Hip, Back, etc.
Surgical Intervention BTPB
Pain and Swelling Resolved
Unresolved pain and /or swelling
Physician Follow Up
Return to Previous Activity
Physical Therapy Referral
Phase I: 0-1 weeks
Terrific ten exercise, establish if delayed or accelerated protocol
Phase II: 1-4 weeks
Wean immobilizer by 4-6 wks, NWB to FWB by wk 4
PROM to AAROM: 90-40 ° & strengthening exercise for Knee & Hip
Phase III: 4-6 weeks
ROM & WB- full, cont. with Phase II regimen.
Squats, step downs, ambulation, balance, SL stand
Phase IV: 6-10 weeks
Squats to 45 ° with control, SL standing, KT 1000, SL press 70-10, OKC leg ext. 90-40, treadmill walking fwd & bwd
Phase V: 10-16 weeks
SL squat, jumps to 6", SL press Isokinetic test, functional assess @ 4 months, shuffles, jump rope, light jog, bilateral ground plyometrics,
Phase VI: 16-20 weeks
Goals; Ind. ½ speed running, jump down, rotational jumps, landings & SL landings, lat hops, figure 8, zigzag cutting, later shuffles
Phase VII: 20-24 weeks
SL plyometrics, resisted, full speed running, sports specific, cutting and stopping, advanced functional assessment- may return to full activity when patient has met isokinetic goals and passed advanced functional assessment test.
Algorithm is based on Physician Protocol. The Bone and Joint Center- November 2004

REFERENCES

1. Noronha JC. Reconstruction of the Anterior Cruciate Ligament with Quadriceps Tendon. Arthroscopy: *The Journal of Arthroscopic and Related Surgery.* 2002; 18(7): 1-5.
2. Noyes FR, Barber-Westin SD. Revision Anterior Cruciate Surgery with Use of Bone-Patellar Tendon-Bone Autogenous Grafts. *The Journal of Bone and Joint Surgery* 2001; 83A (8): 1131-1143.
3. Prentice WE. *Rehabilitation Techniques in Sports Medicine.* 3rd ed. Boston, MA: Magraw-Hill Co. Inc; 1999: 445-447, 464-469.
4. Herrington I, Warpson C, Matthews M, Matthews H. Anterior Cruciate Ligament reconstruction, hamstring versus bone-patella tendon-bone grafts: a systematic literature review of outcome from surgery. *The Knee.* 2005; 12(1): 41-50.
5. Gobbi A, Francisco R. Factors affecting return to sports after anterior cruciate ligament reconstruction with patella tendon and hamstring graft: a prospective clinical investigation. *Knee Surg Sports Traumatol Arthrosc.* (unpublished data, Epub ahead of print, February, 2006).
6. Kisner C, Colby LA. *Therapeutic Exercise-Foundations and Techniques.* 3rd ed. Philadelphia, PA: F.A. Davis Co; 1996: 443-447.
7. The Bone and Joint Center, Orthopedic Center of Excellence. ACL Reconstruction Protocol. 2004; Nov.
8. Norkin CC, White DJ. *Measurement of Joint Motion: A Guide to Goniometry.* 2nd ed. Philadelphia, PA: F.A. Davis Co; 1995: 137-146.
9. Gogia PP, et al: Reliability and validity of goniometric measurements at the knee. *Phys Ther* 67:192, 1987.
10. Hislop HJ, Montgomery J. Daniels and Worthingham's *Muscle Testing: Techniques of Manual Examination.* 6th ed. Philadelphia, PA: W.B. Saunders Co; 1995.
11. Guide to Physical Therapist Practice. *Phys Ther.* 1997; (77): 1163-1650.

12. Briggs K, Kocher M, Rodkey W, Steadman JR. Reliability, Validity, and Responsiveness of the Lysholm Knee Score and Tegner Activity Scale of Patients with Meniscal Injury of the Knee. *Journal of Bone and Joint Surgery.* 2006; 88A (4): 698-705.

13. Dauty M, Tortellier L, Rochcongar P. Isokinetic and Anterior Cruciate Ligament Reconstruction with Hamstrings or patella Tendon Graft: Analysis of Literature. *Int J Sports Med* 2005; 26:599-605.

14. Beard DJ, Anderson JL, Davies S, Price AJ, Dodd CAF. Hamstring vs. patella tendon for anterior cruciate ligament reconstruction: a randomized controlled trial. *The Knee.* 2001; 8: 45-50.

15. Foster MC, Foster IW. Patellar tendon or four-strand hamstring? A systematic review of autografts for anterior cruciate ligament reconstruction. *The Knee.* 2005; 12: 225-230.

16. Mikkelsen C, Werner S, Eriksson E. Closed kinetic chain alone compared to combined open and closed kinetic chain exercises for quadriceps strengthening after anterior cruciate ligament reconstruction with respect to return to sports: a prospective matched follow-up study. *Knee Surg Sports Traumatol Arthrosc.* 2000; 8(6): 337-42.

17. Shelbourne KD, Klootwyk TE, Wilkens JH, De Carlos MS. Ligament stability two to six years after anterior cruciate ligament reconstruction with autogenous patella tendon graft and participation in accelerated rehabilitation program. *Am J Sports Med.* 1995; 23(5): 575-579.

18. Beynnon BD, Uh BS, Johnson RJ, et al. Rehabilitation After Anterior Cruciate Ligament Reconstruction: A prospective, Randomized, Double-Blind Comparison of Programs Administered Over 2 Different Time Intervals. *The American Journal of Sports Medicine.* 2005; 33: 347-359.

19. Glasgow SG, Gabriel JP, Sapega AA, Glasgow MT, Torg JS. The effect of early versus late return to vigorous activities on the outcome of anterior cruciate ligament reconstruction. *Am J Sports Med.* 1993; 21(2): 243-8.

20. Bynum EB, Barrack RL, Alexander AH. Open versus closed chain kinetic exercises after anterior cruciate ligament reconstruction. A prospective randomized study. *Am J Sports Med.* 1995; 23(4): 401-406.